The future of sustainable land use across ecosystems, landscapes and biomes

53rd Annual Conference of the German Ecological Society

Freising, Germany, 9th — 13th September 2024

Contents

Calendar

Time	Sunday, 08.09	Monday, 09.09	Tuesday, 10.09	Wednesday, 11.09	Thursday, 12.09	Friday, 13.09	Saturday, 14.09

Time: 07:30, 08:00, 08:15, 08:30, 08:45, 09:00, 09:15, 09:30, 09:45, 10:00, 10:15, 10:30, 10:45, 11:00, 11:15, 11:30, 11:45, 12:00, 12:15, 12:30, 12:45, 13:00, 13:15, 13:30, 13:45, 14:00, 14:15, 14:30, 14:45, 15:00, 15:15, 15:30, 15:45, 16:00, 16:15, 16:30, 16:45, 17:00, 17:15, 17:30, 17:45, 18:00, 18:15, 18:30, 18:45, 19:00, 19:15, 19:30, 19:45, 20:00, 20:15, 20:30, 20:45, 21:00, 21:15, 21:30, 21:45, 22:00, -->01:30

Sunday, 08.09
- Excursion 1: Uper Isar w/ Thomas Wagner
- Excursion 3: Vegetation and management of calcareous grasslands... w/ Johannes Kollmann

Monday, 09.09
- Registration
- Opening ceremony
- Transit
- PE1 | FE1 | NC1 | NC2 | CM1 | SL1
- Coffee break
- PE1 | FE1 | NC1 | NC2 | CM1 | SL1
- Transit
- Key note: Emily Poppenborg-Martin
- Transit
- Mixer

Tuesday, 10.09
- Morning coffee
- Keynote: Leander Anderegg
- Transit
- NC3 | PE1 | FE1 | EE1 | UE1 | SC1 | ME1
- Coffee break
- NC3 | PE1 | FE1 | EE1 | UE1 | SC2 | ME1
- Poster Pitches
- Lunch break | Activity: Disco | Activity: Yoga | Activity: Publishing tips....
- Poster sessions
- Transit
- Award ceremony: Honour medal 2024: Christian Körner
- Coffee break
- NC3 | PE1 | FE1 | EE2 | UE2 | SC3 | ME1
- Transit
- AK meetings
- Transit
- Award ceremony: Best dissertation: Vera Wersebeckmann GfÖ award: Rachel Oh
- Public talk: Rupert Seidl

Wednesday, 11.09
- Morning coffee
- Honour medal 2023: Sandra Lavorel
- Transit
- NC4 | PE2 | FE2 | EE3 | UE3 | CM2 | ME2
- Coffee break
- NC4 | PE2 | FE3 | EE3 | UE3 | CM3 | ME3
- Poster Pitches
- Lunch break | Activity: Yoga | Activity: Open data publishing...
- Poster sessions
- Transit
- Keynote: Sarah Bekessy
- Coffee break
- NC4 | NC5 | PE3 | EE4 | CM4 | UE4
- Transit
- GfÖ general assembly
- Transit
- Theater

Thursday, 12.09
- Morning coffee
- Keynote: Sara Meerow
- Transit
- NC6 | EE5 | FE4 | PE4 | PE5 | RS1 | AG1
- Coffee break
- NC7 | EE5 | FE4 | PE4 | PE5 | RS1 | AG1
- Lunch break | Activity: Yoga | Activity: What is the role of ecologists...
- Keynote: Aude Zingraff-Hammed
- Transit
- NC8 | EE6 | FE4 | PE4 | PE5 | RS2 | AG2
- Coffee break
- NC8 | EE6 | FE4 | PE4 | PE6 | RS2 | AG3
- Transit
- Closing ceremony
- Poster awards
- Conference dinner
- Disco night

Friday, 13.09
- Excursion 4: KROOF w/ Häberle and Grams
- Excursion 5: Murnauer Moos w/Hanno Schaefer
- Excursion 6: Exploring city oases w/ Monika Egerer
- Excursion 7: Weltacker Landshut w/Theresia Endriß
- Excursion 8: Berchtesgaden National Park w/ Ruper Seidl
- W1: Better manage your data!
- W2: Effective digital note taking
- W3: Bringing ecology into urban planning
- W4: Copernicus data Space ecosystem

Saturday, 14.09
- Excursion 8: Berchtesgaden National Park w/ Ruper Seidl

Preface

Greetings from the GfÖ Board of Directors for the 53rd annual meeting of the GfÖ

In times of change and uncertainty it is even more important than under normal circumstances that the Ecological Society of Germany, Austria and Switzerland takes up important ecological topics with political relevance. It is equally important to create awareness about recent developments affecting ecosystems not only among its members but also among the scientific community as well as the general society. The conference motto ‘The future of sustainable land use across ecosystems, landscapes and biomes’ chosen by the Freising colleagues organising the conference meets this claim perfectly. Only few issues are of greater concern to scientific ecology and large parts of the public than the question of how land use can be designed in such a way that negative consequences for biodiversity and the functionality of ecosystems can be largely avoided.

As the board of directors, we would like to express our gratitude to the scientific and the organising committee of this year’s GfÖ meeting for having organised and structured such an inspiring and topical program. We are impressed by so many interesting sessions, workshops and keynotes which provide excellent opportunities for the exchange of research findings and views. We wish all the speakers, contributors and participants a successful conference. Feel encouraged to discuss the various topics not only in the sessions but also during the coffee breaks, take time to interact, and to even think about how to bring the discussed topics also to the general society beyond the scientific community.

All the best and enjoy the conference,

Christian Ammer & Christine Römermann
President & Vice-president of the GfÖ

Greetings by Wolfgang Haber, Co-founder of GfÖ and former President

Welcome all participants to Freising-Weihenstephan for the annual GfÖ conference!

The conference location, the historic Weihenstephan monastery, is a perfect fit for this year's conference theme. The monks developed and practiced agriculture for centuries, and they even invented a world-famous method of brewing beer (which I am sure you will enjoy during your visit). After the monastery was abolished at the beginning of the 19th century, the Bavarian state founded an agricultural school and a state brewery in Weihenstephan. These became research departments of the Technical University of Munich in the 20th century.

In 1965, the Bavarian Ministry of Science established a Chair for Landscape Ecology within the agricultural school (today the TUM School of Life Sciences). One of this chair's first strategic developments was the creation of a 'Land Conservation' module. This module brought together students of landscape architecture and landscape ecology in a common basic course to facilitate innovative teaching and research. At the same time, the Weihenstephan-Triesdorf University of Applied Sciences, then a technical college, developed a similar course of studies that linked artistic design with science in Weihenstephan. As a result, Weihenstephan became an epicenter for the study and teaching of vegetation ecology, soil biology, plant and animal ecology, ecosystem research and landscape planning. For this purpose, a high number of strategic appointments have been made in the past two decades as can be seen in this year's conference. Notably, the Weihenstephan Ecology Center has contributed significantly to the advancement of the discipline. This includes the founding of the 'Gesellschaft für Ökologie' in 1970 by 18 ecologists, among them Heinz Ellenberg, Lore Steubing, Heinrich Walter, Otti Wilmanns and myself.

I wish the participants of this year's conference a productive exchange of the latest discoveries in our discipline and a pleasant time on the green and biodiverse Weihenstephan campus!

Welcome by Tobias Eschenbacher, Mayor of Freising

As mayor of the city of Freising, I would like to warmly welcome you to the annual meeting of the ‘Gesellschaft für Ökologie’ in September 2024. Freising is a historic city with a rich tradition of applied research in the life sciences and land use. This tradition is exemplified at the Weihenstephan Science Campus through the outstanding efforts of the Technical University of Munich, the Weihenstephan-Triesdorf University of Applied Sciences, the State Institute for Agriculture, the State Institute for Forestry and Forestry, the Fraunhofer Institute and the Weihenstephan Brewery.

Scientific research, teaching and application hold great significance for the city of Freising, fostering a high level of mutual appreciation. We are always delighted to host international conferences, and this year’s gathering is especially meaningful as the city celebrates the 1,300th anniversary of Saint Corbinian’s arrival, who founded the diocese of Freising. In preparation for this event, the city has undertaken numerous renovations of historical buildings, redesigned urban spaces, and created new facilities that blend the remarkable heritage of the old town with culture and nature.

I invite you to explore this diversity during the GfÖ24 conference. While visiting one of our many cafés, pubs or restaurants, please take time to observe how we have thoughtfully designed our charming city in the spirit of sustainability and climate adaptation. Maybe you will even be lucky enough to see a beaver swim through the little Moosach river that flows through Freising! For now, I wish you a scientifically fruitful and enjoyable meeting that you will remember fondly.

Welcome by the Organising Committee GfÖ24

We are pleased to welcome over 750 participants from 28 countries to the 53th conference of the Gesellschaft für Ökologie in Freising. This year's theme focuses on the future of sustainable land use across ecosystems, landscapes and biomes. Land-use change and unsustainable land management practices are the main drivers of biodiversity losses and the decline of ecological functions worldwide. To combat this, sustainable land use in agriculture, forestry and urbanism must be multifunctional and incorporate the latest advances in both basic and applied ecology. This need is underscored by challenges such as climate change, biological invasions and environmental pollution. This conference, held from September 8th to 14th, 2024, provides a platform to present and discuss ecological knowledge that contributes to innovative land use and adapted management strategies of populations, communities and ecosystems.

The research campus in Freising-Weihenstephan is an ideal location for the GfÖ24 conference. It hosts the Technical University of Munich, the University of Applied Sciences Weihenstephan-Triesdorf and several applied research institutions, providing local expertise in ecology, forestry, agriculture, urbanism and freshwater science. The campus' green environment and the historic city of Freising offers a charming setting for this meeting.

We are privileged to support the scientific and personal exchange of so many experts and have curated a program rich in diverse topics and experiences. Acknowledging the dense schedule, we have included a mix of social and cultural activities to provide a balanced experience. We are excited to see how everybody enjoys this festival of ecological sciences!

Awardees

Awardee talk
01

Concepts in plant ecology

Christian Körner

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Concepts are mind models or paradigms that shape theory and hypothesis formulation. I will challenge a number of popular paradigms in plant and ecosystem ecology. A most popular but flawed concept is, that leaf photosynthesis (A) drives growth. Outside horticulture, it is the opposite: growth controls A by demand, because the nutrient cycle, soil moisture and temperature, first affect meristems, and much later A, but we have no algorithms for cell production, but elegant press-button gas exchange equipment. That's why. Carbon cycle assumptions are currently the most popular conceptual pitfalls. In the carbon sequestration debate, it is widely assumed that the process of carbon uptake (growth) represents carbon stocks, neglecting the fact that biomass C-pools are determined by C-turnover, that is, the residence time of C, that cannot be assessed in experiments, at least not for forests. Hydraulic stem failure, is another conceptual hype, suggesting that conduits cannot match evaporative demand and thus, are the ultimate cause of tree death under drought. In reality, it is the interruption of the soil-root capillary continuum that kills, with stomatal closure under drought causing the conduit's capacity to become massively oversized. If cavitation becomes fatal, it is because of a failure of post-drought conduit recovery, a poorly understood cell physiological issue. Why then is stem hydraulic capacity treated critical? Because we can measure it, while we have no means to measure root surface processes some 5-10 m deep in the soil profile. The concepts of functional traits and plant functional types are biased by considering simple to obtain individual traits rather than trait syndroms and response traits. A classical concept is what is considered stressful or limiting, by implicitly adopting a crop grower's concern about yield, while evolution selects for fitness. Most plants in the wild would get locally extinct, when exposed to conditions that maximize their growth. These misconceptions are often driven by the availability of scientific tools that shape our paradigms. Aspects of plant life that are difficult to study are blinded out from conceptual frameworks.

Awardee talk

02

Terracing in steep slope viticulture and its potential to promote biodiversity in vineyard ecosystems

Vera Wersebeckmann

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Viticulture on steep slopes has shaped exceptionally species-rich cultural landscapes in Germany. However, viticultural area suffered strong declines in recent decades due to insufficient profitability. A solution to reduce further abandonment and maintain cultivation economically viable could be vineyard terracing. Yet, little is known about the effects of vineyard abandonment and a change of vineyard management type on biodiversity. Over three years, we determined the effects of vineyard management types (vertically oriented vs. terraced) in contrast to vineyard fallows, local conditions, and the surrounding landscape on plant, Orthoptera, wild bee and spider diversity in 45 study sites along the Upper Middle Rhine Valley (UMRV) in Germany. The small-structured landscape of the UMRV supported high species diversity, high numbers of threatened species and diverse species communities across vineyard management types and fallows. Species responses were group- and taxon-specific and driven by distinct management intensities, local vegetation structures, and landscape structure. In brief, plant and Orthoptera diversity profited from terraced vineyards with nutrient-poor and extensively managed terrace embankments. Wild bee diversity was determined by their distinct nesting needs and particularly supported by woody structures of fallows while spiders benefited from the high landscape complexity. In summary, heterogeneous landscapes, including actively managed and abandoned vineyards and natural elements that complementary provide resources were critical to fulfilling the many specific needs. However, to preserve the characteristic flora and fauna of steep slope viticultural landscapes, active vineyard management is mandatory. Especially when revegetated with regional seed mixtures, terraced vineyards have high biodiversity potential and can contribute to combining economically viable viticulture on steep slopes and nature conservation objectives in a land-sharing approach.

Awardee talk
03

Assessing the prevalence and consequences of study designs in nature and mental-health studies

Rachel R.Y. Oh

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The use of nature exposure as a health intervention has intensified, yet the credibility of the supporting evidence hinges on the quality of study designs employed. These designs vary in their susceptibility to bias and ability to accurately assess the true impact of nature exposure on health outcomes. Here, we examine the prevalence of different study designs used in nature and mental health research, considering geographical, disciplinary, and temporal variations. Our initial findings show a trade-off between obtaining precise, unbiased answers to narrowly defined questions and deriving broader, albeit more uncertain, insights from complex questions. Despite global variation in study design diversity, most studies used uncontrolled and observational methods, which produce more biased estimates compared to controlled and randomized designs. Furthermore, the existing body of knowledge does not adequately represent the global population. We discuss the implications of these findings for evidence synthesis and policy development, emphasizing the need for more globally representative research.

Keynote speakers

Keynote
01

Harnessing agricultural landscapes for biodiversity and ecosystem services: key evidence and knowledge gaps

Emily Poppenborg Martin

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Managing agricultural landscapes to support biodiversity and associated ecosystem services, such as pollination and natural pest control, could be a key avenue towards sustainable and climate-resilient agriculture that works for farmers. However, precisely how to manage these landscapes – and how effective this will be – is unclear. In syntheses of data from studies across Europe and the world, I examine how landscape composition and configuration impact arthropods, pest control, pollination and yields. Based on these results and 'syndromes' of species' traits, pathways to predictively assess ecosystem service potential can be derived to anticipate the effects of landscape- and field-scale management strategies towards workable ecological intensifilcation of agriculture under global change. Bridging conventional European and smallholder farming systems in East Africa and South America, I then highlight knowledge gaps for the expansion of biodiversity-enhancing intensification practices and discuss implications for future biodiversity-driven agroecosystems.

Keynote
02

Persistent problems in plant functional ecology: Why can't we predict traits from climate?

Leander Anderegg

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Plant functional traits are powerful ecological tools, but the relationships between plant traits and climate (or environmental variables more broadly) are often remarkably weak. This presents a paradox: Plant traits govern plant interactions with their environment, but the environment does not strongly predict the traits of plants living there. Unpacking this paradox requires differentiating the mechanisms of trait variation and potential confounds of trait–environment relationships at different evolutionary and ecological scales ranging from within species to among communities. However, even after we sift through the problems of scale and sampling that plague many of our analyses, we find that trait-environment relationships often continue to disappoint. This suggests that we may need to look critically at some of our underlying assumptions in plant functional ecology. I argue that we need a more integrated understanding of physiological and evolutionary equifinality among many traits and plant strategies, and a better grasp on how supposedly 'functional' traits integrate into a whole-organism phenotype in ways that may be largely orthogonal to environmental tolerances.

Keynote
03

Changing forest-disturbance regimes – implications for sustainable land use

Rupert Seidl

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Disturbances are discrete events that disrupt the structure of forest ecosystems. They are a key component of natural ecosystem dynamics and important determinants of forest biodiversity. However, disturbances are also among the most climate sensitive processes in forest ecosystems, and ongoing climate change leads to profound alterations of forest disturbance regimes around the globe. In Central Europe, for instance, the rate of disturbance has more than doubled over the last 35 years, and a further increase in disturbance activity is likely in the coming decades. These changes have profound implications for the sustainable use of forest ecosystems: They challenge the provisioning of ecosystem services and can lead to amplifying climate feedback, making disturbance resilience an increasingly central element of forest management. At the same time, disturbances also hold opportunities for management, as they trigger the reorganization of forest ecosystems and foster biodiversity. Here, I will review the current understanding of changing forest disturbance regimes with specific focus on the situation in Europe. I will subsequently highlight implications for sustainable forest management and conclude with suggested future avenues for fundamental and applied research on forest disturbance and resilience.

Keynote

04

Pathways to climate-smart rural landscapes

Sandra Lavorel

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Nature-based solutions aim to address the joint climate and biodiversity crises, while supporting global Sustainable Development Goals. In climate-smart landscapes people create these solutions by reconfiguring land use for multifunctional goals of biodiversity conservation, sustainable production, climate change adaptation and mitigation. Nature and people interact and decisions are made in landscapes through trade-offs between these goals. Landscape research has only started to discover their ecological mechanisms and critical spatial dimensions of ecological and governance processes. In this presentation, I will show how the effects of landscape configuration on climate-smart landscape multifunctionality can start to be understood systematically using modelling to produce novel principles formalising interacting effects of landscape composition and configuration on multifunctionality. Such theory is essential to assess alternative landscape templates that combine conservation, restoration and sustainable management. I will then consider how actor networks influence the collaborative governance and pathways towards climate-smart landscapes, highlighting the need to simultaneously analyse ecological (nature-nature), social (people-people) and social-ecological (people-nature) interactions.

Keynote
05

Designing cities for everyday nature

Sarah Bekessy

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The motivations for designing for nature in cities have arguably never been more compelling. Re-enchanting urban residents with nature can deliver a range of health and well-being benefits, while creating more climate change resilient cities. Creating 'everyday nature' in cities presents opportunities to reverse the fate of many threatened species and connect people with nature and living cultural traditions. But this requires more than just urban greening; it involves ensuring daily doses of nature in a way that also supports non-human organisms. The future of liveable cities may well depend on this new conceptualization, but a major shift in the way nature is conceived of and designed for is required. Key to achieving this shift is establishing meaningful professional engagement between ecologists, planners and designers. Building on our experience working in this interdisciplinary space, I outline principles, processes and challenges for effectively designing for everyday nature in cities.

Planning urban green infrastructure to enhance social-ecological resilience

Sara Meerow

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Cities around the world are grappling with unprecedented heat waves, floods, droughts, and other interconnected impacts of climate change, which will only worsen in the coming years. To combat these threats and provide other social and ecological resilience co-benefits, cities are making historic investments in vegetated green infrastructure or nature-based solutions (e.g. urban forests, rain gardens, bioswales). In this presentation I will discuss my research unpacking the knowledge systems and politics that underpin urban green infrastructure planning. This work suggests that there are important tradeoffs in benefits provided by different green infrastructure types, designs, and locations, with environmental justice implications, but these trade-offs are rarely evaluated in implementation. I will also discuss my efforts to develop new tools to support more strategic and equitable green infrastructure spatial planning decisions.

Keynote
07

Blue nature-based solutions: value, knowledge, and rules hindering and leveraging river restoration

Aude Zingraff-Hamed

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In Europe, river planning and management took a decisive turn in the late 19th and early 20th centuries with the ratification of the EU's Water Framework Directive (WFD). The WFD orchestrates restoration efforts and demands that all water bodies achieve a good ecological status (or potential). Along with the implementation of the WFD, the concept of nature-based solutions (NBS) to mitigate hydro-meteorological risk has also grown in popularity, especially in the context of climate changes. While NBS, such as river restoration, have been recognized as essential for the reestablishment of the socio-ecological functions of rivers and are presented as "the no-regret solution" to global challenges, their implementation is facing many limitations. Especially at the level of the decision-making process is the missing trust in the solutions a major bottleneck to their implementation. This plenary talk will use the value-rule-knowledge framework for NBS decision context to discuss the facts and the beliefs around river restorations as blue NBS. It will present the results of more than 156 case study site analyses and deliver an understanding of the bottlenecks and levers of the decision-making process.

GfÖ
2024

Agriculture (AG)

Role of IPM-based biodiversity measures in agricultural landscape transformation

Short title: IPM supports agricultural landscape transformation

Chairs: Tiemo von Steimker, Tanja Rottstock, Stephanie I. J. Holzhauer, Bastian Häfner

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Agricultural landscapes are not only important to ensure food security. They also provide habitats and resources for a wide range of organisms thus supporting key ecosystem services such as pest control and pollination. However, landscape simplification and agricultural intensification, e.g. the use of chemical and mechanical inputs, put biodiversity at risk. Integrated Pest Management (IPM) takes a holistic approach, and its general principles provide the basis for decision making for sustainable pest control. IPM offers the potential to maintain the productivity of the system while promoting and protecting biodiversity. Adapting field and landscape management strategies can support beneficial insects by reducing disturbance and providing additional food resources and (reproductive) habitats. Thus, IPM methods can be a valuable approach in a transformation process and contribute to the increase of resilience in agricultural cropping systems and a reduction of chemical–synthetic pesticides. Although IPM is not a new concept, a further advanced, holistic and consistent consideration of agroecological concepts and enhancement of beneficials in agricultural practices, offers greater potential for transformation. A wide range of creative, regionally tailored policies and transdisciplinary actions involving scientists, farmers, and other stakeholders are needed to achieve a transformation towards more sustainable agricultural systems that support and secure biodiversity and ecosystem services. Specially designed monitoring and management strategies must support these actions. In joint efforts, trade-offs between ecological and economical demands must be considered and met to ensure the acceptance and success of the transformation. In addition to the cost-effectiveness, the regional adaptation of measures and practicability must be considered to facilitate a long-term transformation, which addresses all aspects previously mentioned. In this session, speakers will discuss their experiences, progress, constraints and expectations in using and monitoring IPM measures to transform agricultural landscapes.

The contribution of insect-promoting measures to IPM in agricultural transformation processes – Lessons learned from the FInAL project

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A transformation of agricultural landscapes is required that supports biodiversity and therefore secures ecosystem services (ES) such as pest control and pollination while reducing the use of chemical inputs and maintaining profitability. Integrated Pest Management (IPM) provides an approach to meet these objectives, i.e. by generating an infrastructure of reproduction habitats and foraging resources for insects, while simultaneously changing key steps of management operations through informed decision making and prioritizing non-chemical measures. Thus, a general and specific promotion of beneficials may be achieved. In the project 'Facilitating Insects in Agricultural Landscapes' (FInAL, https://www.final-projekt.de), scientists in close cooperation with farmers aim to attain a sustainable landscape transformation through the implementation of insect-promoting measures. Since 2021, regionally adapted measures have been realized in three distinct agricultural regions across Germany in accordance with collaboratively developed regional transformation scenarios. Each region constitutes a living lab covering 3 km x 3 km of study area and a reference landscape representing the status-quo management, without the implementation of FInAL measures. We examined disparities regarding the intensity of pesticide application for each of the three model regions between landscape labs and reference landscapes in the main crops: winter oilseed rape, winter wheat and maize. We analysed the timespan before, during, and after (2020–2022) the implementation of the first insect-promoting measures. Our analysis provides important preliminary insights on indirect effects and highlights areas of further adaptation of crop protection methods towards a sustainable landscape transformation as well as options for strategies regarding the reduction of pesticides. Over time, this may lead to a largely self-sustaining agroecosystem, with minimized chemical inputs while maintaining its productivity.

Positive effects of wildflower strips on invertebrate organisms and ecosystem services above and below ground

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Wildflower strips (WFSs) are a promising measure to enhance local biodiversity and ecosystem service provision in intensively managed agricultural landscapes. Many studies have evaluated the effects of WFSs on pollinators, but the evidence for WFS influence on the abundance and species richness of other animal taxa and ecosystem services levels is limited. In this talk, we will introduce our experimental study system where WFSs of various types were established in 2020/21 in collaboration with local farmers. Using the BACI approach, i.e. collecting data before as well as during several years after WFS establishment, we gathered long-term data for the responses of eleven invertebrate taxa (bees and wasps, butterflies, carabids, hoverflies, leaf beetles, myriapods, spiders, true bugs, weevils, earthworms, soil-dwelling arthropods) and three ecosystem services (decomposition and pest and weed seed predation). In addition, short-term studies to investigate WFS effects on pest suppression (pest egg predation), winter performance (arthropod overwintering) and the effects of WFSs management on arthropods were conducted. Preliminary results indicate that the presence of WFSs supports invertebrate abundance and diversity across diverse invertebrate groups both above and below ground. In contrast, positive effects on ecosystem services levels were less obvious. In addition to existing evidence of WFS benefits for local biodiversity during the growing season, we also highlight their importance during the winter season. WFS management (mowing intensity) significantly affect invertebrate communities inhabiting WFSs, where a partial mowing scheme seems to be the best solution. These results will provide useful recommendations for WFSs optimization.

Overwintering of ground-dwelling arthropods in wildflower strips: do agricultural practices matter?

Alfredo Venturo[1], Lucija Andjel[2], Martin Štrobl[1], Vojtěch Pařízek[1], Michal Knapp[1]

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Wildflower strips (WFS) are known to support beneficial arthropods in agroecosystems by providing food and nesting resources. However, their potential role as winter shelters is still overlooked. Moreover, agricultural practices may impact the survival of overwintering arthropods. Therefore, we investigated the effects of WFS mowing and soil tillage on ground beetles, rove beetles, spiders, and myriapods during winter, considering both insect larval and adult stages. From early January to late March 2023, we conducted pitfall samplings in ten fields (five tilled and five untilled) with mown and unmown WFS at three locations: in WFSs, on edges, and in field interiors. Adult specimens were identified morphologically, while larval ones were identified using a metabarcoding approach. Our results reveal a higher activity density for all taxa in WFS compared to neighbouring arable fields during winter, with a prevalence of ground and rove beetles on WFS edges. Furthermore, soil tillage and WFS mowing impact ground-dwelling arthropods, but their effect varies among taxa. These findings underscore the importance of WFSs for the survival of beneficial arthropods and highlight the need for further research to control the effects of agricultural practices.

The effect of strip cropping with oilseed rape and wheat on pest densities and natural enemies

Michelle Grote[1], Gunnar Breustedt[2], Doreen Gabriel[1]

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[2]*Christian-Albrechts-University of Kiel, Institute for Agricultural Economics, Kiel, DE*

Agricultural intensification and associated land-use changes have led to increased productivity but have also had profound negative effects on ecosystems and the environment. Intensive agricultural practices, characterised by increased chemical use, reduced crop diversity and larger field sizes, accelerate the loss of habitat and biodiversity. Diversified cropping systems such as strip cropping, where multiple crops are grown on the same field, offer a strategy to promote farmland biodiversity and associated ecosystem services such as biological pest control. This study assesses the effect of strip cropping with oilseed rape and wheat on pest densities (i.e. pollen beetles and cereal aphids), natural enemies (predatory arthropods), and crop yield. In 2022 and 2023, 24 triplet fields were selected on individual farms in Germany, each consisting of a strip cropping field and a pure oilseed rape and a pure wheat field as reference (n = 72). The results indicate a high temporal (within season, year-to-year) and spatial (within field location) variability. Pest densities generally did not differ between strip cropping and reference fields, but the configuration of the strip cropping field, particularly whether oilseed rape was the strip or the main crop, was important. Strip cropping promoted natural enemies through the different crop types at different times of the year. Although crop yields were slightly lower in strip cropping fields compared to reference fields due to edge effects at strip boundaries, strip cropping appears to be a viable strategy for integrating biodiversity conservation into conventional agriculture. However, the effectiveness of strip cropping in promoting biodiversity and ecosystem services may be further improved by combining multiple crop types and non-crop elements in different strip widths and configuration patterns.

AG1
05

Understanding the impact of insect-promoting measures on beneficial and pest occurrence: The FInAL project approach

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The positive impact of insect-promoting measures, such as conservation tillage and tailored flowering strips for beneficials are important components of integrated pest management (IPM). These measures are expected to promote beneficials, increasing their abundances or vitality and thereby enhancing natural pest regulation. In the collaborative project 'Facilitating Insects in Agricultural Landscapes' (FInAL, www.final-projekt.de), we aim to determine whether field-level monitoring can effectively measure the potential landscape-scale effects of a combination of insect-facilitating measures on pest and beneficial abundance over time through beneficial-pest ratios. This can be achieved by quantifying the number of beneficial insects relative to the number of pests. For example, the parasitoid wasp *Tersilochus heterocerus* significantly reduces the number of individuals from *Brassicogethes* aeneus, a major pest in winter oilseed rape, by parasitising its larvae. In FInAL, we use a co-design approach where we develop and implement together with farmers innovative insect-promoting measures in laboratory landscapes. The monitoring results are compared to those of reference landscapes. From 2021 to 2024, *B. aenus* larvae were collected in Lower Saxony (Elm) using trapping bowls positioned at varying distances from the field edge to capture larvae descending for pupation. Subsequently, collected larvae underwent examination to detect potential parasitisation by *T. heterocerus*. Annual fluctuations in parasitisation rates were observed, but effects directly attributable to insect-promoting measures have not yet been identified between reference and lab landscapes. Advancing measures to promote beneficial insects is crucial for assessing their potential impact and the resulting potential improvement in pest control. Further analyses, including the incorporation of information on soil management or landscape structure, are planned.

Less yield for more biodiversity – seeking a compromise when undersowing maize with biodiversity-enhancing partners

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In view of the biodiversity loss through agricultural intensification and expansion, on-field measures to protect agrobiodiversity and ensure ecosystem service provision are urgently needed. Cultivating maize is highly efficient and profitable but its productivity comes with high environmental costs and low biodiversity. In Germany, maize covers 21% of all arable land but on-field measures to mitigate the negative effects of maize cultivation are rarely applied. Undersowing maize with flowering-partner crops provides an opportunity for diversifying maize cultivation. Flowering-partners grown with maize can promote pollinators by providing additional food sources. In addition, increased habitat structure might support arthropods and related pest control services. But the competition between maize and undersowings can reduce yields substantially. In a field experiment, we established plots of pure maize and of maize with six different undersowing partners (clover, mallow, cress, vetch, marigold-borage, fescue) and their pure pendants in four replications. We recorded maize yields, flower and bare ground cover, pollinator visits, activity-density of epigeic arthropods and proxies related to biological pest control. Maize yields were lower for undersowing treatments in comparison to pure maize and resulted in 15–75% yield reduction. Pollinators benefited from increased flower availability through undersowings, but differences between pollinators for pure and mixed plots were small. Tall-growing undersowings (e.g. mallow) were highly competitive, inhibited maize growth and thus reduced differences, thereby also greatly reducing yields. In contrast, low-growing undersowings were less competitive. For arthropods and their related services, we observed contrasting patterns. Here, we present in various scenarios the biodiversity–yield trade-off and discuss the point at which yield, biodiversity and ecosystem functions can be compromised.

Including beneficial functional traits of weeds in control strategies

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Beyond their competition with crops for essential resources, weeds also play a significant role in agroecosystems by providing food and shelter for small vertebrates and invertebrates. While the ecological benefits of a high plant diversity are increasingly valuated in some fields, such as organic farming or urban planning, intensive weed control with herbicides applied over the entire field is still frequently conducted in conventional agriculture. Threshold concepts for weed control enable the targeted use of herbicides adapted to farmers' goals. 'Economic thresholds', which determine the economic profitability of a weed control application, already exist. When the weed density exceeds this fixed threshold, controlling these weeds is estimated to result in higher economic net returns. Two recently developed approaches refine this purely economic threshold by directly including weed (beneficial) functional traits. These novel approaches, therefore, allow for weed management that enhances the ecological benefits of weeds for agricultural production and biodiversity. Both approaches consider the species-specific traits of weeds, describing their beneficial ecological services as well as traits describing crop competition. The approach 'eco2-threshold' was developed as an extension of the 'economic threshold'. It monetises functional traits and includes them in the calculation of economic thresholds. The 'site-specific functional trait threshold' was developed for site-specific weed control and merges weed distribution maps with the species-specific functional traits. To compare the performance of both approaches, we created individual weed control maps for five study arable fields. Manual weed sampling was conducted on a pre-defined grid in each field and a weed distribution map for each species was generated using an interpolation approach. Employing both approaches, a weed control map for each study field was generated. The resulting weed management maps were compared in their performance to assess their ecological and economic profitability.

Sound manipulation and proximity to natural vegetation augment bat abundance in Mediterranean vineyards

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There is a growing need worldwide for sustainable pest suppression methods. One such method is conservation biological control, in which pest suppression is enhanced by promoting the activity of pests' natural enemies. Insectivorous bats have been shown to be effective pest suppressors, so enhancement of their activity in agroecosystems may be beneficial. Thus, we tested the efficacy of sound manipulation for augmenting bat activity in vineyards, and the effect of crops' proximity to natural habitat on the presence of bats. Based on bats' eavesdropping behaviour, we hypothesized that foraging bats will be attracted to calls of others, especially of conspecifics. Furthermore, as natural habitats can support bats populations, we hypothesized that bat activity within crops will increase with proximity to natural habitats. Thus, we recorded passing bats in vineyards adjacent and away from Mediterranean maquis. We broadcasted playbacks of bat echolocation calls as a sound manipulation, and with a block design we simultaneously recorded the response of passing bats in three plots, a control plot, and plots broadcasting calls from either local or foreign populations of Pipistrellus kuhlii. We predicted that the activity of P. kuhlii will be higher in broadcasting plots compared to control, and when the broadcasted calls originate from a local population than from a foreign one. The results show that sound manipulation had a significant positive impact on the activity level of bats in vineyards, but there was no significant effect of the playback calls origin. Proximity to natural habitat had a significant positive effect on bat abundance late in the season after the grape harvest. Our results indicate that natural habitat supports bat populations, and that due to its augmentation of bat activity, sound manipulation should be considered as a means for sustainable pest suppression.

AG1
09

Differential contribution of biological control by bats and birds and the role of the landscape structure

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The integration of ecosystem services that promote crop health and yield in critical for sustainable agriculture. Bats and birds have been shown to play an important role in biological control by foraging on insect pests, thereby reducing crop damage and increasing yields. In our study, we investigated the diversity and composition of bat and bird species in the agroecosystem of macadamia orchards in South Africa. We further used exclusion plots to assess the biological control services provided by bats and birds in relation to landscape cover composition (natural habitat cover) and at different locations in the orchard, either at edges or orchard centers (50 m from the edge). Our findings suggest that a greater amount of natural habitat coverage correlates to a higher bird diversity and abundance in and around the orchards. Bird communities at the orchard edges differ from those within the orchards, with edges having more insectivorous and omnivorous species. Higher bird abundance within the orchards is negatively related to macadamia nut insect damage, while at the orchard edges, the opposite relationship is observed. Bat activity shows a clear negative relationship with insect damage, suggesting their effectiveness in biological pest control. In contrast, yield is only positively correlated with natural habitat cover, indicating that natural habitats promote additional ecosystem services, such as pollination. This study underlines the important role of bats in biological control and highlights that among birds, certain functional groups contribute positively to pest control while others do not. Our results emphasise the broader role of natural habitat in supporting multiple ecosystem services in agroecosystems.

AG1
O10

Increases in ecological infrastructure and the potential of changing pest dynamics by structural complexity: a review of effective strategies in orchards

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Fruit orchards can make a good contribution towards a high level of biodiversity in intensively managed agriculture, thus contributing to insect diversity and promoting pest control within a mosaic of different ecosystems and near-natural structures at the local and landscape scale. However, apples for instance, belong to the most intensively produced fruit crops in the world and this entails the risk of a decrease in biodiversity and biodiversity-based ecosystem functions and ecosystem services that underpin agricultural production. Increasing diversity can support self-regulating mechanisms in pest problems of monocultures at the same time it should reduce the number of chemical plant protection treatments. Integrated Pest Management (IPM) utilizes natural mechanisms and thus associated ecosystem services such as natural pest control to use chemical plant protection as a last resort in reducing economic damage from insect pests. The beneficial measures (in IPM), however, are only implemented sparingly in practice with uncertainty about the costs on one side and the difficulty of classification for the benefit for pest control. Here, we focus on the demonstration of increases in natural enemy abundance by introducing a high diversity of structures over several years. First, findings from the previously conducted experiments are shown. To highlight the latest findings on effective strategies, a review of the current literature has been conducted for apple and pear orchards. The demonstration focuses on control methods to target important European insect pests through biological control strategies.

O11

Utilizing functional biodiversity in fruit and arable farming. Socioeconomic lessons learned from project experience

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IPM-based biodiversity-enhancing measures can reduce pesticide need and control weeds. They may also have additional environmental benefits such as improving soil fertility and pollination. The measures can be implemented in annual or perennial crops and in the field or outside the production area. Common measures are e.g. flower strips and intercropping. As part of the EcoStack project, numerous biodiversity-enhancing measures in several crops and at different European locations were investigated. During data collection, a deficiency of economic data was encountered. Additionally, the applied landscape model had limitations. However, positive and negative socioeconomic effects of single off-crop and in-crop measures were identified. Although cost-benefit analyses are a common tool to evaluate measures from a socioeconomic perspective, the quantitative description of the costs and benefits associated with a specific measure is often a major challenge. Cost-benefit analyses of environmental measures require data from interdisciplinary teams. Whilst the evaluation of costs is usually the simpler step, these are often only partially considered. The difficulty in evaluating the benefits is that they often cannot be clearly assigned to a specific measure. Results may only apply to individual measures under certain regional conditions and are difficult to generalize. Based on the findings of such earlier studies, an adapted concept for the economic assessment of measures is being developed as part of the FUBIOO project. Focus is limited to four German regions, a small number of measures, and the cultivation of permanent fruit crops. The participating farms serve as demonstration sites for best practices. In close cooperation with the farms, economic data as well as biodiversity monitoring data are collected. This data is incorporated into cost-benefit analyses for each measure in its local and regional context.

AG1

O12

Fruit production in coffee (*Coffea arabica* L.) crops is enhanced by the behaviour of wild bees (Hymenoptera: Apidae)

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There is a diversity of studies investigating how the diversity of floral visitors and changes in their communities affect coffee production. However, very few studies have focused on understanding how insect visiting behaviour affects coffee production, especially in different types of crop management. Here we assessed how foraging behaviour (flower visitation rate, collection time in flowers and contact stigma/anther) of honey and stingless bees affect coffee pollination in two types of crop management (conventional and agroecological). For this, we quantified local floral resources, we characterize the use of agrochemicals, the richness of associated cultivated species and the presence of high-level shade trees in both type of management crops. We also recorded the diversity of bees and the behaviour of each of the most common species when visiting coffee flowers. We found that the managed honeybee A. mellifera and three wild bees *T. angustula*, *S. mexicana*, and *P. bilineata* are the principal floral visitors of coffee crops in Guatemala. We observed that the total abundance but not the richness of all the bees was significantly higher in agroecological crops compared to conventional ones Regarding their behaviour, we observed that the average number of flowers visited by *P. bilineata* and the behaviour of touching the nectaries of coffee flowers were positively related with fruit set, while only the percentage of A. mellifera carrying pollen was positively related with fruit weight, suggesting that although A. mellifera is found in large quantities, wild bees are efficient pollinators of coffee in the region and their populations should be conserved. These patterns of behaviour of the bees on coffee fruit set were constant across both types of crop management, except for fruit weight, which was heavier in agroecological areas.

AG1

P1

Development of an artificial nesting system for the potential biocontrol agent *Pempherdon lethifer* (Hymenoptera: Crabronidae)

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Aphids are a common pest of many crops. The digger wasp species *Pemphredon lethifer* (SHUCKARD 1837) is a promising biocontrol agent for aphid control: It is widespread in Europe and collects aphids from the plants by transporting them to their nests to provide food for hatching larvae. In nature, nests are dug in pithy twigs such as *Sambucus* spp. or *Rubus* spp. However, in order to rear *P. lethifer* as for future commercial use as biocontrol agent, a suitable nesting system is required. To develop a suitable nesting substrate and rearing system, we tested different materials, dimensions and shapes. In a first step we developed a wood foam, based on *Sambucus nigra*, which is accepted by *P. lethifer.* In a next step, different pith shapes were studied in the laboratory in a choice experiment. For this we placed a female wasp of *P. lethifer* in a cage with two wooden nest tubes filled with wood foam, one with a round and one with an angular shaped foam pith. Nesting was documented. We also tested the acceptance of complete foam nest blocks in the laboratory. Preliminary results show that *P. lethifer* accepts both, round as well as angular shaped pith for nesting, as well as complete foam blocks. We use the findings to develop a prototype nesting system for *P. lethifer*. The findings are crucial for further experiments and the commercial use of *P. lethifer* for biological control.

AG1
P2

ConservES – Conserving biodiversity and maximising ecosystem services in Europe's agricultural landscapes

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To increase agricultural production, cropland has been expanded at the expense of landscape complexity and insect diversity, with unknown – and likely negative – consequences for ecosystem stability and functioning under global change. To reverse this trend, agri-environmental schemes maintain or restore structure and plant diversity, which can benefit insect diversity, crop pollination and natural pest regulation. However, these schemes are often established without consideration of the local, landscape and climatic context, which can lead to variable and sub-optimal outcomes for both biodiversity and ecosystem services. Here, we address the question of how insect diversity and natural pest control are influenced by the establishment of flower strips near hedgerows compared to grassy field margins in landscapes with different proportions of non-crop habitat and under mild or harsh winter conditions (European gradient from France to the Czech Republic). Flower strips were established within cereal fields in autumn 2023. Pollinating insects, ground-dwelling predators, canopy-active predators, aphids and cereal leaf beetles were monitored from autumn 2023 onwards, complemented by predation rate experiments with different types of sentinel prey. We expect that flower strips, hedges and landscape complexity will have a positive effect on insect diversity and natural pest control, but that the combination of flower strips and hedges will be particularly beneficial in simplified landscapes. Harsh or mild winter conditions may affect the development of flower strips and insect survival, with consequences for insect diversity in the following spring and summer.

Above- and belowground structures and traits of agroforestry systems: chances and trade-offs

Short title: Agroforestry management: Chances and trade-offs

Chairs: Friderike Beyer, Peter Annighöfer

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Agroforestry systems exist in a large variety and complexity. As a result they can differ strongly in structures and traits. To gain a mechanistic understanding of dynamics inherent to the systems, interactions and potential trade-offs of above- and the belowground systems need to be understood. However, research on both above- and belowground structures and traits is still comparably scarce. This session aims at presenting recent findings of the often overlooked above- and belowground interactions that shape the functioning of agroforestry systems. By exploring innovative methodologies and recent data integration, we would like to advance the scientific foundation of agroforestry. We believe that a comprehensive understanding of both components is essential for optimizing agroforestry systems, influencing nutrient cycling, water-holding capacity, soil and plant health, as well as optimizing ecosystem services. As an imperative, research needs to identify sustainable practices such as optimizing water use efficiency, carbon sequestration, and adapting to changing soil conditions in order to mitigate and adapt to the effects of climate change. We invite researchers, practitioners, and experts to contribute presentations that showcase their work in this field and present case studies to e.g. standardize research protocols and thus make results comparable. From novel research findings to practical applications, we seek diverse perspectives that contribute to the collective knowledge on the dynamics of agroforestry systems.

AG2
01

From traditional to modern agroforestry systems: Benefits for biodiversity, animal welfare, productivity and climate resilience

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Traditional fruit orchards, tree pastures or dehesas are traditional agroforestry systems that are maintained because of the biodiversity and ecosystem services they provide. Modern agroforestry systems are developed with the goal of providing those services as well, but also of being more profitable and attractive to today's farmers. Here we summarize the evidence collected from eight long-term agroforestry experiments across Europe. Combining field observations and empirical data with process modelling we found that biodiversity was significantly increased, animal welfare and productivity were improved and that already low tree densities can increase the resilience of crop production towards climate extremes. European scale analysis indicates hot spots for the introduction of modern agroforestry systems and allow estimating the ecosystem service benefits that could be obtained from introducing more trees into modern farming systems.

AG2

02

Long-term yield dynamics in arable alley cropping agroforestry under the influence of climatic water balance and soil properties — a case study

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In the face of climate change, European agriculture is in urgent need of adaptation options. Warm-season droughts peaking in summer are becoming more frequent in central Europe, causing severe yield losses in cereal crops. Agroforestry is widely regarded as a key adaptation measure in the face of increasingly extreme weather events due to climate change. While there is a growing body of literature investigating yield dynamics in temperate agroforestry systems, due to the limited availability of long-term time series data, assessments of yield dynamics in temperate agroforestry systems rarely allow for assumptions on the effect of inter-annual variability in water availability in interaction with soil properties on crop yields. Thus, little is known about the influence of agroforestry on yield performance between dry and wet years comparing between different soil characteristics. We analyse winter crop yields at the 16-year-old arable alley cropping agroforestry trial site at the Ihinger Hof Research Station. To analyse yield dynamics over time, we used yield data of five winter crops in the period 2012–2023. We used linear mixed effects models (LMM) to analyse the effects of soil properties and climatic water balance on yields in alley cropping agroforestry. Significant effects of tree rows on crop yields occurred for all agroforestry practices from the beginning of the time series in the fourth year after establishment of the agroforestry site. We show that both climatic water availability and soil properties significantly influence the yield responses of the evaluated cropping practices. Our results contribute to the understanding of yield dynamics in agroforestry practices under inter-annual variability in water surpluses or deficits in relation to soil characteristics and inform decision making when applying agroforestry as an adaptation measure to climate change induced weather extremes.

Drought resistance and regeneration ability of three savannah tree species from agroforestry systems in the Sahel zone – results of a greenhouse experiment

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Western Africa experienced annual drought periods that sharply contrast with the humid conditions of the tropical rain forests in the southern parts, especially at the transition zone to the dry Sahel in the north. Climate change exacerbates these droughts, negatively impacting rural livelihoods, and thus more knowledge is wanted on improved agroforestry systems. *Combretum glutinosum, Pterocarpus erinaceus* and *Terminalia laxiflora* are widespread tree species, that are used by local populations in semi-natural agroforestry systems for providing shade, fodder, medicine, wood and erosion control. Understanding the drought stress tolerance and regeneration ability of these species after partial browsing or dieback is crucial for sustainable management. This study investigated these aspects in a greenhouse experiment at Technical University of Munich. Seedlings of three tree species from Burkina Faso were grown for two years in pots after seeds' germination in an incubator. 48 plants per species derived from three provenances (north, intermediate, south), each. Half of them underwent repeated moderate drought cycles with the consequence of decreased radial growth. There were no differences found between the provenances in any of the species. Afterwards five trees per species underwent irrigation cessation for up to 10 days, with soil moisture monitored using TDR sensors and diurnal diameter changes tracked with electrical dendrometers and compared to well-watered control plants. Xylem water potential was measured at peak of the drought according to the Scholander technique. Combretum survived pre-dawn water potentials as low as -5.5 MPa. At the end of the experiment all three species proofed their high resilience by resprouting after coppicing quite fast. The results are discussed against the background of anatomical and physiological measurements that characterize the water relations of these species, providing insights into their potential for enhancing agroforestry systems in drought-prone regions like Burkina Faso.

AG2

04

Grafting as a method for the conservation of cacao genetic diversity and local biodiversity in tropical agroforests

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Tropical agroforests are considered a sustainable alternative to produce several commodity crops, combining biodiversity conservation and high crop yields. However, crop yield of commodities as cacao declines with time, often leading smallholders to expand plantations at the expense of tropical forests. Therefore, alternatives to sustain crop yield while safeguarding tropical biodiversity are imperative. We investigated the socio-ecological value of grafting, a widely used vegetable propagation method, to swiftly restore yield of cacao agroforests. We replaced low-yielding varieties with six elite genotypes of the Gran Blanco de Piura native cacao variety in twelve cacao agroforests of Peru and assessed the diversity of diurnal and nocturnal arthropods on the young grafts three, six and nine months after grafting. Moreover, we monitored graft productivity 2–4 years after grafting. We found that already two years after grafting cacao yield increased by an average of 30%, but diversifying the genetic composition of crops at plant and plot level did not significantly increase this benefit. Compared to non-grafted cacao, arthropod abundance was 25% lower on 3-month-old grafts but recovered ca. 13% three months later. Abundance of phytophagous insects (mainly aphids) did not decrease with grafting. However, we found fewer beetles and predatory arthropods (mainly spiders) on young (but not old) grafts, warning of a potential temporary decrease in pest control services by mesopredatory arthropods in early grafting stages. Overall, grafting is a successful measure to rejuvenate old unproductive cacao trees, alleviating pressure on smallholders' livelihoods and forests in agricultural landscapes. Rejuvenation of cacao trees by grafting should be promoted and implemented as a promising strategy for sustainable social-ecological cacao management, with economic and ecological benefits for smallholding farmers.

AG2

05

Factors driving tree community structure in traditional home gardens in the Mayan forest

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Peasant populations around the world's tropical areas maintain traditional home gardens (THG) as a sourcing asset in their homes. THG harbor a significant plant biodiversity, most of which is directly related to food production. In the case of tree species, an important component of their diversity is the incorporation of locally rare species related to firewood, cultural and ornamental uses, shade, and wind barriers. Hence, THG are considered refuges for endangered or rare species. Previous studies have considered factors driving tree diversity in THG; however, few have considered these agroecosystems as effectively semi-natural ecosystems, where natural biological and environmental factors shape tree diversity and development. Analysing 48 THG across a precipitation gradient in the Mexican Yucatan Peninsula, we show that tree abundances in THG is mainly explained by the relative abundance of voluntary individuals (i.e. not deliberately established), organic carbon content in soil, and surrounding forest integrity. Management history of THG by peasants, including factors such as irrigation, TGH area, and fertilization showed smaller, but significant differences. Tree distribution is influenced by the precipitation gradient present in the Yucatan Peninsula showing different abundances even for cultivated species. Our results suggest that biological and environmental factors can exert a higher impact on tree abundance and distribution than anthropic activities in THG. Moreover, we identified rare, region-specific, and indicator species associated with these anthropized environments, which may contribute to conservation efforts of tree diversity.

Boosting birds and bats with agroforestry

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Despite decades of agri-environment schemes, biodiversity remains low in most European farmland. Agroforestry systems have been proposed to restore structural diversity to agricultural landscapes, facilitating animals like birds and bats that depend on heterogeneous environments. As part of the EU Project AGROMIX, we studied the effects of mature agroforestry systems on biodiversity in eight European countries. The richness of breeding birds was multiple times higher in any type of agroforestry compared to open farmland. By contrast, the activity and foraging success of bats was increased in silvo-pastoral but not in silvo-arable agroforestry. In addition, bats benefitted more from old and deciduous trees than from younger trees and conifers. According to our results, agroforestry is a promising element to make substantial progress towards biodiversity-friendly agriculture.

Unfolding the leaf economics spectrum for wheat: trait analysis and genomic associations across cultivars

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The leaf economics spectrum (LES) is an ecophysiological concept that describes the trade-offs between leaf structural and physiological traits. It has been extensively studied across various scales. However, the coordination hypothesis has rarely been tested at the intraspecific scale, especially in crops, for understanding yield increases or predicting evolutionary trajectories. Here, we first tested the relationships among leaf traits and examined the genetic coordination among 209 wheat genotypes. Compared to non-crop grass species, wheat is a fast-growing species, and tends to have a higher value of photosynthetic rate, leaf nitrogen concentration and leaf lifespan at a given leaf mass per area, although it does align with the predicted direction of the 'fast–slow' spectrum. We conducted a principal component analysis (PCA) to compare different traits within wheat. The first axis from PCA is significantly positively associated with the agronomic traits, especially grain yield ($R^2 = 0.11$, $P < 0.001$). Partially independent changes in leaf nitrogen content and leaf mass per area may allow crops to maximize photosynthetic rates without sacrificing leaf lifespan. The results reveal that some loci are simultaneously associated with different traits, which may be the genetic basis for the formation of trait-trait relationships. The current study deepens the understanding of LES traits in wheat at the intraspecific and genetic levels, supporting the trait-based adaptation strategies to improve wheat productivity and resource-use efficiency.

Agroforestry practices in sustainable land use systems in Ghana

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Food production worldwide context increased at the same rate as that of human population. The rapid growing population in the world is currently depending on conventional forms of agriculture that are unsustainable. With growing public awareness of the effects of global climate change, there is a movement to embrace agricultural alternatives that promote a more responsible, sustainable and resilient relationship with land use. Productive land is progressively being displaced by urbanization and forest land degraded. Deforestation and forest degradation are also critical parameters threatening ecosystem stability and depleting the natural resource base. The objective of research is to highlight farmers' perception, importance and role of agroforestry as tool in sustainable land use systems in the Ashanti and Brong Ahafo Region of Ghana. The multi-stage sampling technique was employed to selected 300 farmers in the study area. Data obtained from the respondents were analysed using descriptive statistics and inferential analysis. The research found out that agroforestry merits special attention because of the diverse benefits it provides for smallholder farmers across the country. Agroforestry emerges as a promising land use option to overcome the problem of land degradation and the imminent food insecurity. Traditional knowledge needs to be actively built upon. It can therefore be indicated that given the level of awareness among the farmers there is the need to improve on the existing agroforestry practices in the face of increasing population. Farmers indicated that through the integration of trees on farms and in the agricultural landscape, there is sustainable production for increased social, economic and environmental benefits for land users at all levels. The study therefore recommends that more focus should be placed on incentives to promote investments in agroforestry and the development of market-driven tree crop products.

P3

Tree species diversity favours early shade tree survival in an agroforestry experiment in north-eastern Madagascar

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Trees are key elements that support biodiversity and ecosystem functions in human-modified landscapes formerly covered by forest. Shade trees thus make agroforestry systems attractive for ecosystem restoration, potentially benefiting both biodiversity and people. To test effects of (i) tree species diversity, and (ii) tree spacing on biodiversity and ecosystem functioning, we established the agroforestry-focused biodiversity enrichment experiment SAVA-BEE. It is located in the humid SAVA region of north-eastern Madagascar and comprises a total of 45 plots including the land-use types trees only, crops only, no trees no crops. The experiment covers a total area of 7.9 ha. Before planting, the area was dominated by the noxious invasive grass *Imperata cylindrica*, the native *Ravenala* sp. and partly shrubs and small-statured trees. We planted six native tree species, including four endemics, in gradients of diversity (1–6) and spacing (8 m x 8 m to 2 m x 2 m). Crops were planted in identical mixtures of vanilla, pepper, coffee, cacao, banana, pineapple and watermelon on all agricultural and agroforestry plots. Survival of trees was high (84%) seven months after planting. Tree species identity was the major factor in tree survival. Remarkably, the probability of tree survival was strongly enhanced by growing in mixtures, and slightly reduced at close spacing. Survival of trees was probably reduced by biotic agents, mostly insect herbivory, when growing with conspecifics and at close spacing. Previous land cover also influenced tree survival with *I. cylindrica* dominated areas performing worse. Overall, we conclude that tree diversity favours early shade tree survival, thus promising a better achievement of goals in agroforestry-based ecosystem restoration.

AG2
P4

Towards meeting sustainable biodiversity: Evidence from cocoa agroforestry system in Ghana

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Cocoa agroforestry system is regarded as a multiple-win practice as it can protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss for a sustainable future. The primary objective of the paper is to examine cocoa agroforestry as an option in meeting sustainable biodiversity. This paper aims at bridging the knowledge gap by providing empirical by seeking to evaluate conservation value of cocoa and forest interaction as well as showing how cocoa agroforestry system can contribute to the development of rural and community forestry to achieve the sustainable development in Ghana. Simple random sampling technique was used to select four cocoa growing communities and 400 cocoa agroforestry farmers in the Western Region of Ghana were selected. Both descriptive and inferential analyses were used to analyse the data. About 95% of the respondents indicated that cocoa agroforestry places emphasis on the potential of smallholder tree-based systems to expand regional forest resources and, produce forest products and services as well as representing a major contribution to local livelihoods for rural communities. Further analysis showed that cocoa agroforestry has multiple benefits in the form of both products and services: they yield food, fuelwood, fodder, timber and medicines. Over 25 species of timber trees were retained on the farm. Farmers indicated that retaining shade trees on cocoa farms improved yield, create a microclimatic environment for sustainable yield over time. In conclusion from the study, cocoa agroforestry system emerges as a promising land use option to meet the biodiversity and Sustainable Development Goals. Policies to promote this integrated landscape approach, that incorporates agroforestry concepts and practices, to overcome barriers and accelerate action for achieving biodiversity goals associated targets need being promoted.

Ecological and social dimensions of future renewable energy systems

Short title: The biodiversity-energy nexus

Chairs: Finn Rehling, Nora Adam

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To reduce the reliance on fossil fuels and associated carbon emissions, the development of renewable energies must be accelerated. Developing renewable energies impacts large areas of land. If such projects are not designed and managed properly, detrimental consequences for biodiversity and the environment could take place. In addition, the development of renewables can compete with other types of land uses, including food and timber production. To simultaneously mitigate green-green and land use conflicts, concepts of spatial and environmental planning must integrate ecological and social perspectives. This will foster improved linkages among stakeholders across scales and enhance social acceptance of renewable energy development. To support this process, this session aims to unit researchers from diverse disciplines studying socio-ecological transitions of energy systems and biodiversity management, and will provide unique inputs from practitioners in the renewable sector. Therefore, the scope of this session is broad and provides a stage for interdisciplinary research on the biodiversity-energy nexus, including (i) green-green conflicts of developing renewable energies, (ii) current limitations in technology, the regulatory framework and governance of sustainable energy transitions, and (iii) paths forward towards multi-functional land use that addresses needs of biodiversity, renewables and society.

AG3
01

Innovative hydropower: fish passage, mortality and habitat effects

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Innovative hydropower developments promise to improve fish passage and to reduce fish mortality and habitat deterioration. So far, these promises have rarely been validated in realistic field settings. In a large-scale field study, we compared fish passage, mortality, external and internal injury patterns, movement corridors, and habitat effects at eight different types of innovative and conventional hydropower plants in Germany under different operational regimes. The suite of methodological approaches included sonar-based fish behaviour assessment, the use of sensor fish as well as mortality/injury assessments of wild fish and hatchery-reared test fish, biological community monitoring and habitat characterization. The findings revealed that innovative hydropower technologies sometimes produced greater adverse ecological effects than conventional ones, and that operational modes had a strong effect on the observed fish mortalities and injury patterns across species. Strong differences in seasonal and diurnal fish movement patterns were evident. Most fish followed the main current through the turbine corridor and did not use alternative bypasses. Physical barriers with 15 mm and 20 mm bar spacing could not prevent most fish from entrainment and were passed by specimens exceeding the expected size thresholds from modelling. Concerning habitat quality, dams and weirs interrupted the river continuum, reduced flow current and increased siltation upstream of dams, resulting in biological community shifts. These effects were not significantly mitigated by most innovative technologies over the study period, despite the promise of some of them to do so. This study provides novel insights into which technologies and operational modes are least harmful under the given site conditions. It also suggests that assessments of fish passage and ecological effects can greatly benefit from realistic field studies. Such information can help improve the operation of existing and the design of future hydropower plants.

AG3
02

Environmental impacts of floating PV

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As the demand for renewable energy grows, finding solutions that maximize efficiency and make the best use of available space is crucial. Floating photovoltaic (FPV) systems, which deploy solar panels on water bodies, are a promising technology. BayWa r.e. has extensive experience in the floating solar industry for the past 5 years, with 18 operational projects with a total capacity of 270 MWp across four countries. While technology advancements and market growth are exciting, understanding the environmental impact of these installations is crucial for further development of the projects. BayWa r.e. along with its Dutch subsidiary Groenleven in collaboration with universities and independent research institutes such as Ecocean, Royal Haskoning DHV, Enviso, Deltares, and Royal Haskoning DHV, has started various research studies on its operational Floating solar farms that assessed the impact of floating solar on water quality, ecosystem health, and surrounding environments. This presentation explores initial findings from some of the environmental studies conducted at operational floating solar farms and will delve into the key findings from: (i) Bomhofsplas (27.4MW) Biohut Monitoring by Ecocean: This study explored the use of artificial habitats biohuts for aquatic life by monitoring the development of fish and invertebrate species under the solar panels. (ii) Weperpolder (2.1MW) Bird monitoring: This study investigated FPV's impact on the birds before and after the construction of the solar farm. (iii) Bomhofsplas and Nij-beets (27.4MW) Bird monitoring by Burro Bakker AKTB: This study monitored the breeding birds and their behavioural changes. Overall, the findings demonstrating the potential for floating PV systems, coupled with habitat enhancements, to contribute to both clean energy generation and a thriving aquatic ecosystem will be presented.

The role of stakeholders in corporate biodiversity management in the Middle East and North Africa (MENA) region

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Renewable energy is one of the rapidly growing sectors in Middle East and North Africa region, this attributes to different aspects. First, MENA countries' abundance of sunny days for solar power generation and adequate locations for wind systems installation. Second, the geographical proximity to Europe and the willing to contribute to the EU's green deal via setting ambitious renewable energy portfolio for local generation and exporting to EU countries. Despite the fact that renewable energy sector has significant positive impacts in terms of reducing reliance on fossil fuels and subsequently decreasing Greenhouse Gases GHGs, rapid growth without prior social and environmental impact assessment and proper stakeholders engagement planning may result in adverse implications on biodiversity. Key examples on MENA region countries competing on sitting high renewable energy targets are: Egypt, Morocco, Jordan and UAE with renewable energy substitution rates reaching 42, 52, 50 and 44% by 2035, respectively (IRENA 2023). Each country has set a diversified renewable energy mix consisting of solar, wind and green hydrogen production. Therefore, it is crucial to ensure that regulatory frameworks promoting biodiversity protection and disclosure of related indicators in annual sector's companies Environmental, Social and Governance - ESG reporting, in addition to comprehensive biodiversity management plans, with stakeholders roles identified are currently in place. Hence, the presentation will aim at providing an in-depth review on the status quo of biodiversity management policies, regulatory frameworks and stakeholders engagement plans for renewable energy sector for solar, wind and green hydrogen subsectors in the above-mentioned countries.

Integration of nature-based solutions in ground mounted photovoltaic and onshore wind energy sites for a nature positive energy transition

Gayathri Mohan
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Green pathways such as renewable energies and nature-based solutions (NbS) have the potential to reduce greenhouse gas emissions, while facilitating the conservation of biodiversity and ecosystem services. Coupling NbS with the development of renewable energy could deal with urban societal and environmental challenges such as land and energy scarcity, and the growing biodiversity crisis. Research in integrating NbS with green energy is especially of interest to energy corporations who are motivated by a sense of urgency to increase social acceptance of wind and utility scale solar parks. Hence, to enable renewable energy (RE) companies to better incorporate NbS in their projects, more in-depth analyses is required to understand the most common issues in and around the project sites that could be addressed with NbS and to what extent the planning, implementation and management of such measures are influenced by factors like the geographical location, and social and political environments. Site-specific NbS measures have the potential to pave the way for 'nature positive' outcomes, that go far beyond just 'biodiversity positive'. The research focuses on nature-based measures employed on utility scale solar and onshore wind energy sites to address adverse ecological impacts of RE development, role of policy and industry best practices in driving the employment of these measures, and the most common barriers for RE companies to employ and manage these measures effectively. Here, the definition and scope of NbS are broad and it is considered as an umbrella concept that encompasses a range of ecosystem-related actions and interventions.

AG3
05

Red kites and wind power: Increasing the cut-in speeds of wind turbines can contribute to more effective protection of the species

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To reduce climate-changing CO_2 emissions, more and more wind turbines have been built in open land and forests in recent decades. Birds of prey, especially red kites (*Milvus milvus*), are particularly vulnerable to collisions with wind turbines due to their soaring behaviour. One promising approach to reducing the risk of collision is to use algorithms to regulate the operating times of wind turbines based on local weather conditions. To better tune these algorithms, we investigate how weather, land use type and season influence flight height and activity. To this end, we observed flight activities of 37 adult GPS-tagged red kites in different landscapes in Hesse, Germany, over a period of seven years - resulting in more than 582,800 location points from 127 individual years. Specifically, we analysed flight height and flight activity as a function of local environmental variables such as wind speed and land use - in the form of open land, forest and anthropogenic structures. We found a consistently high level of activity across the entire range of occurring wind speeds. Flight activity changed over the breeding season and over the course of the day However, local weather variables such as temperature, precipitation and wind speed were poor predictors of flight activity and altitude. Flight altitudes varied greatly between individuals and land use types, with most flights of approximately 62% occurring over open land. More than a quarter of the flight movements occurred at the height of the rotor swept areas of current wind turbines. One promising approach to mitigate the risk of collision is to increase the cut-in wind speeds of wind turbines. An increase in the currently recommended average cut-in wind speed of 2.2 m/s over open land and 2.4 m/s over forest would be sufficient to eliminate 90% of all flight movements from the risk of collision with rotors of modern wind turbines in Hesse.

Wind turbines in forests: Implications for species conservation and regulatory responses using the example of Germany

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More and more wind turbines are being built globally to reduce carbon gas emissions and mitigate the consequences of climate change. However, space for turbine construction is limited and, particularly in densely populated regions like Germany, forests are becoming attractive sites for wind energy development away from settlements. Recent changes in the German legal framework have facilitated this trend. At the same time, evidence of negative impacts of wind turbine operation on forest biodiversity is accumulating. For our article, we summarised the current state of knowledge on the wildlife-wind energy conflict in forests and compiled how (i) habitat is lost or permanently modified where wind turbines are built, (ii) bats and birds suffer from collisions with wind turbine rotors and (iii) several animal groups are displaced by wind turbines. While a total exclusion of forest as sites for wind turbines could have negative side-effects for typical open landscape species, a differentiated regulatory framework based on current German law could reduce conflicts by setting minimum requirements for biodiversity conservation during forest wind energy development. This should include identifying ecologically sensitive forest areas during planning, implementing site-specific mitigation measures, and compensating for negative impacts for example through habitat restoration elsewhere. Filling regulatory gaps and improving ecological monitoring are essential to mitigate ecological conflicts and ensure sustainable wind energy development in forests.

AG3
P1

A meta-analysis on displacement effects of wind turbines on animals

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Operating wind turbines disturb and partly displace animals from otherwise suitable habitats. A recent literature review found that in two thirds of studied cases, animals are displaced by wind turbines, partly up to 5000 m. This suggests that the increasing expansion of wind energy will lead to a significant loss of habitat for many animal species. To mitigate this loss, compensatory measures related to wind turbine deployment could be applied that consider the average displacement effects of turbines on animals. We will conduct a meta-analysis to synthesize studies that used an impact-gradient design to investigate displacement effects of wind turbines on animals. Our analysis will account for differences in turbine characteristics among wind parks, differences among habitats and animal species, and differences in the quality of scientific studies using a standardized evaluation assessment tool. We will present latest results of our analyses at the conference, aiming to inform evidence-based policies and practices for future wind energy expansion.

AG3
P2

Environmental Impacts of Floating-PV

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Low or no impact on water quality: Water quality parameters such as water temperature, dissolved oxygen concentration, and electrical conductivity are not negatively affected and remain in the healthy range under Floating PV. Meaning that they can continue supporting aquatic biodiversity depending on the water type, water depth, and water ecology. The project *Enhancing Biodiversity with Floating-PV Installations: A Case Study at Bomhofsplas* is located in the Netherlands, and was commissioned in March 2020 by Groenleven, a Dutch subsidiary branch of BayWa r.e. with a capacity of 27.4 MWp. Since its completion, the plant has been used to investigate the impacts of FPV on water ecosystems. In 2020, 20 biohuts were installed at the Bomhofsplas FPV plant. These underwater structures serve as (i) nurseries for young fish, and (ii) habitat and spawning grounds for fish, invertebrates, and microorganisms. Three years of monitoring success in 2020–2023), researchers from Ecocean observed a positive trend in species colonization and development within the FPV environment. A total of 2382 individuals were recorded (1951 invertebrates and 431 fish) across the three monitoring campaigns, i.e. clean energy and clean water: a winning combination. Floating PV offers a sustainable energy solution, but concerns about water contamination can arise, especially for drinking water supplies. BayWa r.e. prioritizes safety and utilizes innovative strategies to ensure clean water. (i) Material selection: BayWa r.e. meticulously selects materials to prevent harmful substances from leaching into the water; and (ii) Biodegradable fluids: Transformers use safe, biodegradable alternatives to traditional oil, minimizing environmental impact in case of leaks. BayWa r.e. completed the first 4.9 MWp project on a drinking water reservoir which was tested independently to prove compatibility with drinking water.

Computational/Methods (CM)

Bringing together theory and data to understand ecological communities

Short title: When theory meets data

Chairs: Virginia Domínguez-García, David García-Callejas

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In the face of unprecedented global change, unravelling the intricate responses of ecological communities becomes increasingly crucial for effective conservation and management strategies. To achieve a more comprehensive and mechanistic understanding of community dynamics, we recognize the imperative need to bridge the gap between advanced theoretical models and high-quality empirical data. However, studies combining these two ingredients remain scarce: for example, only a mere 4% of studies in ecological stability currently integrate both perspectives. The main reason behind this profound divide is that the methods that are more easily developed in a purely theoretical framework tend to be more difficult to implement in the field (and vice versa). Theoretical developments are often disconnected from the community-level properties that can be observed in the field and thus are exceedingly difficult to test in real conditions. From the other point of view, empirical studies are often designed without considering advanced ecological theory, leading to missed opportunities for positive feedback between theory and field studies. Historically, this has prevented the empirical testing of many theoretical advances. Likewise, field studies without strong connections to the theoretical developments in community ecology face the risk of becoming collections of interesting but isolated case studies. In order to bridge that gap, a truly interdisciplinary approach to studying ecological communities is needed, which can only come from a tight collaboration between theoreticians that develop new approaches, and field and empirical ecologists that design experiments able to generate high-quality data that allow the testing of these new theoretical models. By assembling a diverse group of researchers committed to this interdisciplinary endeavour, our symposium aims to showcase recent breakthroughs, shed light on emerging challenges, and foster collaborative discussions that bridge theory and empiricism in different areas of community ecology. We have already contacted a list of 8 researchers, well balanced in terms of gender and career stage, who agreed to participate in this session and are listed below.

CM1
01

Do we have the right data? Which ecosystem properties matter?

Yuval Zelnik
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Which ecosystem properties are inherent and universally important to an ecosystem? What measurable properties inform us of community dynamics? Do we measure some things better than others, and what needs to be measured, anyway? In this talk, I will present some work on quantifying ecosystem properties, and share some realizations about the lack of data for basic ecological properties that are important for theory and models. I will consider the role of synthetic parameters that describe community dynamics, which may underlie many seemingly unrelated patterns. I will further consider issues of measurements, and how they differ between aquatic and terrestrial ecosystems.

Ecological resilience: Inconsistencies, challenges, and new empirical approaches

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In the current context of global change, promoting ecological resilience has become a pivotal target for biological conservation. Unfortunately, the urgency of empirically understanding ecosystem resilience has led to a profusion of metrics and analyses that are not always directly related to resilience theory. Many empirical approaches widely applied to assess resilience have relied on the underlying assumption that ecosystems would be in a static baseline state in the absence of disturbances. In reality, ecological systems are highly dynamic and undergo phases of development and reorganization resulting from natural successional changes and their response to multiple interacting variables. As such, ecosystem states can be better described by 'dynamic regimes' rather than stationary states. In this context, there is an urgent need to expand the common equilibrium-based approaches used in empirical ecology to apply them to non-static ecosystems. Implementing the resilience theory in empirical ecology requires accounting for at least four important challenges: (i) the types of attractors and transient dynamics, (ii) the variability and stochasticity of ecological dynamics, (iii) the multidimensionality of ecological dynamics, and (iv) the temporal variation of the stability landscape. Novel approaches based on ecological dynamic regimes and temporal trajectories offer a new perspective to identify and characterize the domains of attraction of natural systems and empirically assess ecological resilience overcoming the mentioned challenges. Notably, these approaches facilitate the identification of the factors that must receive special attention for enhancing ecosystems' resilience and provide more accurate information about the management effort necessary to restore a disturbed system.

CM1
03

Disentangling metacommunity assembly mechanisms from eDNA using joint species distribution models

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New advances and technologies are leading to an unprecedented high resolution of community data, perhaps making it possible for the first time to unravel the mechanisms of metacommunity assembly. Environmental filtering, species interactions, ecological drift, and dispersal determine community composition in local communities, but disentangling their relative importance has proven elusive, likely due to inappropriate tools. Here, we show that joint species distribution models (JSDM) and variance partitioning can provide a solution. First, JSDM reveals the 'internal structure' of communities and species that can be correlated in a second step against environmental and spatial distinctiveness, thereby revealing the importance of metacommunity assembly mechanisms. We demonstrate that this approach can detect environmental filtering and dispersal limitation in a pond metacommunity. We conclude that JSDMs are a powerful tool for metacommunity analysis, especially for large community data.

CM1
04

The multiple advantages of bridging theory and data in the study of interaction networks

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Our understanding of interaction networks is often clouded by conflicting perspectives and a gap between advanced theoretical models and high-quality empirical data. To bridge this gap, we embarked on a journey to unify perspectives, focusing on pollination, seed dispersal, and malaria to address two key dilemmas: nestedness vs. modularity and trade-offs vs. resource breadth. The unification of these dilemmas led to the development of the 'Integrative Hypothesis of Specialization' (IHS), which explores the relationship between performance and generalization and its implications. Extending the IHS to ectoparasitic interactions, we discovered that ecological specialization is hierarchically structured, with networks forming modular structures with nested submodules. To analyse these patterns, we created a protocol for examining compound topologies in interaction networks, along with a new index of weighted nestedness and a framework for assessing nestedness. Our proof of concept revealed that network topologies, including nested, modular, and compound structures, primarily arise from resource heterogeneity. We also introduced an index of ecological specialization that is robust against neutral and sampling effects. Applying the IHS to multilayer networks of bat-plant interactions, we found that geographical, phylogenetic, and organismal traits shape network assembly. This multilayer approach led to the development of a new centrality metric, enhancing our ability to identify keystone species across various interaction types and ecosystem services. By refining the IHS into a semantic theory, we have elucidated the dynamic processes shaping ecological networks, developed new tools and protocols for disentangling these complexities, and highlighted the advantages of holistic perspectives in bridging theory and data. Our journey also paved the way to apply the IHS to study socioecological systems, aiming to help achieve some of UN's sustainable development goals.

CM1
05

Dynamics of a plant-pollinator network: Extending the Bianconi-Barabási model

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To understand the hidden mechanisms of pollination, we study the dynamical assembly of weighted bipartite networks, expanding the Bianconi-Barabási model to the situation where nodes have specific properties. Allowing for a non-linear interaction rate, which represents seasonality, our analysis reveals similarity of the extended Bianconi-Barabási model with field observations. While our current approach may not fully account for the diverse range of interaction accretion slopes observed in real-world scenarios, we regard it as an important step towards enriching theoretical models with biological realism.

CM1
06

Species diversity, food web structure and the temporal stability of ecosystems: bridging the gap between theory and data?

Elisa Thebault

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The consequences of diversity and food web structure on the stability of ecological communities have been debated for more than five decades. While the understanding of the relation between diversity and the stability of properties at community and ecosystem levels has gained from joint empirical, experimental and theoretical insights, the question of the relation between food web structure and stability has received almost exclusively theoretical attention. The lack of empirical studies on this issue is partly since theoretical studies are often disconnected from the stability of natural ecosystems, and to the difficulty of describing and manipulating food web structure in the field. Here I will present the results of two joint studies, one based on a theoretical food web model and the other on the data analysis of time-series of fish communities, aiming to investigate in parallel the relations between diversity, food web structure and the stability of community-level properties.

CM1
07

Ecological coexistence, in theory and practice

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Coexistence is simultaneously one of the most fundamental concepts of ecology, and one of the most difficult to define and quantify. A particular challenge is that despite almost a century of theoretical advances in our understanding of coexistence, the field remains largely fractured, resulting in multiple schools of thought with their own distinct definitions for what qualifies as coexistence, and surprisingly few attempts to reconcile their dominant concepts and metrics. This fragmentation has largely limited opportunities for synthesizing insights about coexistence across empirical studies, both because of differences in the definitions and metrics that they use, and because existing metrics are challenging to apply in empirical contexts, often requiring special expertise, ample data, and strong theoretical assumptions. This talk provides a broad overview of the most common concepts and metrics currently used to study ecological coexistence, with the goal of unifying existing theoretical paradigms to help make them more empirically tractable. We will first review four classes of behaviour that describe different aspects of community dynamics: (i) the existence of a feasible steady state, i.e. where all coexisting species retain positive abundances in the long-term in the absence of interference by external forces; (ii) the existence of a local attractor that draws the community towards a feasible steady state from within a restricted set of starting conditions; (iii): the existence of a global attractor that draws the community towards feasible steady states from any feasible starting condition; and (iv) a null transient state, where species abundances vary over time irrespective of steady states and attractors. Next, we will discuss how these classes of behaviour relate to commonly used metrics for classifying and quantifying coexistence, including analyses of time to extinction, parameter sensitivity, asymptotic return rates, and invasion growth rates. Finally, we delve into the scope and limitations of each of these behavioural definitions and corresponding metrics, with a particular focus on applications in empirical systems. Finally, we close with a brief prospectus looking forward to opportunities to better advance and integrate research on coexistence.

CM1
08

An empirical validation test of modern coexistence theory to forecast time-to-extinction under rising temperatures

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Interspecific interactions are expected to be an important part of ecological responses to climate change but pose a considerable challenge to include into species forecasts. 'Modern' coexistence theory (MCT) offers the potential to predict the outcome of competition between pairs of species under particular conditions from parameterised models and is being increasingly applied to forecast responses to climate change. However, predictions from this framework have rarely been critically tested and make several significant simplifying assumptions. First, I will discuss the challenges inherent in applying MCT to empirical settings for practical forecasts. I will then present results from an experiment using highly replicated multi-generational *Drosophila* mesocosms to test if MCT can accurately predict time-to-extirpation in the face of rising temperatures in the context of environmental stochasticity and competition from a heat-tolerant species. In these trials, the temperature at which coexistence was forecast to be lost aligned with the mean observations of the extirpation time of the resident species. However, predictive precision was low and predictions depended on the underlying model used. Nonetheless, these results support the careful, scale-aware, use of coexistence theory for near-term forecasting.

Combined land-use and climate change: Using a metabolic community model to simulate drought effects on species coexistence in fragmented landscapes

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Biodiversity is threatened by changes in land-use and climate. Although these processes are known to influence species survival and diversity, it remains challenging to predict their effects on communities especially when it comes to combined changes. Lately, extreme events such as droughts have occurred more frequently and threatened biodiversity, e.g. in agricultural landscapes. We aim to disentangle the effects of drought induced resource shortage and habitat fragmentation on species coexistence. As both fragmentation and droughts affect individual movement and physiology, we use an individual-based metabolic modelling approach simulating a small mammal community of ten species. Individuals forage in the landscape to ingest energy, hence, survival depends on landscape features, available resources, and competition. The ingested energy is allocated to basal maintenance, digestion, growth, locomotion, reproduction, and storage. If individuals of several species can balance their energy needs and additionally store energy as fat reserve, they may overcome periods of droughts with limited resources and coexist. We find that short and severe droughts have a more pronounced effect on species survival than longer less severe droughts. Additionally, species recover best after a drought when they live in medium fragmented landscapes compared to low or high fragmentation. Real drought time series show that the effect of recently increasing droughts on species richness was more severe in fragmented landscapes. We suggest that especially with accelerating climate change, it becomes more important to design landscapes that allow for species coexistence and high biodiversity. The combination of global changes should be considered to predict and preserve future biodiversity. Our presented community model includes metabolic and behavioural reactions of individuals and scales them up to the community level, which offers great potential to support nature conservation.

CM1
O10

Revealing species coexistence mechanisms through the lens of causations among environmental hypervolume niches, functional traits, and phylogeny

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Understanding the mechanisms governing species coexistence is a fundamental challenge in modern community ecology and biodiversity. Despite various hypotheses, a unified framework that integrates the interplay of factors such as ecological niches, functional traits, evolution, and competition remains elusive. This study systematically investigates how the various factors may influence coexistence and aims to contribute to a unified framework. We constructed environmental hypervolume niches, functional trait hypervolumes, and a phylogenetic tree for co-occurring tree species in a 50-ha forest plot on Barro Colorado Island, Panama. We calculated pair-wise differentiations of environmental niches, functional traits, and phylogenetic distances among all tree species, as well as spatial interspecific competition intensities and species coexistence probabilities based on their abundance. We then evaluated all these species co-occurrence driving factors to understand their correlations and causal relationships. Our results demonstrate that environmental filtering and limiting similarity operate concurrently, facilitating coexistence through distinct pathways. Species in similar environmental niches exhibit similar functional traits, constraining trait divergence and supporting coexistence. Conversely, different environmental niches promote competition, leading to the coexistence of phylogenetically distant species. For the first time, we reveal the causal roles of these mechanisms in driving species coexistence. We propose a theoretical framework integrating competition, environmental niches, phylogeny, and functional traits to explain species coexistence. This framework advances our understanding of biodiversity maintenance and highlights the need to explore the relative importance and causal relationships of these mechanisms across ecosystems for a more profound understanding of species coexistence.

011

Foreseeing forest futures: ARIMA vs. Neural Networks vs. TBATS in tree growth predictions

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Over the past two decades, significant advancements in machine learning have revolutionized various scientific fields, including ecology. These innovations offer new opportunities for accurately predicting tree growth using high-resolution (1 hour) data. Long term monitoring of tree growth and environmetnal conditions in six plots along Austria over the last ten years provides an unique set up to evaluate the performance of prediction models for both yearly variations and changes over long time. This study presents a comparative analysis of three modelling approaches: ARIMA, TBATS, and Artificial Neural Networks, to forecast Diameter at Breast Height (DBH) in trees of central Europe. High-resolution growth data were utilized to train and test each model. The findings indicate that although Artificial Neural Networks exhibit high performance and complexity, ARIMA and TBATS models demonstrated superior accuracy in predicting tree growth when considering the variability of environmental predictors (to simulate climate change scenarios for example). This research highlights the efficacy of traditional statistical methods like ARIMA and TBATS in time series ecological forecasting, even in the era of advanced machine learning techniques. The implications of this study are significant for ecological forecasting, especially in the context of rapid environmental changes and limited data availability. Understanding these models' strengths can enhance predictive accuracy and model strategy selection, which is crucial for forest management and conservation efforts. Additionally, the study emphasizes the value of maintaining proficiency in traditional statistical methods alongside newer machine learning approaches.

O12

Mechanistic insights into animal movement and its ecological implications

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Movement is a critical ecological process that shapes spatial patterns within and across species, connecting populations, communities, and ecosystems. Foraging movements are critical within local habitats, driving encounter rates between mobile species and influencing species interactions and community composition. Dispersal movements connect habitats and ecosystems, impacting species distributions and biodiversity patterns. The vast quantity and quality of data on animal movement patterns calls for a more mechanistic understanding of the underlying processes, while also integrating this information into theoretical frameworks to predict spatial patterns across communities and ecosystems. I will illustrate how mechanistic models can enhance our understanding and prediction of animal movement capacity, and how this, in turn, can inform complex models encompassing dispersal dynamics, thermal performance, and community patterns.

CM1
P1

Effect of changing interactions in pollinator persistence

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Few studies follow the interactions in plant-pollinator communities through long periods of time, which means that most of the information we have on empirical plant-pollinator communities are like 'photos', showing a particular state of the community, but not its full behaviour. However, looking at these studies it is still not clear to what extent interaction structure remains constant, with several studies showing some consistency in the species interaction pattern in plant-pollinator communities through time, but others showing that while the general pattern is conserved, species roles change constantly. Here, we use a well-resolved data set on abundances and interactions between plants and pollinators in a long-term study carried out on twelve independent sites exposed to changing environmental conditions over 6 years, and using null models of interaction rewiring, we show to what extent these rewiring in the network of interactions affects the ability of pollinators to persist in the field.

The future of bio- and eco-acoustic monitoring across scales and ecosystems: Methods, challenges and applications

Short title: Acoustic monitoring methods and applications

Chairs: Andrew J. Fairbairn, Michael Beckmann, Dominik Arend

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Goal of the session: Understanding the impact that humans are having on natural systems is one of the greatest challenges we face today. As such, there is a growing need to monitor biodiversity and ecosystems at spatial and temporal scales that have historically not been possible. Acoustic monitoring approaches offer a solution and are increasingly being used across terrestrial, aquatic and marine ecosystems. These techniques allow ecologists to study novel questions and gain new insights into ecological processes and interactions at previously unattainable spatial and temporal scales. Additionally, the growing demands of government monitoring schemes, such as Natura 2000, put great pressure on a limited number of experts. Bio- and eco-acoustic monitoring has the potential to reduce this pressure by supplementing or replacing components of traditional monitoring schemes or improving the scales at which sites are monitored. Further, the scalability of acoustic monitoring opens opportunities to track the impact of restoration projects or land-use regimes quickly. However, the increased scale, in turn, creates new challenges in terms of data management, processing, objectivity, transferability, scalability, and AI-based analysis workflows. Practitioners and researchers might not be familiar with the latest developments in AI. Whereas those developing the methods to analyse the unprecedented stream of data don't necessarily understand the demands of ecological research. With this session, we would like to create a platform for interdisciplinary exchange on all aspects of bio- and eco-acoustic monitoring, including the development and application of methods, new and novel applications, and challenges. We would like to invite speakers from computer science, software and hardware developers and ecologists working in all realms to exchange ideas on shared challenges and opportunities.

CM2
01

Exploring the impact of forest management on diurnal soundscape dynamics: Insights from a forest experiment

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Forest management significantly impacts ecosystems by altering biotic resources and abiotic conditions. Shifted light and temperature regimes can influence temporal avian vocalization dynamics, and deadwood availability affects soniferous species abundance through food availability. This study, conducted within Germany's Biodiversity Exploratories research platform, investigates the relationship between forest management practices, forest structure, and temporal patterns of the soundscape. Within a nested, full factorial research design (n = 30), two key drivers of forest management were experimentally manipulated: changes in abiotic conditions through canopy opening and the availability of biotic resources via deadwood enrichment. This was complemented by research plots embedded in regular forest management (n = 150). Using passive acoustic monitoring across multiple seasons, we employed machine-learning techniques and acoustic indices to analyse soundscape patterns. We hypothesize canopy openings will advance diel patterns of the soundscape, and deadwood enrichment will diversify the soundscape. Further, silvicultural management will negatively impact the diversity of the soundscape. Deadwood enrichment and canopy opening did not yield significant effects on diel dynamics of the soundscape. The abundance of microhabitats and structural complexity positively affected the acoustic complexity index in spring. Additionally, the intensity of silvicultural management significantly lowered the levels of acoustic diversity indices (temporal patterns remained), particularly during the late breeding season of birds from dusk to dawn. Effects of forest management and structure highlight the importance of land use for soniferous species. The proximity of experimental sites introduces a limitation of testing treatment effects. Overall, this research provides insights into the interplay between forest management practices and diurnal soundscape dynamics, contributing to our understanding of ecosystem responses to anthropogenic interventions.

Large-scale acoustic monitoring and automated identification of bird species in an Alpine environment

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Passive acoustic monitoring and automated recognition are increasingly used in ecological research to assess avian diversity. However, it takes considerable effort to obtain meaningful results. In particular, the AI-based analysis of song recordings is prone to error and species identification is not always reliable. In spring 2024, we implemented a passive acoustic bird monitoring within the Biodiversity Monitoring South Tyrol (BMS), a long-term monitoring throughout a mountainous region characterized by a gradient of different ecological patterns. We used AudioMoth v.1.2.0 devices at 68 sites categorized by their main habitat to record birds throughout the whole breeding season. To analyse the collected data, we used the bird song recognition software BirdNet Analyser 2.4 and Raven Pro 1.6.5 for batch processing. BirdNet uses confidence values to indicate the likelihood of correctly identifying species. However, it is not a probability of actual true detection. For some species, even predictions with very high confidence scores are often false positives. Our goal is to optimize bird identification by building species-specific confidence thresholds. These allow us to convert confidence values into probability of true identification. To do this, we scored bird detections as true or false positives. By using different confidence scores of the identification and the outcome we fitted a logistic regression that allows us to make assumptions about the probability. Preliminary results show that rare species are prone to misidentification and require higher confidence levels, while lower values are sufficient for most common species. Species-specific thresholds make automated identification quicker and more reliable. To further improve and generalize the settings, large-scale projects within different regions are needed.

CM2
03

Exploring the application of bioacoustics for monitoring the biodiversity, health, and functional diversity of wetland environments

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Along with improvements in audio technology that have raised the prospects for automated and big data collection, passive acoustic monitoring (PAM) is now at the forefront of ecological research. Both eco- and bio- acoustics are well established in terrestrial environments, particularly for monitoring bird presence or absence, however, their application in freshwater environments is rapidly gaining traction. For example, changes in sound complexity, and an increase in sounds from stridulating arthropods has been detected following pond restoration, as has the presence of individual species. In particular, members of the Coleoptera, Hemiptera, Odonata and Trichoptera have been directly observed producing sound. However, how well the sound producing invertebrate community represent ecosystem biodiversity, health, conservation value, and functional diversity, has not been explored to any great depth. Here, we carried out a systematic review of literature to establish current understanding of sound producing invertebrates. This was then applied to a United Kingdom wide sampling of pond environments (387 sites, 463 taxa) to assess how indicative metrics derived from the sound-producing invertebrate assemblages were of those of the whole community biodiversity, ecosystem health (i.e. pollution), conservation value and functional diversity based on diversity and abundance. This was assessed both nationally and regionally and using three increasingly speculative scenarios given the incomplete knowledge of aquatic invertebrate acoustics; directly observed sound production within i) genus, ii) family, iii) order. Furthermore, we used ordination to assess the extent of community and functional nestedness between the sound-producing and whole community of invertebrates. The study adds further need for a concerted effort to record and codify underwater sounds to infill gaps in knowledge and facilitate the development of automated identification systems.

CM2
04

Recent technological developments allow for passive acoustic monitoring of Orthoptera (grasshoppers and crickets) in research and conservation across a broad range of temporal and spatial scales

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Passive acoustic monitoring (PAM) uses stationary recorders to detect wildlife in field conditions. The method has long been valuable for surveying certain species groups, especially bats. However, PAM has been limited by resource costs and availability of automatic classifiers to assist data analysis. With recent developments of inexpensive devices, such as Audiomoth, landscape-scale monitoring has become more feasible. This also opens possibilities to apply PAM to species groups that traditionally have been studied via expert-based, labour-intensive monitoring, such as Orthoptera. Utilizing recordings of Orthoptera from online databases, specialists and from our own recordings, we built a machine-learning classifier to automatically identify 17 Orthoptera species. Assessment included the comparison of PAM to traditional transects surveys. We also compared the performance of inexpensive Audiomoth with classic Batlogger recorders for surveying Orthoptera species with PAM, at eight sites, where we also tested whether adding two additional Audiomoths in 50-m distances from the initial device towards the edge of the wildflower area would increase species detections. We also assessed how the number of species detected changed over time. In total, we detected 20 Orthopteran species during the study. Our new classifier achieved a true positive rate of 86% validated against independent test data. PAM outperformed traditional sweep netting transects overall, although differences were not statistically significant. There was no difference in species composition detected by Audiomoth v1.2 or Batlogger, the composition detected by three devices compared to one device and no difference between hedgerow and centre communities. Relatively inexpensive equipment allows for effective PAM of Orthoptera. Our classifier could represent a useful tool for future PAM research in northern Europe, and serve as an extendable basis for studies elsewhere. If the species predictions are verified by an expert, the classifier could assist monitoring and conservation of Orthoptera at broad temporal and spatial scales.

CM2
05

Landscape-level monitoring of farmland birds using automated recordings and BirdNET identification

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Farmland biodiversity is threatened and continues to decline. Birds are affected by agricultural expansion and intensification. However, it is still very difficult to assess bird diversity on a large scale because point counts require a lot of manpower. This is where acoustic monitoring methods combined with automated detections using artificial intelligence (e.g. BirdNET) come into play and allow large scale, long term monitoring. However, these automated detections need to be handled with care and present their own challenges, as they still require some manual verification to improve the reliability of detections and species identifications. Here, we used automated sound recordings to record birds in 14 1-km^2 landscapes at 16 recording sites per landscape for 6 days of 1.5 h each, resulting in more than 2,000 h of recordings. Sound recordings were processed using BirdNET and identifications were verified for all bird species known to occur in our study area in southwest Germany. These verifications showed that BirdNET performed very differently for different bird species: some species were never correctly identified, some were always correctly identified, and some were correctly identified but only above a certain species-specific threshold of BirdNET confidence score. In addition, while BirdNET was often accurate in identifying bird species based on their songs, it was harder to verify bird identifications based on their calls. Combining manual verifications with information on BirdNET confidence scores, allowed for much more accurate identification of bird species. In addition to these methodological considerations, I will present results on the influence of landscape complexity and habitats (arable land, grassland, orchard and forest) on bird diversity and their functional composition.

Towards individual bird counting with deep learning

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Passive acoustic monitoring (PAM) has recently emerged as a supplement to field surveys with large potential for a large-scale monitoring of biodiversity. Typically, the recorded audio is analysed using traditional indices that capture complexity and presence indicators that only coarsely characterise the recorded soundscape. Specifically, they primarily distinguish between biophonic and other sources to a soundscape and aim to quantify the relative prominence of the former. Since birds are the most common contributors to biophony, this is often complemented by an automatic recognition of bird species, often relying on public deep learning models like BirdNET. However, these models merely identify the presence of a particular bird species in a recording, while ignoring the fact that oftentimes multiple individuals sing or call together. Moreover, these methods typically struggle with multiple, polyphonic soundscapes such as those that occur during the dawn chorus. Therefore, they are poor indicators for species abundance in a monitored area. To mitigate this, we aim to explore the automatic counting of simultaneously vocalising birds – both from conspecifics and interspecies. This task follows a similar workflow as bird activity detection, but instead treating it as a multilabel problem, it can be recast as a regression problem with the target variable being the number of vocalising individuals in a recording. In this contribution, we present preliminary results of an ongoing effort to create a generalising indicator of bird abundance that can be used in an ongoing PAM study within the Biodiversity Exploratories.

Advancing biodiversity monitoring through automated stations: a European pilot study

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Biodiversity decline is a drastic trend worldwide, but scientific evidence remains fragmented for specific regions or taxonomic groups. Harmonized European biodiversity monitoring schemes and data collection protocols do not exist yet. Therefore, there is an urgent need to develop shared repeatable sampling methods and automate long-term, multi-site monitoring to ensure reliable large-scale trend analysis and improve cost-efficiency. The Automated Biodiversity Monitoring Stations (ABMS) is a pilot study of the European Biodiversity Partnership Biodiversa+. The pilot started in 2024 including 13 EU regions and countries as partners. Focused on birds, bats, and nocturnal insects, ABMS aims to prove the concept of a scalable monitoring scheme using advanced sound and image recognition technologies. Due to the large amount of data and associated management and analysis challenges, ABMS aims to establish best practice guidelines, protocols, and standards for large-scale automated monitoring, ultimately contributing to the EU biodiversity strategy. For the implementation, every partner installed automatic monitoring stations in three different habitat types located in protected areas. Each station has a UKCEH Automated Monitoring of Insects (AMI) trap and continuous recording devices for birds and bats recorders (Song Meter Mini 2 AA, Wildlife Acoustics). The AMI trap uses UV and white light to attract nocturnal insects, particularly moths, which are then photographed and classified using deep-learning algorithms. Recorded bird calls are identified using the BirdNet Analyser software, while bat echolocation calls by automated software and expert-based validation. Processed images and sound data will be uploaded on a freely accessible server. Results will assess methodologies, sensors strengths and weaknesses at different geographical regions. The results contribute to the EU Biodiversity Strategy 2030 targets by supporting cost-efficient monitoring in protected areas.

By-species classification performance of BirdNET: Effects of bird morphology, acoustic traits, and habitat

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Passive Acoustic Monitoring (PAM) is increasingly used in bird monitoring to complement or replace traditional observer-based methods, with low-cost recording devices allowing for unprecedented temporal and spatial resolution. To fully harness the potential of large PAM datasets for ornithological applications, robust, cost-effective, automated analysis methods need to be developed. With the development of BirdNET, a deep learning-based, open-source, multi-species bird sound classifier, significant progress has been made in automating species identification. While the performance of BirdNET varies considerably across species, the underlying patterns remain largely unknown. A thorough analysis of the factors that contribute to the variation in the performance of BirdNET across species would aid model improvement, support the development of ecological models based on PAM data, and inform the appropriate use of PAM in ornithological applications. Therefore, this study investigates the effect of functional traits on the species-specific performance of BirdNET. PAM data collected from an urban soundscape in Munich, Germany, were validated and analysed in conjunction with the results of four previous validation studies from Europe and North America. Species-specific performance varied greatly both between species and between datasets, while no significant correlation was found between species-specific performance of BirdNET and functional traits. These results suggest that species-specific fine-tuning of model performance in PAM applications should be guided primarily by other species-specific factors, such as availability of training data, filtering methods, and functional distinctness. However, the generalizability of this study is constrained by the limited availability of trait and validation data. To further investigate the role of functional traits in automated bird sound classification, large-scale, multi-species, accessible validation data is needed.

PaludiZentrale: Implementing a bioacoustic monitoring for long-term biodiversity assessment in paludiculture projects

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The PaludiZentrale project is a collaborative initiative that includes 8 (9) individual projects within the PaludiNetz network, each with multiple project sites across Germany, primarily in the north and also in Bavaria. As long-term projects with a 10-year duration, we aim to enhance biodiversity monitoring by adding bioacoustic data collection as one of the components. This involves a BACI (Before-After-Control-Impact) design, collecting data before, during, and after rewetting of project sites managed through paludiculture, with control sites, which are non-rewetted managed areas. Bioacoustic data collection began this year using affordable programmable audio recorders (AudioMoths). The recordings cover an entire vegetation period to capture migration and phenology of different species. Each site uses two recorders to capture various species groups, including birds, bats, amphibians, grasshoppers, and cicadas. Data is collected locally and analysed centrally using established AI methods. This poster aims to provide initial insights from preliminary data analyses and, importantly, to present and discuss the sampling design. This discussion will help refine our methods and ensure the robustness of the bioacoustic monitoring framework across all project sites.

Aggregated time-series features boost species-specific differentiation of true and false positives in passive acoustic monitoring of bird assemblages

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Passive acoustic monitoring (PAM) has gained increasing popularity to study behaviour, habitat preferences, distribution and community assembly of birds and other animals. Automated species classification algorithms like 'BirdNET' are capable of detecting and classifying avian vocalizations within extensive audio data, covering entire species assemblages. PAM reveals substantial potential for biodiversity monitoring that informs evidence-based conservation. Nevertheless, fully realizing this potential remains challenging, especially due to the issue of false-positive species detections. Here, we introduce an optimized thresholding framework, which incorporates contextual information extracted from the time-series of automated species detections (i.e. covariates on quality and quantity of species' detections measured at varying time intervals) to improve the differentiation of true and false positives. We verified a sample of BirdNET detections per species and modelled species-specific thresholds using conditional inference trees. These thresholds were designed to minimize false-positive detections while maximizing the preservation of true positives in the dataset. We tested this framework for a large dataset of BirdNET detections (5760 h of audio data, 60 sites) recorded over an entire breeding season. Ourresults revealed considerable interspecific variability of precision (percentage of true positives) within raw BirdNET data. Our optimized thresholding approach achieved high precision (≥0.9) for 70% of the 61 detected species, while species-specific thresholds solely relying on the BirdNET confidence scores achieved high precision for only 31% of the species. Conservative universal thresholds (not species-specific) reached high precision for 48% of the species. Our thresholding approach outperformed previous thresholding approaches and enhanced interspecific comparability for bird community analyses. By incorporating contextual information from the time-series of species detections, the differentiation of true and false positives was substantially improved. Our approach may enhance a straightforward application of PAM in biodiversity research, landscape planning and evidence-based conservation.

CM2
P5

Soundscapes across cityscapes: linking songbird biodiversity to urban soundscapes and local vegetation structures

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As urbanization and densification often lead to significant biodiversity loss, understanding and monitoring urban biodiversity patterns and their connection to the urban landscape is crucial. Traditional monitoring methods are costly, time-consuming, and require specialized expertise. Passive acoustic monitoring and soundscape ecology have emerged as promising, non-invasive techniques for spatial and temporal ecosystem monitoring. Using a total of 168 acoustic recording hours in 90 sites in and around green spaces in Munich, Germany, we derived the local songbird biodiversity via BirdNET and described the urban soundscapes with different acoustic indices. We tested how vegetation structural aspects within urban green spaces derived from mobile laser scanning (MLS), along with structural aspects in the surrounding gray spaces, relate to the local urban soundscape and if these factors could significantly predict the songbird biodiversity. Our results show that the heterogeneity in the vertical profile of the vegetation was a significant driver of bird alpha diversity in urban green spaces, emphasizing the necessity of understory vegetation in urban contexts. However, the distance to the city center and the greenness of the neighbourhood remains an essential driver of avifauna, regardless of the local vegetation structure. Although anthropogenic sounds dominated the urban soundscapes in our selected sites in Munich, we identified a potential buffering effect by vegetation, with dense and vertically complex vegetation structures reducing anthropogenic sounds. Our findings revealed that acoustic indices can only partly predict bird diversity due to the masking effects of anthropogenic and geophonic sounds. For future research, we suggest optimizing and applying acoustic filters prior to analysis to enhance the applicability of acoustic indices as an efficient tool for urban ecosystem monitoring.

Advancing ecology with deep learning

Chairs: Marc Grünig, Werner Rammer

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Artificial intelligence and deep learning have the potential to revolutionize ecological research by providing new ways to analyse and understand complex ecological systems. This session explores recent advances in applying deep learning to ecological questions. We welcome contributions demonstrating cutting-edge methods, including using neural networks in the context of ecological modelling, data mining to support biodiversity monitoring, or analysing empirical data streams in novel ways. Moreover, we encourage contributions that improve our understanding of using deep learning to support conservation and decision-making. Of interest are also contributions that discuss the challenges, limitations, and ethical implications of using these approaches, as well as potential future directions for their use in ecological research. Overall, this session will offer a methods-focused overview of the current state of the field, highlighting the potential of deep learning to drive significant breakthroughs in ecological research.

CM3
01

Next-generation biodiversity assessment: An automated approach

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Traditional identification methods for insects rely heavily on expert knowledge and meticulous examinations under microscopes. While this work is fundamental, it faces challenges due to the vast number and variety of species involved. Although vision-based AI is conceptually well-suited for such tasks, existing methods have typically focused on very specific objectives or species groups, while a comprehensive solution has yet to be developed. Our AI-based method aims to address this gap by taking a general approach, ensuring a more balanced treatment of all insect groups. Therefore, we employ a combination of traditional collection methods and advanced analytical technology. After collection, insects are categorized by size using a in house developed automated sorting machine, optimizing the samples for photographic capture with a specialized Stack-and-Stitch machine. This machine produces high-resolution images of multiple objects per size fraction, which are then analysed by a custom AI-based software platform. The software accurately isolates and then classifies individual insects using a hierarchical AI architecture that assigns each insect to appropriate taxonomic categories. Although we are still in the early stages of the project, initial results are highly promising. For now, approximately 50,000 images of single individuals have been produced and classified with high accuracy, mostly at the family level. This approach not only has the potential of enhancing the efficiency of insect species identification but also to expand the scope of biodiversity monitoring, helping to close significant knowledge gaps and thereby support conservation efforts.

CM3
02

From pixels to populations: AI-driven insights into grassland insect ecology

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Insect populations in grasslands are declining significantly, affecting ecosystem functions and services. However, the varying effects of land use intensification and management practices on insect taxa remain poorly understood due to monitoring data and resolution limitations. A potential solution lies in artificial intelligence (AI) based camera systems that autonomously monitor insects in the field. While these systems are still under development, the AIforIBM project integrates RGB camera trap systems with AI and deploys the first prototypes across 30 grassland sites along land-use gradients within the Biodiversity Exploratories across Germany. These camera traps automatically capture photos of insects on designated lure surfaces, providing data on insect activity and taxonomic and morphologic diversity. Using this data, we investigate the impact of land management practices, such as mowing, on insect populations. Our presentation will share preliminary results and insights from our experience with AI camera trap systems deployed in the field. Ultimately, we aim to develop an AI model capable of automatically identifying insects in captured images, offering a long-term solution for efficient insect monitoring.

CM3
03

Automated plant-pollinator interaction monitoring with an open-source DIY camera trap

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Monitoring of plant-pollinator interaction changes over space and time can give insights into potential drivers of declining insect abundance/richness and quantify their effects on the essential ecosystem service of pollination. However, many of the traditional monitoring methods are time-consuming and expensive. For this reason, they are often deployed with a low number of replicates, which restricts the potential for analysis and interpretation. Automated monitoring methods require significantly less effort and can therefore acquire data at a higher spatiotemporal resolution. In the project SEPPI (Standardized European monitoring of plant-pollinator interactions) we are going to evaluate a modified version of the Insect Detect DIY camera trap. The system is based on low-cost hardware components and open-source software. It includes a specific chip for on-device AI inference, which enables real-time insect detection and tracking with custom trained deep-learning models. For each detected insect, an image is cropped from synchronized high-resolution frames and is saved together with relevant metadata. All insect images are automatically identified by a classification model in a subsequent step. The camera trap was tested in a field study in 2023 with an artificial flower platform as insect attractant and is currently used by several groups and individuals, including citizen scientists. The modified version will be set up on top of real flowers. Several camera traps will be deployed in eight European countries at sites along differing environmental gradients. All sampling rounds will also include traditional monitoring methods, such as transect walks, sweep netting and pan traps. Our goal is to test if it is possible to capture the same spatial trends in several response variables (pollinator diversity and composition, visitation rate) with both approaches, which would allow for a first validation of our proposed automated method for large-scale field deployment.

CM3
04

Computer-vision based automated assessment of post-disturbance forest resilience

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As a result of climate change, disturbances regimes are changing around the globe. This is challenging the sustainable provisioning of ecosystem services to society. Understanding the disturbance resilience of forest ecosystems is crucial for forest management, yet estimating resilience in the field remains difficult. A rapid assessment of important indicators associated with failing tree regeneration post disturbance would help managers to prioritize efforts on disturbed areas. Here, we propose an innovative approach for resilience assessment leveraging recent advancements in computer vision and deep neural networks (DNNs) to estimate post disturbance resilience based on indicators derived from pictures taken in the field. We build on an extensive empirical dataset of post-disturbance development pathways (resilience, restructuring, replacement or reassembly) derived across four forest types (spruce, beech, pine, oak) in Bavaria. We use these empirical data in combination with computer vision models trained on images collected from disturbed plots and their surroundings (N = 1240 images) to predict indicators related to ground cover (e.g. percent covered by grass) and forest structure (e.g. deadwood, structural complexity). These computer-vision derived indicators were subsequently related to the field-based resilience assessment to test their ability to predict post-disturbance pathways. Preliminary results demonstrate a medium to strong ability of computer vision-derived indicators to correctly predict post-disturbance forest development. Our findings suggest that computer-vision methods offer a low-cost, low-threshold tool to support forest managers in prioritizing post-disturbance management decisions.

CM3
05

Integrating empirical connectivity models and deep learning to prioritize sites for greening to improve ecological connectivity for urban birds

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Urban green infrastructures, besides cooling and draining water, also support biodiversity, which in turn contributes to human wellbeing. Due to their various functions, urban planning needs to mitigate many requirements out of which conservation is often not highly prioritized. Urban connectivity models can quantify the importance of green spaces for small-scale resource accessibility for urban animals and thereby provide planners with data-driven, quantitative support for biodiversity conservation. Here, we introduce the use of home range connectivity models to prioritize urban green infrastructure for a species assemblage. We combine them with deep learning to select sites that – once greened – most effectively improve the species-specific and multi-species resource network. We used nine bird species to investigate the species-specific barrier effects and the importance of connectivity for their occurrence. Higher connectivity of the home range significantly increased the probability of detection. The data-driven model parametrization showed that the resistance to movement across urban land covers and the resource patch isolation distance varied between species, some being more sensible to buildings and others to streets. Nevertheless, areas supporting high resource accessibility for all species could be identified in a spatial PCA on the species-specific connectivity maps. Using a deep reinforcement learning algorithm efficient at spatial optimization, we identified sites that would most effectively improve the Probability of Connectivity index of the entire resource patch network. Our results show that data-driven multi-species connectivity models enable the quantification of planning impacts and the importance of barriers and stepping-stones. Moreover, they show the fruitful integration of connectivity models with deep learning that results in new insights into the spatial configuration of urban resource networks and can become a useful tool for planners.

Building an open atlas of knowledge for invasion science and beyond: key results of the enKORE project in the Hi Knowledge initiative

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With the exponential increase in scientific publications, new conceptual and technological tools are needed to help scientists, students, practitioners and policy makers to navigate and digest current scientific knowledge. Hi Knowledge is an initiative to synthesise and visualise scientific knowledge with a focus on invasion science. The enKORE project within this initiative has ended this spring, and we are presenting key results of this work from the last years, in particular: (i) a new conceptual classification scheme of invasion science, consisting of the major themes, overarching research questions and major hypotheses of the field; (ii) a growing corpus of the invasion literature hosted by Wikidata, already including more than 50,000 publications from more than 10,000 authors; (iii) visualization tools through Scholia and Open Knowledge Maps to explore and dive into this corpus in various ways; (iv) interactive hypothesis networks and causal networks, also extending to neighbouring fields such as urban ecology; and (v) an observatory hosted by the Open Research Knowledge Graph connected with on-demand analyses to explore publications addressing major invasion hypotheses. We will provide an overview of these results and give an outlook on important next steps towards an open atlas of knowledge for invasion science and beyond.

A window to the past – The use of archive data for collecting baseline information on biodiversity

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Repeated observations are crucial for understanding long-term biodiversity changes, yet robust monitoring programs are a relatively recent development. Conversely, archive data offer invaluable insights into ecosystem dynamics over extended periods, underscoring their significance despite being often overlooked. This project explores modern AI techniques to harness historical forest data for biodiversity research, aiming to develop forward-looking and user-friendly tools for effectively analysing and visualizing time-series maps. The focus is on a collection of over 1000 repeated forest inventory maps from 1850 to 2000 in Thuringia, Germany. Initially digitized from paper formats, the maps undergo preprocessing, including removal of blank spaces and grid lines, followed by extraction of forest regions to emphasize spatial distribution and characteristics. Finally, identification and classification of different forest types based on map legends are performed. The whole process utilizes image-based deep learning approaches, combining convolutional neural networks and computer vision to tackle task complexity. Overall, preliminary results demonstrate the effectiveness of machine learning techniques for tasks such as image stitching, image segmentation, and colour recognition in historical map analysis. This automated or semi-automated approach provides an efficient means of processing historical biodiversity records, laying a crucial foundation for future ecological studies.

CM3

P3

A digital twin for biological field research: Modelling tidal marsh ecosystem dynamics in response to climate change

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Understanding the effects of tides, air temperatures, and precipitation is a prerequisite for modelling the dynamics of the soil environment in tidal marshes and the hosted species communities, including soil biota and vegetation. To assess the impact of climate change on these communities over different time scales (minutes to decades), we are currently designing a DIGITAL TWIN for a globally unique warming experiment in a Wadden Sea salt marsh. The Marsh Ecosystem Response to Increased Temperatures (MERIT) experiment was established in 2018 on the North Sea coast of Germany, implementing soil warming treatments (ambient, +1.5 °C, +3.0 °C) in three salt marsh zones (pioneer zone, low marsh, high marsh) with different tidal regimes (flooding: daily, monthly, only during storm surges) along the elevational gradient. Overall, the soil temperatures within the 27 plots are actively controlled and regularly monitored, along with environmental parameters such as tide levels, air temperatures, and photosynthetically active radiation. As a proxy for short-term responses to the warming treatments and to environmental parameters, the belowground redox potential is measured per plot every minute at different soil depths, while the NDVI is recorded per plot to address aboveground changes during the growing season. Changes in vegetation community structure and composition proxy long-term changes in ecosystem functioning due to soil warming. These regular measurements are complemented by selectively conducted recordings of biogeochemical data (e.g. greenhouse gas fluxes, carbon sequestration and turnover), seedling emergence and density, as well as the abundance of soil biota. The digital twin facilitates understanding the system without being physically present at the field site by providing a platform not only for simulating the dynamics between interacting environmental parameters, but also for applying deep learning approaches to link selectively conducted recordings, such as biogeochemical data, into the modelled system. To our knowledge, this is the first approach using a digital twin to monitor and control a remote field experiment while setting the stage for using integrated deep learning approaches to predict tidal marsh ecosystem dynamics in response to climate change.

CM3
P4

Training and interpreting deep neural networks with the cito R package

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Cito is an easy-to-use R package for deep learning that allows users to build neural networks using the familiar formula syntax of many other R packages. Yet, cito allows flexible modification of network architecture and hyperparameters, allowing users to test and apply most deep learning techniques without having to focus on coding. In addition, cito includes many user-friendly functions for model interpretation based on explicable AI and additional features such as confidence intervals (p-values). We explain how to extract effects (like linear effects from regression models) and variable importance (like ANOVA) from the fitted DNN and how to interpret these effects. Finally, we will show how cito can be used to fit convolutional neural networks (CNN) for image classification and regression.

Training and assessment of spatial prediction models: challenges, conceptual frameworks and implemented strategies in the R package CAST

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One key task in environmental science is to map environmental variables continuously in space or even in space and time. Machine learning algorithms are frequently used for this task, leveraging local field observations and comprehensive predictor variables to generate spatial predictions by estimating the variable of interest in locations where direct measurements are unavailable. However, the application of machine learning strategies for spatial mapping involves additional challenges compared to 'non-spatial' prediction tasks that often originate from spatial autocorrelation and from training data that are not independent and identically distributed. In the past few years, we developed a number of methods to support the application of machine learning for spatial data which involves the development of suitable cross-validation strategies for performance assessment and model selection, spatial feature selection, and methods to assess the area of applicability of the trained models. The objective of the CAST package is to support the application of machine learning strategies for predictive mapping by implementing such methods and making them available for easy integration into modelling workflows. Here we introduce the CAST package and its core functionalities, exploring both its conceptual framework and practical applications. Using a plant species richness case study as an example, we will go through the different steps of the modelling workflow and show how CAST can be used to support more reliable spatial predictions.

Can good modelling practices foster sustainable land management?

Short title: Good modelling practices for sustainable use

Chairs: Tatiane Micheletti, Marie-Christin Wimmler

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Ecological models serve as invaluable tools for unravelling the complexity of ecological processes and can provide land managers with information to manage land sustainably, especially in the face of rapid global change. The spectrum of ecological model types available is broad, and their purposes range from understanding specific ecological phenomena, to predicting the response of ecological systems to biotic and abiotic change, to supporting decision-making related to land management. However, the integration of scientific advances into management decisions is often slow and remains more subjective than it should be. This is partly due to persistent challenges in validating, reproducing, predicting, and comparing ecological models, as well as to the reduced confidence in model outputs and their interpretation by practitioners. Several of these challenges can be mitigated and even overcome through the adoption of good modelling practices (GMPs) supported by established standards and principles, such as the ODD protocol for agent-based modelling and PERFICT for predictive ecological models. Yet, the adoption of GMPs and their implementation in ecological models is still in its infancy. This is true despite the growing demand for improved GMPs in ecology; published descriptions of models still often lack the necessary information for reproducibility and reusability, and often provide no or inoperable code. Therefore, in this session, we aim to explore the overarching characteristics of standards and principles that can help researchers achieve better modelling practices, discuss the challenges associated with adopting good modelling practices and how such challenges might be overcome, and provide examples that illustrate the potential of good modelling practices, particularly agent-based and predictive ecological models, to enhance sustainable land management efforts. We welcome contributions that discuss experiences and challenges in applying GMP from different areas of ecological modelling.

CM4
01

Beyond guides, protocols and acronyms: adoption of good modelling practices depends on challenging academia's status quo in ecology

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Implementing good modelling practices (GMP) in ecological sciences is key to improving scientific reliability for analysing the functioning of ecological systems or predicting their responses to environmental changes. Despite the increased availability of guidelines and protocols detailing how principles such as FAIR and PERFICT can be implemented to improve accessibility, reproducibility, reusability, modularity, fitness-for-purpose, and transparency, the sharing of reproducible code and workflows remains remarkably low. We delve into the potential root causes of this discrepancy, identifying key factors inherent to the current academic structure that, in our experience, might be playing an important role in hindering a wider adoption of GMP: (i) acknowledgment of the time required to implement GMP in projects within expected budget and timelines, (ii) the lack of GMP and programming training among ecologists, and (iii) perception of GMP short-term benefits as potentially unrewarding. We argue that there is an urgent need for systemic changes that include (i) a cultural shift to value the incorporation of GMP across projects, emphasising the need for explicit budget allocation and careful scheduling of its implementation, (ii) redesigning academic curricula to explicitly include GMP and programming as fundamental disciplines in ecology, and (iii) an increase in recognition and reward for open code and workflows for career advancement. We call for concerted efforts for bridging this gap and propose a hopeful outlook emphasising the role of a new generation of scientists and tools committed to reproducible science. Proposing concrete actions, we aim to start a discussion on challenging academia's status quo in ecology and support scientists in bringing a significant paradigm shift to ecological modelling.

Reusable building blocks for strengthening agent-based modelling and theory of socio-ecological systems

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Virtually all social-ecological systems (SES) are shaped and driven by the behaviour and interactions of organisms, humans, and organisations, and can thus be considered as agent-based complex SES. To predict how SES respond to change and intervention, agent-based models (ABMs) are an indispensable tool. However, most ABMs that attempt to represent real systems tend to be complex and case-specific. General insights into both individual behaviour and decision making as well as into system dynamics are limited but urgently needed, as we cannot develop ABMs for each and every system and question. We argue that reusable building blocks (RBBs) can alleviate this problem. An RBB is a submodel that represents a particular mechanism or process that is relevant across many ABMs in an application domain, such as plant competition in vegetation models, or reinforcement learning in a behavioural model. RBBs are "atomic" enough to be more easily reused in different contexts than modules which represent entire subsystems and include more than one mechanism and process. We first summarize a joint effort by experts from social sciences, economics, epidemiology, geography, anthropology, archaeology, philosophers of science, and epistemologists to create a platform for sharing RBBs that has been established to promote theory development with agent-based modelling. We then present a case study as an example of a systemic comparison of existing building blocks developed to describe plant growth or local plant interactions, and discuss how such studies can be effectively used to derive general insights into forest dynamics. We discuss the direct benefits to the community as a whole and to individual modellers. Finally, and most importantly, we discuss how a modular framework of plant growth and competition RBBs can be used to systematically identify general solutions.

CM4
03

Developing multidisciplinary models for sustainable land use: challenges and approaches

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Land use is shaped by many different ecological, physical, and social processes. Current biodiversity models often struggle to adequately represent the complexity of such social-ecological systems, as many have a very narrow disciplinary focus. This hinders our ability to understand Global Change phenomena and address pressing sustainability challenges. We therefore need to learn how to couple ecological models to models produced by other disciplines, such as climate science, hydrology, or economics. However, constructing such integrated models is not easy, and requires a high degree of technical know-how. In this talk, we draw on the established standards and principles of computer science and several other environmental modelling disciplines to identify relevant lessons for ecological modelling. We present and compare five different software engineering techniques that can be used to build simulation models, and discuss to which extent and under what circumstances each is suited to constructing integrated models. We give examples of how these techniques have been used in other fields and relate our experiences with them when working with agent-based models in ecology. The techniques we present here can greatly help model interoperability and reusability, and are thus an important contribution to FAIR modelling in ecology. Good modelling practice established in other fields has shown that following the FAIR principles is a game-changer in improving model performance, validating and comparing model output, and building trust amongst decision makers. We therefore encourage ecological modellers to learn about progress made in these fields, in order to aid the establishment of similar good modelling practices in ecological models, and contribute to a better, more holistic understanding of ecosystem dynamics and biodiversity loss.

CM4
04

pyMANGA: Harnessing the power of modularity and reusability for robust ecological modelling

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Agent-based ecological models are essential tools for understanding and managing ecological systems, especially in the context of rapid global change. However, challenges in validating, reproducing, and comparing these models persist, hindering their effective integration into decision-making processes. In this poster, we present pyMANGA, a free and open-source platform designed to address these challenges. pyMANGA's modular design facilitates the incorporation of different plant growth, resource, and competition concepts, allowing systematic testing of related hypotheses, e.g. to identify dominant processes in forest development. We also present a systematic benchmarking strategy to ensure platform reliability and discuss how pyMANGA can be used to compare models of different levels of abstraction and complexity.

CM4
05

BeeScapeR: The Swiss army knife for BEE-STEWARD research

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Mechanistic models offer invaluable insights into the ongoing pollinator decline, contributing to the development of effective mitigation measures. Agent-based models, such as BEEHAVE and BEE-STEWARD, which provide structural realism and the capability to incorporate real land cover data, have been developed and successfully applied over the last decade. However, the lack of a standardized framework to conduct and publish research using these models poses challenges in their reproducibility, comparability, and reusability. Herein, we present BeeScapeR, an R-package that provides a convenient infrastructure for standardized, reproducible, and reusable BEE-STEWARD research. It encapsulates common steps in the application of BEE-STEWARD with land cover data and stores all digital components as a Research Compendium. This substantially facilitates the conduct of reproducible of BEE-STEWARD studies and enhances the reliability and trustworthiness of the research. Consequently, BeeScapeR supports the adoption of BEE-STEWARD as a robust tool for informing political and land management decisions.

Project WATARA-MODE: A model for the cost-benefit analysis of management options for controlling new plant pests

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Global warming influences the risk of new plant pests establishing and spreading in Germany and other European countries. Many of these new pests have the potential to cause considerable damage, particularly in fruit and vegetable crops and in forests. For decision-makers, predictions of the expected economic damage are therefore an important tool to evaluate different management options. Process-oriented simulation models are effective tools for predicting the spread and damage risks of climate-sensitive plant pests. In the project *ProgRAMM*, the simulation model MoPSi for predicting the establishment- and spread potential of pests was developed based on species-specific physiological parameters, spread characteristics and climate data. This model is being further developed in the project *WATARA-MODE*. Based on the calculated probabilities for establishment and spread, the model is used to determine the potential economic impact of plant pests as well as the effectiveness and costs of management measures. Starting with selected well known pest species, a database was created that contains data on host plants and their distribution, host plant yields and market prices, host plant sensitivity to pests, and the costs of various management measures such as treatment, quarantine measures, removal and replanting of host plants. The *MoPSi-econ* model with its database are designed to be easily extended. The model can be used to determine the expected damage costs and the cost and effectiveness of different management measures, including the calculation of thresholds based on the expected spread of the pest and the host plant distribution. These cost-benefit analyses will be used to provide a specific assessment of the proportionality of management options. The results are displayed spatially on maps, e.g. to identify hotspots with high economic damage potential. Overall, *MoPSi-econ* is a helpful tool for various stakeholders in reducing economic damage caused by pests.

How suitable are the existing agent-based models to support the management of mangrove restoration? – A review from the ontogenetic perspective of trees

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The degradation and loss of mangroves jeopardizes the health of coastal regions, aquatic biodiversity, coastal stability, livelihood of people and other ecological services. Not surprisingly, the UN Decade for Ecosystem Restoration has prioritized the restoration of mangroves, and planting *Rhizophora* spp. has become a trend. The success has been modest since monocultures established according to guidelines developed for terrestrial forests are not always appropriate. Attention has thus been shifted to promoting ecological functioning and natural multi-species regeneration. Predicting the outcomes of mangrove regeneration is thus demanded. But compared to other ecosystems, agent-based models (ABM) have not been widely used for this task. The question is why and how we can sharpen the tool for this purpose. We reviewed the state of the art of the existing ABM on how well they describe the life cycle stages of mangrove trees. The results confirmed that the majority of ABM focus on mature trees only which covers merely 20% of the whole life cycle. In the last 10 years, there has been a shift from a phenomenological to a process-oriented description of tree growth that takes a mechanistic view of water uptake, photosynthesis and biomass accumulation. Only a few models have been identified that explicitly deal with the dispersal and establishment, while the flowering and fruiting phase has been completely ignored. We define the challenges for upgrading ABM to make them suitable to assess and predict natural regeneration on former lost or degraded mangrove areas; and outline conceptually the building blocks (modules) to be developed by highlighting the factors and processes to be considered (e.g. swimming dynamics of propagules during flooding; self-trapping of propagules; reduced survival of stranded propagules and herbivory). We illustrated the challenges for implementation of such a module. We provide suggestions on designing, parameterizing, and validating natural regeneration modules for ABM with the intention to stimulate the development of building blocks which can be incorporated into ABM to make them suitable for studying and supporting mangrove regeneration and restoration measures.

CM4

P3

Towards a more biodiversity aware agriculture — a biodiversity potential index for crops

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Agricultural areas, comprising about 50% of Germany's total landscape, play a pivotal role in sustainable land use, food security, climate change mitigation and biodiversity conservation. In the interdisciplinary NBiomasseBW project we combine economical, hydrological and ecological aspects in a digital sustainability analysis tool to inform about the consequences of crop choice. As part of this we aim to understand how crops differ in their potential value for biodiversity. Previous research focussed on the comparison of a small number of common crops. This does not reflect the variety of crop rotations and cover crops and does not allow for across crop comparisons. To allow the comparison of 135 crop types we used a combination of biodiversity relevant measures to create a 'Biodiversity Potential Index' for each crop type. The index includes data on biodiversity, plant-insect interactions and agricultural intensity that are available from data bases, with the aim to provide comparable values for the potential biodiversity of crops cultivated across central Europe. The index aligns with results of previous field studies but extends the number of evaluated crops drastically and fills a critical gap in agricultural research and illustrates the impact of crop choice on biodiversity in agricultural regions. Included in the sustainability analysis tool the `Biodiversity Potential Index' enables farmers and other stakeholders to take economically and biodiversity sustainable decisions at the farm level.

Ecosystem Ecology (EE)

Pollinators and pollination services under global change

Short title: Pollination under global change

Chairs: Ingo Grass, Sara Leonhardt

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The scientific session will address the multi-faceted impacts of global change on pollinators and the central role they play in sustaining crop production and wild plant reproduction. With the overarching goal of comprehensively understanding the threats of global change to pollinators and pollination services, and how these threats can be mitigated or reversed, the session will unravel the complex interactions of global change drivers, including habitat destruction, climate change, invasive species and eutrophication, and their collective impacts on pollinators. Participants will gain insights into the specific threats posed by each factor and their synergistic effects, emphasizing the urgency of effective conservation action. The meeting will also explore the cascading consequences of global change on crop and wild plant pollination and provide insights into the changing dynamics of plant-pollinator communities through network studies and assessments of changes in community structure and functioning. In addition, the session will focus on restoration efforts that mitigate or reverse the negative impacts of global change on pollinators and pollination services. The session will also showcase the usage of modern methods in pollinator ecology, such as metabarcoding, artificial intelligence and remote sensing, as well as predictive models of pollinator dynamics. Participants will learn about innovative experimental approaches that use these technologies to unravel the complexity of pollinator responses to global change and gain a deeper understanding of the underlying mechanisms. In summary, the session will be a comprehensive exploration of the intricate interplay between global change and pollinators, examining impacts on both crops and wild plant ecosystems. By integrating state-of-the-art methods and predictive models, the session is expected to contribute valuable insights to the ongoing dialog on pollinator decline, pollination services and coping with global change.

Pollinator dependency and regional climate affect crop yield development under climate change

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Considering the enormous impact of global change on the fitness of both insect pollinators and flowering plants, climate change-induced alterations to pollination services are to be expected. Focusing on two climatically distinct regions (warm-dry vs. cool-moist) and varying levels of pollinator dependency (none, moderate, great) among cultural crops, we investigated past links between climate conditions and crop yield. We measured correlations of yield data with (i) time (indirect measure of progressing climate change) and (ii) a composite climate parameter (direct measure relatable to progressing climate change). We found no direct effects of regional climate or pollinator dependency on the development of crop yields over time. Despite the continuous increase of average temperatures and drought events in the past, overall yields increased in both regions, which could be attributed to advances in crop breeding and agricultural technology. However, for crops that are more dependent on pollinators, the increase tended to be less pronounced, indicating a higher vulnerability under climate change. In direct response to climate, we found marked differences in optimal yields of crops with different levels of pollinator dependence and from different regions, most likely due to differences in the climatic characteristics of specific pollinator communities: Following our expectations, the optimal yield conditions for moderately pollinator dependent plants shifted to warmer and drier conditions under warm-dry regional climate. Surprisingly, crops that are highly dependent on pollinators for fruit set showed increased yields with higher temperatures and drier conditions. These results point to several possible developments of pollination service provision in the future, depending on crop pollinator dependence and regional climate, and emphasize the importance of considering these factors in yield predictions and climate adaptation strategies.

EE1
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Trait-based responses of wild pollinators in fragmented calcareous grasslands to habitat-associated and agricultural matrix variables

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Wild pollinator diversity is declining due to habitat loss and land-use change. Calcareous grasslands are remaining species-rich refuge in the agricultural landscape. Due to the progressive intensification of agriculture, calcareous grasslands are becoming more isolated and are nowadays highly endangered and so are wild pollinators. However, drivers of pollinators in high-value habitats at the local and landscape scale and trait-based responses remain unclear. In 2022 we sampled bees, butterflies, and hoverflies in 40 highly protected calcareous grasslands in Bavaria, Germany and assessed the effects of habitat area, quality and connectivity, as well as the impact of the surrounding agricultural matrix on pollinator species richness and abundance. In total, 231 wild bee, 90 butterfly and 62 hoverfly species were recorded and classified according to various traits to test the influence of habitat-associated vs. matrix variables on different pollinator groups. We expect that pollinators in protected high-value grasslands benefit if the quality of the agricultural matrix is increased by organic farming, sown flower fields and mass-flowering crops and by a reduction of field sizes. However, these effects might be restricted to large and generalist pollinators, while small and specialist pollinators rely on large grasslands of high quality and high connectivity. Knowledge about drivers and the disentanglement of trait-based responses of wild pollinators in valuable habitats embedded in an agricultural landscape helps to make management decisions in agricultural policy and nature conservation. Identifying important factors influencing wild pollinators at the local and landscape scale can be used to derive concrete management schemes, that will ensure the survival of wild pollinators.

Small-scale, mixed food production systems and semi-natural grasslands support complementary pollinator populations

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Land use change and agricultural intensification are among the main drivers of pollinator decline. Despite efforts, uptake of measures to halt these declines at both landscape-level (e.g. habitat restoration) and farm-level (e.g. flower strip) is low. Implementation of a new crop production paradigm is therefore a suggested solution to provide food security while at the same time minimizing environmental degradation and associated biodiversity loss. Indeed, various agricultural diversification strategies (e.g. crop diversification, organic farming) are known to promote multiple ecosystem services and even crop yield. Yet, the effect of agricultural diversification on pollinator populations in farm-scale, observational studies remain underrepresented. Here, we examine the importance of mixed, high-diverse food production systems in their capacity to support wild pollinator communities. Floral resources and wild pollinators (bees, hoverflies, wasps and butterflies) were sampled in both mixed food systems and semi-natural grasslands in 16 landscapes in Belgium. During summer, the time when fieldwork was done, these grasslands provide an important source of floral resources whereby they serve as a benchmark habitat in this study, to which the mixed food systems are compared. Our study highlights the value of mixed food production systems as they provide diverse and abundant floral resources compared to semi-natural grasslands. In addition, floral resource composition was found to be complementary between both habitats. Pollinator diversity and abundance between both habitats was found to be equal, while pollinator community composition was different. The latter indicates that different pollinator communities used the complementary resources provided by both habitat types. Landscape composition analyses and plant-pollinator network analyses will further be used to explore how pollinator communities benefit from the resources distributed across these two habitats.

Buzzing in the city: How garden features affect bee functional diversity along an urban gradient

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Urbanisation is a severe driver of land use change and biodiversity loss globally. While cities reduce natural habitats of pollinators, they can still provide diverse habitats for many taxa like wild bees. For example, a wide range of wild bee species can find food- and nesting resources in urban green spaces like urban gardens. Depending on their functional traits like body size, nesting type, food specialisation or activity period, wild bee species can respond differently to the degree of urbanisation in the landscape and the type of garden features. Even though it is central to understand these links for supporting pollinators in cities, few studies investigate which and how local features affect the species composition and taxonomic as well as functional trait diversity of wild bees or how they might vary with the city context. Here, we investigated these open questions in an urban community garden system. We measured potential food- and nesting resources, the urban context and sampled wild bees using active and passive sampling techniques over two summer seasons in 33 urban community gardens in Munich and Berlin, Germany. We will present our results on the effects of garden features and urbanisation on wild bee diversity, and our findings on how wild bees with specific functional traits respond to the urban landscape as well as on resources provided within gardens. Our results will not only increase our understanding of the interplay between local and landscape drivers on urban wild bee populations but may also help to improve and maintain trait-specific habitats within cities. As urban densification and growth will not stop soon, creating pollinator-friendly habitats must be an essential aim now and in the future.

How plants and bees are exposed and affected by something tiny: micro plastics

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The potential effects of micro plastics from various sources on insects, especially pollinators, are still poorly understood. Since these materials are structurally and chemically diverse, the effects are equally diverse but tend to depend strongly on material size, surface structure and concentration. Therefore, it is crucial to know the level to which insects are exposed. As these particles get constantly released into the air, they cannot only adhere to the cuticle and hairs of flying insects but also sediment on plants and soils, providing several pathways into insects. We address this topic in wild bees foraging on flowers as it has been recently shown that the effect of solid pollutants, like micro plastics, can negatively affect bees. We aim to understand the precise mechanisms of uptake, the amount of particles e.g. in nectar, a major food source of bees, and the amount of particles that finally end up in the digestive tract of the animals after feeding on flowers under field conditions. We sampled nectar from bee pollinated plants as well as the bee species feeding on them. Both bees and plants were sampled together along pollution gradients. Additionally, information on potentially relevant factors for plastic pollution, e.g. weather, traffic and flower visitation, were recorded. We analysed nectar and gut contents of associated bees using Nile Red staining and fluorescent microscopy to screen for micro plastics with an adapted existing protocol. Findings were related to the recorded biotic and abiotic factors. This will provide first insights into micro plastic contamination levels of flowers and the feeding pollinators - using bees as our main example. This first assessment under field conditions is important, as it will enable us to make realistic predictions on contamination levels of wild bee and flower populations, which will improve recommendations for future measurements regarding micro plastic pollution in the environment.

Nutrient-driven foraging behaviour: Pollen collection patterns among alpine bumble bee species

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Most flowering plants rely on pollinators for successful cross-pollination and offer them rewards, such as nectar or pollen. Bees, in particular, rely exclusively on pollen as a resource to rear their brood. Pollen exhibits high variability in its nutrient composition, often termed pollen quality, both among and within plant species. Nutrients encompass amino acids, fatty acids, sterols, vitamins, minerals, and plant secondary metabolites. Consequently, the suitability of pollen as a food source also varies among and between plant species. Bees thus need to adjust their foraging behaviour to obtain nutritionally appropriate food. They possess the ability to discern differences in nutrient concentrations through chemotactile sensation via their antennae. In this study, we investigated whether the nutrient composition of pollen influences the foraging behaviour of alpine bumblebee species. We collected pollen from various alpine flowering plant species in the National Park Hohe Tauern throughout the season. We analysed the nutrient composition using GCMS (gas chromatography-mass spectrometry) for fatty acids and sterols and IEC (ion exchange chromatography) for amino acids. Simultaneously, we collected pollen loads from alpine bumblebees and hoverflies (as a control group), which were then subjected to metabarcoding to determine the pollen's taxonomic origin. Based on the diverse impacts that different nutrients have on bee health and fitness and taking into account the bees' capacity to discern these variations, we hypothesized that: (i) Bumblebees select pollen from flowering plant species which differ from those collected by hoverflies. (ii) These disparities are driven by the nutritional composition of pollen rather than by phylogenetic relationships between plant species. Our comprehensive analysis enhances our understanding of pollinator-plant interactions, highlighting the complex relationship between nutrient availability, perception, and foraging patterns.

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07

How can we better understand the impact of global change on bees using mechanistic simulation models and monitoring campaigns?

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Insect pollinators face multiple stressors, including land-use and climate change. However, it is difficult to predict and disentangle the impact of these multiple stressors on bee vitality. To help to fill this knowledge gap, we have analysed how temporal and spatial floral resource availability together with temperature and sunshine hours impact honey yield for 185 colonies distributed all over Germany. Floral resources have been estimated from a land cover classification map by Preidl et al. (2020, Remote Sensing of Environment) that is based on Sentinel-2A data. This map has a resolution of 20 m, representing 19 land cover classes (e.g. oilseed rape, maize, forest) and is covering the whole of Germany. Honey yield was estimated using daily changes in hive weights using data from the TrachtNet campaign. We were using random forests as machine learning based methods and generalized linear models to analyse the data. As expected, daily changes in hive weight were mainly driven by temperature and daily sunshine hours. We were also able to identify the importance of interactions between land cover types such as oil seed rape and grassland. However, we could not detect direct effects from single mass flowering crops such as oil seed rape, indicating that it is very likely that biotic factors such as colony size and colony health need to be considered in our study. Therefore, we develop workflows for mechanistic honeybee (BEEHAVE) and bumble bee (BEESTEWARD) models to use the same land cover and weather information to simulate honey harvest and population dynamics for a variety of biotic scenarios. We will present a prototype digital twin for honeybees where this workflow is implemented and that can be freely be used by the community for any point in Germany.

Using complex networks to understand species persistence in empirical plant-pollinator communities

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Pollinators and their mutualistic interactions with plants are key components of our ecosystems because they sustain terrestrial biodiversity and human food security. Currently, the clear evidence of pollinator declines caused by human-induced rapid environmental changes (e.g. landscape fragmentation or climate change) clashes with our poor ability to predict pollinator communities prone to collapse or species at risk of local extinction. It is therefore urgent to develop mechanistic models for the probability of pollinators to persist that allow drawing sound predictions that can be used by conservationists. To that end, the structuralist approach has emerged as a solid theoretical framework suited to ecological communities. This approach is readily available to evaluate how the observed mutualistic network of plants and pollinators defines the range of environmental changes in which species can persist. Here, using high-resolution data from a 6-year study following 12 independent plant-pollinator communities over a landscape fragmentation gradient, we investigate whether empirical observation of species persistence is explained by the structure of the plant-pollinator interactions networks. We observe that pollinator communities with higher opportunities for species to coexist (i.e. with higher average persistence probability) strongly correspond with higher mean pollinator persistence observed in the field, indicating that the structure of species interactions contains information on how can species, on average, persist under changing environments. In addition, landscape fragmentation seems to affect the expected persistence probability trough changes in how the interactions are organized, with communities in larger habitat patches tending to exhibit higher persistence and more shared mutualistic partners.

How resilient are tropical pollinators? Flower-visiting insect communities show diverse recovery trajectories in a neotropical rainforest biodiversity hotspot

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In the face of global insect decline and loss of biological complexity due to anthropogenic disturbances, little is known about the rules that underlie the reassembly of insect communities when ecosystems are allowed passive regeneration. This gap is evident in the tropical forests that account for many of today's Biodiversity Hotspots, particularly concerning pollinators, which have a fundamental contribution to the first stages of plant reproduction and establishment. Within the quickly vanishing Ecuadorian Chocó, we sampled several groups of diurnal and nocturnal insects to shed light on the trajectories and rules behind the recovery of community complexity using a trait-based framework. Within a unique chronosequence composed of 46 plots with zero to 38 years of passive regeneration after land use, plus 16 old-growth forests, more than 27,000 insects were collected, showing group-specific recovery trajectories. Eusocial stingless bee diversity and abundance showed a fast increase towards older secondary forests, particularly for smaller species that were strongly associated with the canopy of old-growth forests. Nocturnal solitary bees showed a similar high dependence on the upper layer of older forests. Moths showed a slower yet steady increase toward old-growth sites. Although some species appeared to adapt well to disturbance (e.g. larger and fast-flying moths), their general diversity also tended to increase in particular in the canopy towards older forests. Conversely, small diurnal solitary bees were associated with disturbed sites and early regenerations, decreasing sharply in diversity as the forest aged. These findings indicate that recovery trajectories are not entirely predictable by traits and can vary substantially among taxa. We provide a first insight into the resilience of different pollinator groups and highlight the importance of structurally complex forests for the reestablishment of many insect taxa, while also underlining the importance of species phylogeny and life history.

The bare necessities of a ground nesting bee species

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Ground-nesting bees constitute the majority of all wild bee species and provide several crucial ecosystem services. This important functional group is especially endangered through global change, loosing nesting opportunities through urbanization, management intensification and eutrophication of our landscapes. Still, they are neglected in research, as most studies focus on cavity nesting bees. Especially knowledge about their nesting requirements are lacking, while most nest site descriptions are vague and not data-based. Species specific nest site descriptions are important to understand, how ground-nesting bees can be promoted. These kinds of autecological studies are barely internationally published and often refer only to one single nesting site. In our study, we conducted precise measurements of relevant soil parameters in 27 nesting aggregations of the oligolectic mining bee species *Andrena vaga* and compared them to un-colonised control areas, where no bee nests could be found. Our results allow conclusions, how public places like parks, cemeteries or roadsides can be managed to help mitigate negative effects on ground-nesting bees. Further, it gives insight on the origins of nesting aggregations.

The influence of boron supply on oilseed rape pollination and yield

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Plants, including the high demanding oilseed rape Brassica napus, require the micronutrient Boron (B) for successful growth and reproduction. However, altered precipitation patterns due to global change are expected to make B deficiency occur more frequently. While the consequences of B deficiency on plants are becoming better understood and fertilisers are applied accordingly in agriculture, the effects of B on crop-pollinator interaction are still unclear. To evaluate the interaction between insect pollinators and B deficiency in plants, three rapeseed accessions *DAKTARI*, *CR3153* and *CR2267* were grown on B deficient and B sufficient substrate in the greenhouse. Upon flowering, the plants were moved outside the greenhouse during the day to allow for and to record flower visits by pollinating insects. Some plants were covered with semi-permeable plastic bags to obtain a self-pollination control and to quantify insect pollination services. After fruit ripening, siliques were harvested to measure fruit set. All three accessions displayed significantly stronger phenological B deficiency symptoms (necrotic flower buds, wrinkled flowers, reduced silique development, reduced shoot height) under B deficiency conditions compared to favourable B availability. Both B inefficient accessions *DAKTARI* and *CR3153* were visited by significantly higher numbers of pollinating insects under favourable conditions than under B deficiency. However, the availability of B did not affect pollinator visits of the B efficient accession *CR2267* which overall attracted a similar number of pollinators as B inefficient plants grown under B deficiency. All three accessions produced lighter and fewer seeds per silique on average under B deficiency, while insect pollination increased the mean number of seeds per silique only for B inefficient types. The results suggest that sufficient B supply is crucial for successful rapeseed growth and yield while it promotes rapeseed flower visits by pollinating insects.

A generalized model reveals the effect of nestedness, connectance and network size on the stability of plant-pollinator interaction networks

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Plant-pollinator interaction networks play a key functional role in many ecosystems on earth. Due to anthropogenic disturbances, such as ecosystem destruction and climate change, they are increasingly under pressure. Thus, studying the response of these systems to perturbation is of high relevance. A research focus in recent years has been on the role of the interaction network structure, especially nestedness, connectance and network size, in stabilizing plant-pollinator networks. However, diverging results were found regarding the stabilizing role of these network properties, mainly due to the sensitivity of the used models to the chosen parameterization. These diverging results call for new modelling approaches to obtain further insights. Here, we use a generalized modelling approach, based on a consumer-resource model explicitly taking into account resource dynamics. We investigate the influence of structural properties of mutualistic interaction networks on the dynamical stability of plant-pollinator systems. Generalized models are a powerful tool, which have already been used for example for food webs. They allow efficient calculation of dynamical stability, while being parameterized through biological mechanisms and therefore allow direct biological interpretation. Our model reveals that intermediate connectance and nestedness leads to maximum stability. We also find that dynamical stability increases with network size for plant-pollinator networks, contrasting findings that large random networks tend to instability.

Limestone quarries as secondary habitats: Interactive effects of landscape and local habitat characteristics on trap-nesting wild bee communities

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Dry grasslands and their associated species are increasingly threatened by abandonment and agricultural intensification. Secondary habitats that developed through anthropogenic influence, like quarries, can become important alternative habitats for these species, including wild bees. Therefore, it is important to understand which local and landscape characteristics are crucial for promoting high bee diversity in quarries and make them a valuable secondary habitat. However, interactive effects of local habitat and landscape characteristics of limestone quarries on trap-nesting wild bee communities remain unclear. Therefore, we investigated the effects of local habitat characteristics (shrub cover, flowering plant species richness, habitat area and age) as well as landscape characteristics (landscape diversity and connectivity to surrounding grasslands and quarries) and their interactions on trap-nesting wild bees. We studied 19 abandoned limestone quarries by installing trap nests in each quarry. Preliminary results indicate that the number of bee brood cells in these trap nests were positively affected by landscape diversity. The number of bee brood cells also increased with quarry age, but only at sites with moderate shrub cover. Quarry area positively affected the number of bee brood cells, but only when connectivity to grasslands and quarries was low. At younger sites, bee species richness increased with increasing connectivity to surrounding grasslands and quarries. These interactive effects highlight the importance of combining analyses of local and landscape characteristics to better guide conservation measures for trap-nesting bees in these secondary habitats.

Effect of the antiparasitic moxidectin on non-target organisms

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Moxidectin is intensively used to control animal parasitic diseases worldwide. The substance is lipophilic and possess low a metabolization rate in animal guts, traits that entail an abundant quantity that is released unchanged into the environment via faeces, where it affects non-target organisms. In recent years many studies have reported negative effects of moxidectin on coprophagous arthropods. However, there is a knowledge gap about unwanted effects of moxidectin on other non-target species such as pollinators, herbivores and predators as well as on plants. Given this background, we conduct two semi-field experiments. The first experiment aims at exposing plants to moxidectin and measuring its uptake and accumulation in plant compartments and its effects on the survival and growth of plants. The second aims to expose two pollinator species to blooming plants grown in soil-containing field moxidectin concentrations, assessing its effects on insect´s performance and fitness. We work with the pollinators *Episyrphus balteatus* and *Pieris brassicae* as two model species with different life history traits, in order to assess potential sublethal or lethal effects of moxidectin. We expect to deepen the knowledge of the mechanisms and consequences of the effects of moxidectin to non-target species. Due to the increase in the use of anthelmintics worldwide, it is important to study the specific effects of this pesticides in non-target organisms, since it may produce negative effects on ecosystem functions of pastures. Finally, our study contributes to the development of management approaches to halt biodiversity loss in pastures.

Effects of land-use change on pollinator species and functional diversity in Eastern Europe - Romania

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Biodiversity is declining across the world, and there is an urgent need for a better understanding of the drivers that cause this change across different taxa and regions. Biodiversity research is well established in Western and Central Europe, but the degree to which land abandonment and land use intensification alters species and functional diversity of mesophilic meadows is currently not well understood in Eastern Europe, e.g. Romania, particularly for Diptera. Mesophilic semi-natural grasslands are global plant biodiversity hotspots, but less is known about their pollinator diversity, and how it varies across anthropogenic gradients. To address this knowledge gap, we assessed pollinator species and functional diversity in Eastern Europe's - Romanian mesophilic meadows occurring along a land-use gradient. As land-use change can act as a strong filter we expect that pollinator species diversity would decrease with land-use intensity. However, pollinator groups are likely to respond differently, depending on their tolerance to increasing disturbance. To account for differences between taxa we assessed the variation in species and functional diversity across land-use gradients separately for Hymenoptera (Apoidea) and Diptera (Syrphidae and Tachinidae). Our research showed that traditional hay meadows tended to be more diverse in pollinator species than both abandoned and intensively grazed meadows. However, these overall patterns masked some group-specific trends. Functional diversity remained similar across different land-use types. The study concludes that land-use change had a filtering effect on species, but not on functional groups, suggesting that currently ecosystem functions may still be maintained even in the face of land-use change.

Effects of overwintering conditions and early spring on potential bee-plant asynchronies of wild bees

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Environmental cues such as temperatures and humidity are key to determining insect and plant phenology (i.e. hatching and flowering). Potential phenological shifts due to climate change can lead to temporal mismatches of plant-insect interactions with great detriment to ecosystem services and functions. However, there is a lack of simultaneous phenological studies of insects and associated plants towards rising winter temperatures. We investigated how different naturally occurring winter conditions in two climatically distinct locations (at Greifswald and Freising) and a simulated early spring affected two species of solitary wild bee (*Osmia bicornis* and *Osmia cornuta*) and their interactions with flowering plants. Preliminary results suggest an influence of higher environmental temperature on insect and plant phenology (hatching and shooting/flowering time on average earlier), as well as plant growth and mortality (higher mortality and slower growth with higher temperature). The early spring treatment results in a lower mortality rate of early-hatching bee species and a higher mortality rate of late-hatching bee species. We also saw a difference in the gender ratio (a higher number of males in the early spring treatment). In addition, the bee-plant preference study reveals strong selections towards the concurrent treatment-specific peak flowering plants. Our study provides insights into the methodologies regarding parallel studies of phenological responses of insects and associated plants, specifically focusing on environmental changes that represent future climate change effects.

The effect of floral plantings on the emergence of the crop pollination service

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A world with zero hunger is one of UN's Sustainable Development Goals. Unfortunately, our demand for food will likely increase in the near future as the human population continues to grow, potentially leading to intensified agricultural practices. Nevertheless, these practices threaten bees, which are responsible for crop pollination worldwide. Therein lies a dilemma: agricultural intensification ultimately threatens crop pollination and our own food security. That is why actions aimed not only at preserving bees but also their crop pollination service are critical. The cultivation of floral plantings associated with crops seems promising. However, their success depends on key environmental factors. To identify these factors, we first need to synthesize knowledge. Here, we present a systematic and bibliometric map made within the research weaving framework. We assessed the evidence available and main knowledge gaps. We also identified the main scientists producing knowledge about the topic, and where their studies have been carried out. On the databases Web of Science, Scopus, and Scielo, we identified 1,535 papers. Following the screening stages proposed by PRISMA, we removed duplicates and read the title and abstract of the 1,070 remaining articles. After checking our inclusion criteria, 200 papers remained. We also included papers from other meta-analyses of the effect of floral planting. Finally, we read the methods and results sections of 269 papers. Finally, less than 20% remained and were considered relevant. The majority of the studies were conducted in Europe and North America, where agri-environment schemes and other pollinator-friendly practices are well established. Hedgerows and wildflower strips seem to enhance bee abundance and richness, but their effect on crop pollination vary between crops and regions. Our next step will be to investigate how different factors interact to determine the success of floral plantings.

Allometry and functional diversity of Meliponini (Apidae: Apinae) along a forest recovery gradient in a South American tropical lowland rainforest

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Understanding the allometry of bees is important for shedding light onto pollination mechanisms and estimating their functional diversity. Morphological traits like proboscis length and body size determine which plants can be used for foraging and thus can be pollinated, while wing length is related to foraging distance. Meliponini are a dominant tribe of tropical, eusocial bees in the family of Apidae with a key role as pollinators of a large segment of the tropical flora. According to many studies, they are highly dependent on forests and, therefore, might be particularly vulnerable to deforestation and land use. Information on their allometry and its relationship with land use is, however, lacking. We measured morphological traits of 44 Meliponini species from 15 genera from the Ecuadorian Chocó rainforest along a regeneration chronosequence, including pastures, plantations, secondary forests, and old-growth forests. Functional diversity along this gradient was calculated with three indices: functional richness, evenness, and dispersion. All three differ significantly between plot types and depend on plant functional diversity. Besides this, richness and evenness depend on regeneration age, while distance to the next old-growth forest changes functional dispersion. The measured morphological data was tested against a model described in a recent study estimating proboscis length by family and intertegular distance, and it was found that the model could not accurately predict this difficult-to-measure trait in Meliponini. An updated model and a species-specific dataset of the measured traits are provided. Our work was able to show that functional diversity of Meliponini changes within the process of forest restoration. We were able to identify the main drivers of their functional diversity and, with the datasets provided, ensured that researchers and conservationists can assess the functional diversity of Meliponini accurately.

EE1
P10

Deciphering the influence of hedges on the habitat suitability of ground-nesting bees

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Pollinators, especially wild bees, as key contributors to biodiversity maintenance, face significant challenges in agricultural landscapes, which compromise their positive impact. This includes the conversion of natural habitats to simplified managed ecosystems providing limited floral resources for pollinators. Yet, the connection of semi natural habitats with a high floral diversity in agricultural landscapes seems to be important for the maintenance of pollinator diversity. One structural element in agroecosystems that could provide high floral rewards for pollinators are hedgerows, but there is little evidence if they are suitable nesting habitats and if the composition and availability of floral resources affects ground-nesting bees. In this study, 215 ground-nesting-pollinator traps were installed to catch bees and other pollinators and we quantified intra- and interspecific floral resources of co-flowering plants in hedgerows and the surrounding landscape heterogeneity in South-West Germany. We show, that the composition of floral resources shapes pollinator communities. Pollinators compete for floral resources in hedgerows, which affects the behaviour of ground-nesting bees. In particular, bumble bees (i.e. *Bombus terrestris*) may successfully compete for floral resources and choose hedgerows, so that they may provide important pollination services to wild and crop plants. Therefore, hedgerows are important semi-natural elements in agroecosystems that may support a diverse community of pollinators, lower the detrimental impacts of agricultural pressures on pollinators by providing flower resources and nesting habitat, stabilizing pollinator community dynamics and thereby benefiting both agricultural productivity and ecological health.

EE1
P11

Spatial and temporal effects of mass-flowering crops on the abundance and richness of pollinators in agricultural landscapes

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The ongoing intensification of agricultural land-use and the concomitant intensified crop management and loss of natural nesting and flower resources are a considerable threat to the persistence of wild pollinators in agricultural landscapes. However, thereby, the cultivation of mass-flowering crops like rapeseed increased, providing a lush but very time-limited food resource for pollinators. Possibly, the occurrence of such additional food resources in the landscape can support a higher abundance and richness of wild pollinators but it might also lead to converse effects if populations grew during flowering time of mass-flowering crops and cannot be sustained when resources are missing after the flowering period or if there is no constant supply between years to support populations on the long-term. Especially such temporal effects of the occurrence and diversity of mass-flowering crops are still poorly understood. Therefore, we collected around 5000 individuals of 188 pollinator species (bumble bees, other wild bees, and hoverflies) from 132 sites across Bavaria to analyse the effects of mass-flowering crop area and diversity on pollinator abundance and richness. We also investigated the impact of temporal availability of mass-flowering crops during the course of the year as well as in the previous year to consider possible heritage effects from better or worse winter survival due to precedent resource availability. Further, we considered the availability of mass-flowering crops over the last five years to study effects of temporal stability. Bringing together spatial and temporal effects of mass-flowering crops allows to identify deficits in landscape configuration and/or temporal availability of resources to support pollinator conservation in agricultural landscapes.

Manipulation and control — the experimental foundation of global change research

Short title: Controlled environments in global change research

Chairs: Bálint Georg Jákli, Martin Schädler

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Global change is transforming our ecosystems and will have a lasting impact far into the future. The development of adapted and sustainable land use and management practices requires an interdisciplinary understanding of the function, adaptability and resilience of ecosystems under changing climatic conditions. Essential for this understanding are scientific experiments in which specific environmental variables are deliberately manipulated and controlled. The experimental approaches can differ fundamentally, depending on whether the studies are conducted in the field or in controlled environments such as phytotron facilities, whether the focus is on long-term trends or extreme events, or whether individual parameters are modified incrementally, or complex dynamic climate sequences are simulated. Furthermore, recent advancements in climate control, LED lighting, and lysimeter technology provide new possibilities to simulate complex conditions in controlled environments and, thus, to systematically complement field studies. The session is intended to provide a comprehensive overview of current and innovative methods for environmental manipulation and control in experimental research. Emphasis will be placed on multi-scale, interdisciplinary approaches to reveal interfaces and synergies between experiments conducted in the field and in controlled environments. The session welcomes contributions from a range of disciplines including experimental ecology, plant- and ecophysiology, agroecology, soil science, and other relevant areas. After the session, attendees should be provided with the chance to visit the TUMmesa phytotron facility.

EE2
01

Artificial Light At Night drives diel shifts in soil respiration

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Terrestrial ecosystems acquire carbon via photosynthesis and lose it predominantly through soil respiration. These coupled processes occur rhythmically in diel cycles. Global changes that influence carbon loss vs carbon gain may alter ecosystem carbon storage. Yet, the mechanisms underlying the influence of some global change drivers on ecosystem processes remain undocumented. We test how Artificial Light At Night (ALAN) influences grassland plant-soil communities in a mesocosm experiment. We show that, during peak plant biomass, ALAN reduces soil respiration, a result that was associated with changes in soil moisture and microclimate. However, we detected no ALAN influence on plant photosynthetic responses. Moreover, we found neither soils, nor plants, were sensitive to ALAN later in the season. These results emphasize the importance of temporal dynamics in coupled plant-soil systems. We suggest that an integrated assessment of plant and soil responses is needed to gauge ecosystem responses to global change.

AgraSim: an experimental simulator for the comprehensive analysis of global change impacts on biogeochemical, hydrological and physiological processes in agricultural systems

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The AgraSim large-scale research infrastructure is an experimental simulator consisting of six mesocosms for studying the effects of future climate conditions on plant physiological, biogeochemical, hydrological and atmospheric processes in agroecosystems, which was designed and built by the Forschungszentrum Jülich, Germany. Each mesocosms consists of a temperature-controlled and weighable soil lysimeter unit and a transparent plant chamber within a fully adjustable climate chamber with an LED light source. With a fully automated process control system, defined climate conditions and air compositions can be set and varied with high temporal resolution using a predefined dataset. The soil water balance and the gas exchange between soil, plant and atmosphere are quantified with high time resolution. The nutrient and water use efficiency as well as the exchange of greenhouse gases of the investigated cultivation systems is also examined in detail under all conceivable future climate conditions. AgraSim provides a unique way of imposing future climate conditions which presently cannot be implemented under real-world conditions. It allows monitoring and controlling states and fluxes of a broad range of processes in the soil-plant-atmosphere system. AgraSim will make it possible to simultaneously better understand and quantify the effects of climate change on agricultural yield, nutrient and water use efficiency, long-term carbon storage, water quality and climate-relevant gas fluxes of different cropping systems. This information will then be used as input for process models, to improve process descriptions in the models and to serve as a platform for the development of a digital twin of the soil-plant-atmosphere system.

Does hypobaria affect *Arabidopsis thaliana* along an elevational gradient? Effects of prolonged low air pressure exposition in Ecotron chambers

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In the context of climate change, plants that move upward along elevational gradients to track their pre-warming temperatures will face a lower air pressure the higher they migrate. Hypobaria refers to a condition of low atmospheric pressure, often associated with a reduction in the partial pressure of atmospheric gases, an increase in the vapor pressure deficit, and soil water loss. However, the precise effect of hypobaria on fundamental plant physiological processes, such as photosynthesis pathway and resource allocation is still unknown. Here, using four Ecotron chambers, capable of independently controlling air pressure, we studied the responses of *Arabidopsis thaliana* plants along an elevational gradient. When the air pressure was lower, we found a general decrease in the efficiency of photosynthetic systems associated with an increase in non-photochemical quenching. However, plants increased the Non-structural carbohydrates and luteolin production, probably activating a protective mechanism as a response to low air pressure. Our results demonstrate that plants are vulnerable to hypobaria, and they answer with complex responses that still need to be investigated. We anticipate our assay to be a starting point to explore the ecological impact of climate change on plants and understand how they react to novel stressors in the context of climate change.

Eco-physiological responses of alpine plant species to low air pressure

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Climate change is the predominant factor shaping the plant distribution of alpine area. One notable consequence of climate change is the migration of plant species towards higher altitudes driven by the need to track their thermal niches. Migrating plants will face new ambient conditions where various factors co-vary. The low air pressure is the variable less studied in ecological studies of mountainous areas. Hence, the objective of the following study was to determine the effect of the low air pressure on the eco-physiology of two alpine plant species (*Hieracium pilosella* and *Trifolium pratense*) through studying the effect on leaf gas exchange, chlorophyll fluorescence, growth, non-structural carbohydrates, carbon stable isotopes and nitrogen content. For this purpose, plants were grown in Ecotrons under varying air pressures (85, 75 and 60 kPa) while all other parameters were kept similar. The experiment lasted one month, after which measurements were conducted. The results indicated that low air pressure enhances carbon fixation efficiency and increases the concentration of non-structural carbohydrates in the leaves, while simultaneously reducing plant biomass and chlorophyll content. Furthermore, the magnitude of these effects varied among plant species. We conclude that the distribution pattern of alpine areas may be influenced by the upward shift induced by climate change.

Putting the 'Change' into 'Climate' – current methods of simulating climate in modern controlled environment facilities and ecotrons

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Controlled Environment Facilities (CEFs), including modern lysimeter systems and ecotrons, are powerful and flexible tools in global change research. They enable the simulation of precisely defined scenarios by controlling multiple abiotic environmental variables. Experiments conducted in CEFs have contributed significantly to our understanding of ecological, plant physiological and molecular responses to environmental drivers and have played a crucial role in the development and parametrization of process-based models. The rapid technical progress in climate control and LED lighting has made compact ecotron systems increasingly affordable and facilitates the implementation of complex dynamic climate series with high temporal resolution. Therefore, an increasing number of recent approaches in experimental ecology or climate change research include the forcing of CEF units with records from climate stations or with outputs of downscaled/regionalized global climate models. This opens up novel opportunities for testing new hypotheses and for investigating the impact of climate change on plants/ecosystems at the physiological, molecular or (epi-)genetic level, as well as for optimizing model parameterizations and their validation. In this contribution, we will provide an overview of different approaches of forcing CEFs (including the TUM Model Ecosystem Analyser and the Montpellier European Ecotron) with complex dynamic climate scenarios and discuss their advantages and limitations.

How to optimize sampling effort in ecological experiments and observational studies

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A major aim of experimental and observational ecology ecology is to quantify responses to environmental change. Study designs which optimally capture response patterns are currently debated. A key point in the discussion is how a limited total number of samples should ideally be allocated to replication versus the number of locations along the environmental gradient. Here, we assess how to optimally allocate sampling effort for maximizing prediction accuracy in gradient designs. For this we performed artificial data simulations for different sampling approaches with or without a priori knowledge of the underlying patterns and applied a set of commonly observed response shapes. Overall, unreplicated sampling with equidistant, systematic placement along the gradient of interest at as many locations or levels as affordable turned out to be the best approach for unknown response shapes. Replication was found to be beneficial when a priori knowledge exists about the underlying, simple (e.g. linear or humped) response shape. Unreplicated designs will serve for covering investigated gradients more densely and for pushing experimental systems beyond historical and forecasted extremes. The latter will be decisive for global change impact research, as it enhances our understanding of stressor–response relationships and thresholds in state and impact beyond already realized environmental conditions.

Climate-driven shifts in plant-soil feedback of a perennial grass species

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Plant-soil feedback (PSF) plays a key role in determining the composition of plant communities, and understanding the impact of the ongoing climate change on PSF is thus crucial for predicting the consequences of climate change for ecosystems. Here, we conducted a growth-chamber experiment to examine possible climate-driven shifts in PSF of a perennial grass, Festuca rubra, originating from two climatically distinct sites, by using all factorial combinations of soil biota origin, plant origin, and cultivation climate. All plants, regardless of their origin, exhibited less negative PSF (expressed as relative performance in live vs sterilized soil) when grown under warmer climate than under colder climate, likely due to positive effects of increased activity of soil decomposers and enhanced nutrient cycling. Soil biota generated more negative PSF effects when grown under the climate of its origin. This observation suggests that soil biota, especially soil pathogens, are well adapted to their native climate, exhibiting greater efficiency in suppressing plant growth within their preferred climatic conditions. Consequently, it suggests that rapid climate change may lead to the release of plants from negative PSF, potentially destabilizing plant communities. Plants showed slightly higher PSF under their home than away climate when grown with their allopatric soil biota, but lower when grown with sympatric biota, showing that consequences of plant-soil co-adaptations are climate dependent. Our results highlight the adaptions of soil biota to their native climate as key drivers of PSF interactions and suggest that climate change may disrupt established negative plant-soil interactions, potentially leading to shifts in plant community composition and loss of species diversity. These findings emphasize the need for further investigations to unravel the mechanisms driving these responses and evaluate their consequences for ecosystem resilience in the face of climate change.

EE2

P2

Getting to the root of 21st century allocation changes

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Forest ecosystems in Europe are under a growing threat from recurring drought and heat extremes. Resource acquisition and allocation strategies determine the ability of species to cope with such stresses, so better understanding their variation with the environment is key to forecast species and forest resilience. This calls for an exploration of how plant hydraulic function influences carbon allocation over time. Here, we propose a new experimental design for the paired monitoring of above- and belowground carbon allocation and water fluxes in European tree species with varying levels of drought tolerance. Saplings of each species will be grown in different soils more or less favourable to their growth, and will then be subjected to a drought treatment (i.e. decreased watering until significant canopy damage is achieved). Both root and canopy dynamics (e.g. growth, desiccation/wilting) will be recorded on sub-daily timescales using automated robotic minirhizotrons (underground) and digital photography (aboveground); trunk dendrometers will monitor stem growth. Sub-daily changes in canopy gas exchange and leaf water potential will be measured periodically. Finally, anatomical (e.g. DBH), hydraulic (e.g. P50), and photosynthetic (e.g. Vcmax25) traits will be measured across different organs, as will non-structural carbohydrates. Taken together, the data gathered in our experiment will form a comprehensive picture of inter-species differences in whole-tree carbon allocation patterns and their hydraulic control under drought.

Understanding and safeguarding wetland functioning and ecological networks

Short title: Wetland ecology and functioning

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Wetlands and semi-terrestrial ecosystems provide a wide array of ecosystem services such as biodiversity support, flood protection, and long-term carbon sequestration. However, these ecosystems of high societal importance are being lost worldwide at alarming rates due to land use and climate change. At the same time, management and restoration actions are underway in many parts of the world to restore and safeguard these ecosystems. We believe that the scientific community working on specific wetland ecosystem types is often highly segregated, resulting in limited knowledge exchange and integration, and potentially slowing progress and innovation in the field of wetland ecology and management. The primary goal of our session is to bridge and integrate scientific research across diverse wetland ecosystems and involved disciplines. By convening scientists specializing in various wetland and semi-terrestrial ecosystems, including (but not limited to) coastal and estuarine marshes, floodplains, riparian forests, and peatlands, we aim to facilitate learning from each other and to foster collaboration to advance ecological understanding, as well as management and restoration strategies. We welcome presenters to share their insights on diverse aspects of wetland ecology, such as biotic interactions and food web dynamics, ecosystem connectivity, and carbon and greenhouse gas fluxes. We are particularly interested in contributions exploring synergies between biodiversity support and climate change mitigation, the predictability of restoration and management success, and the stability of ecological networks and ecosystem functioning in a changing climate.

EE3
01

The use of amino acid isotopes and fatty acids to track the utilization of blue, green and brown carbon by predators in riparian habitats

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Global change represents a major challenge for biodiversity and has a particular impact on the interactions that are crucial for ecosystem functioning. Since it can be difficult to study interactions in natural systems directly, analytical approaches are generally used. We investigated trophic interactions in riparian meta-ecosystems, focusing on the connections between aquatic (blue), terrestrial (green), and decomposing (brown) ecosystems. We focused on riparian predators, namely ground-dwelling and web-building spiders, which differ in their hunting strategy. Using carbon isotopes of amino acids (AAs) and polyunsaturated fatty acid (PUFA) profiles, we aimed to decipher dietary preferences and carbon fluxes across interconnected ecosystems. Our results show distinct patterns in PUFA abundance and AA isotope values between blue, green, and brown sources, which was also reflected in the PUFA abundance and AA profiles of the spiders. Mixing models based on either PUFA abundance, AA carbon isotope values or their combination consistently showed that ground-dwelling spiders rely predominantly on brown sources, whereas web-building spiders have a mixed diet with higher reliance on green sources. Moreover, short chain PUFAs, such as linoleic and linolenic acids, show clear associations with protein source. Our results show that riparian spiders depend on three different energy channels, namely blue, green and brown sources. This highlights the importance of spatial heterogeneity and shows that these types of interactions in meta-ecosystems need to be studied as they may be sensitive to global change. Moreover, it demonstrates the importance of brown sources in food webs, which are often overlooked. Overall, our study suggests that AA isotopes and PUFA profiles can be used to study trophic interactions for a wide range of organisms and ecosystems.

Contrasting drivers of occurrence and fertility in an endangered species of a dynamic riparian habitat

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Altered flood regime and associated shifts in vegetation structure result in habitat loss of many riparian species. Sessile organism such as lichens may be especially vulnerable given their slow growth and putatively narrow habitat requirements. Their ecological niche is often unknown, which hinders their use as indicator species. We assessed the main drivers of occurrence and fertility (production of fruiting bodies) in the critically endangered, soil-dwelling lichen species *Stereocaulon incrustatum* growing on gravel bars with infrequent turnover. We recorded sediment size distribution, gravel bank elevation and vegetation structure along 41 transects of 400 m × 10 m along two braided Swiss rivers. Data was sampled in 811 randomly placed 2 m × 2 m plots and analyses were performed using generalized linear mixed effect models in a Bayesian framework. The main drivers of lichen presence probability were elevation, vascular plant cover in the herb layer and cobble cover. Additionally, presence probability increased with moss, but decreased with litter cover. The main positive drivers of lichen fertility were cover of woody plants >3 m, the species' own abundance and shrub cover. Reduced fertility was associated with herb layer and over 40% moss cover. This study shows a shift to sexual reproduction with increasing habitat age given the higher lichen fruiting body production on plots with closing canopies. Elevated gravel bars with sparse vegetation are therefore focal conservation areas as they harbor sexually reproducing source populations for colonization by dispersal. The presence of the lichen species is a good indicator for relatively stable riparian habitats with moderate competition in the herb layer. Still, a powerful flood regime and supply of coarse-grained sediments are crucial to preserve these species. If a recurrent natural disturbance regime is absent, conservation management is needed to mimic habitat dynamics by resetting ecological succession.

A day on the shore: the impact of recreation activities on composition, diversity and structure of lakeshore vegetation

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Swimming in lakes and spending time on the shore are popular summer activities, but as climate change continues and land use intensifies, pressure on lakeshore ecosystems is increasing. Plants are crucial for stabilizing the shoreline and providing habitat, yet they suffer from human-induced trampling and destruction. Recent reviews highlight the poorly understood impact of bathing and lingering on lakeshore vegetation. In this study, we analysed the effects of shoreline use connected with bathing on the structure, composition, and diversity of lakeshore vegetation during a bathing season. Vegetation relevés were recorded in nine bathing and adjacent control sites in the nature park 'Dahme-Heideseen' (Brandenburg, Germany). Additionally, terrestrial laser scanning (TLS) was used to analyse changes in the aboveground spatial distribution of plant material pre and post weekends. Visitor pressure was assessed via visitor counts. Despite differences in herbaceous and shrub cover and species between bathing and control sites, both exhibited non-typical plant species. The vegetation parameters did not correlate with visitor counts. TLS data analyses showed that bathing and control sites exhibited similar changes in reed volume, and the vegetation in the sunbathing area displayed no clear tendency for directed loss or gain in aboveground volume. Although the TLS approach used in this study has great potential for estimating the space occupied by herbaceous vegetation, it has been found to be less effective in measuring reed beds. This is largely due to the flexibility of reed culms. As we studied established bathing sites, the vegetation may have already adapted to human use. Based on these results, there is no immediate need for action. Current visitor intensity seems to have a minimal impact on vegetation, but monitoring recreational activities' ecological effects remains crucial as visitor numbers may rise due to climate change.

Species-specific elevational niches at the salt marsh edge mediated by biotic interactions and site-specific characteristics

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Salt marshes are dynamic systems whose resilience and landscape structure depend on bio-geomorphological interactions. The ecological niches of salt marsh plants are organized along an elevational gradient determining the impact of abiotic factors such as flooding or salinity, and thus generating the typical salt marsh zonation. In the pioneer zone, vegetation must cope with non-optimal environmental conditions due to strong impacts of hydrodynamic forces and sedimentation, and is particularly threatened by climate change-induced sea level rise or increased storminess. To test the hypothesis that species have different elevational niches, which are shaped by local abiotic conditions and interspecific interactions, salt marsh species occurrences and covers were measured along 65 seaward-landward transects at two study sites on the backbarrier island Spiekeroog, Germany, differing in successional age. Elevations were extracted from a digital terrain model. Additionally, soil samples were taken for characterizing interactions between the cover of ecosystem engineer Spartina anglica and soil properties. Zero-augmented beta regression models demonstrated that species elevational niches were mediated both by elevation and biotic interactions. Especially Spartina anglica tended to exclude (*Salicornia procumbens* and *Limonium vulgare*) or facilitate (*Salicornia europaea*) other species. Soil characteristics differed among sites, and among the edges and inner parts of the pioneer zone. The cover of the ecosystem engineer Spartina anglica was negatively associated with a high bulk density and soil pH. Our results provide insights into plant species responses and interactions under highly dynamic conditions in the foremost marsh zone. Knowledge about species-specific responses to their abiotic and biotic environment, as well as of plant-soil-interactions, is an important prerequisite for modelling and predicting future ecosystem shifts in salt marshes under climate change.

EE3
05

Reviving alpine wetlands in China: How ecological restoration boosts soil carbon stability

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Alpine wetlands, particularly those along the eastern edge of the Tibetan Plateau in China, are vital carbon sinks critical for climate change mitigation. Historically affected by extensive overgrazing, these ecosystems have undergone considerable degradation, necessitating urgent ecological restoration to align with global carbon neutrality objectives. This study focuses on the Zoige Wetlands in Hongyuan County, Sichuan Province, where soil samples were analysed to evaluate changes in soil properties, carbon formation, and microbial activity following restoration efforts. Distinct soil organic carbon components, particulate organic carbon (POC) and mineral-associated organic carbon (MAOC), were assessed to quantify microbial necromass carbon and plant residue carbon. The findings reveal that while POC levels remained relatively unchanged, there was a marked improvement in soil properties, microbial activity, and MAOC content post-restoration. Additionally, the microbial necromass carbon in the MAOC fraction of restored wetlands significantly surpassed that in grazed wetlands, indicating enhanced microbial contributions to soil carbon pools. These results underscore the effectiveness of ecological restoration in promoting soil structure, microbial activity, and the stability of soil organic carbon, thereby bolstering the role of alpine wetlands in global carbon cycling and climate change mitigation while preserving their ecological diversity and function.

EE3
06

Rice paddies can help amphibian populations in Swiss agricultural landscapes

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In Switzerland 90% of wetlands disappeared and were repurposed as agricultural land. Recently, trials cultivating paddy rice in Swiss lowlands showed the potential of rice paddies as habitats for amphibians. We investigate the impact of ditches within rice paddies on biodiversity and amphibian abundance, the potential role of rice paddies as additional habitat and the landscape features that promote amphibian presence and abundance. Our findings suggest that rice paddies are important habitats and breeding ground for amphibians and help alleviate fragmentation resulting from wetland loss.

EE3
07

Paludiculture can support biodiversity conservation in rewetted fen peatlands

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Paludiculture, the productive use of wet or rewetted peatlands, offers an option for continued land use by farmers after rewetting formerly drained peatlands, while reducing the greenhouse gas emissions from peat soils. Biodiversity conservation may benefit, but research on how biodiversity responds to paludiculture is scarce. We conducted a multi-taxon study investigating vegetation, breeding bird and arthropod diversity at six rewetted fen sites dominated by *Carex* or *Typha* species. Sites were either unharvested, low- or high-intensity managed, and were located in Mecklenburg-Vorpommern in northeastern Germany. Biodiversity was estimated across the range of Hill numbers using the iNEXT package, and species were checked for Red List status. Here we show that paludiculture sites can provide biodiversity value even while not reflecting historic fen conditions; managed sites had high plant diversity, as well as Red Listed arthropods and breeding birds. Our study demonstrates that paludiculture has the potential to provide valuable habitat for species even while productive management of the land continues.

EE3
08

Greenhouse gas fluxes in tidal marsh soils along a salinity gradient in the Elbe Estuary

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Tidal marshes are highly dynamic ecosystems. They host unique vegetation and soil microbial communities and harbor specialist species that are adapted to the challenging environment. The dynamic abiotic conditions and complex biotic interactions create high spatiotemporal variability in soil conditions. Therefore, a wide variety of greenhouse gas fluxes can be expected from these soils ranging from emissions to uptake. In this study, we measured land-atmosphere fluxes of CH_4 and N_2O because of their relevance for the climate change mitigation potential of tidal marshes. We tested how flux magnitude, directions, temporal variability and controls differed between different vegetation communities along a salinity gradient. The measurements were taken at the research sites of the DFG funded RTG2530 project located in the Elbe estuary in northern Germany. Greenhouse gas fluxes were measured with the manual closed chamber method using portable infrared gas analysers and a mobile soil-sensors system. Preliminary results point to significantly different CH4 fluxes along the salinity gradient; ranging from $-7.3*10^{-2}$ to $8.9*10^{-2}$, -2.1 to 5.2 and 1.8 to 80.0 mg CH_4 m^{-2} h^{-1} for the meso-, oligohaline and freshwater zones respectively. The preliminary results of N_2O ranged from $-1.5*10^{-2}$ to $3.2*10^{-1}$, $-2.0*10^{-2}$ to $2.0*10^{-1}$ and $-2.8*10^{-2}$ to $9.9*10^{-2}$ mg N_2O m^{-2} h^{-1} for the meso-, oligohaline and freshwater zones respectively. At the conference, we will present and discuss our findings from the complete data set covering a period of 15 months of flux measurements from 2022 and 2023.

EE3
09

Livestock grazing controls methane emissions from Baltic and North Sea coastal wetlands

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Coastal wetlands, such as salt marshes, have a high potential to mitigate climate change through their long-term removal of atmospheric carbon dioxide (CO_2). However, the oxygen-free soils that allow coastal wetlands to act as effective carbon (C) sinks also facilitate the generation of highly potent non-CO_2 greenhouse gases (GHGs), such as methane (CH_4) and nitrous oxide (N_2O). Large areas of coastal wetlands in northern Germany have undergone intense grazing over the past decades and centuries. Given the extend of this land use type and the high potential of CH_4 to offset the carbon storage capacity of wetlands, it is of great importance to understand how livestock grazing could mediate CH_4 dynamics. This study concentrates on (i) the direct comparison of grazed and ungrazed coastal wetland areas in their respective methane fluxes and (ii) on identifying biogeochemical drivers of methane dynamics, such as redox potential, that could be mediated by grazing. Plant and soil methane and soil redox measurements were carried out over a whole year in a six-week cycle, comparing grazed and ungrazed North Sea and Baltic Sea coastal wetlands. Preliminary data show higher methane emissions from Baltic Sea compared to North Sea wetlands, and we regularly find grazing to reduce methane emissions in coastal wetlands of both coastlines. Surface elevation and soil redox are important drivers of the observed variability in CH_4 emissions. Currently, we are evaluating the effects of additional biotic and abiotic factors controlling CH_4 emissions, including plant community composition and traits, soil organic matter contents, and porewater characteristics.

EE3

O10

Mesocosm study: How does warming affect the carbon cycle of Baltic coastal marshes?

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As the human population faces challenges of climate change there is growing interest in coastal marshes for their ability to mitigate climate change through carbon sequestration. However, coastal marshes are known sources of methane, potentially offsetting carbon sequestration in terms of greenhouse gas equivalents. Furthermore, it remains unclear how these systems and their ability to sequester carbon perform under climate change. Global warming is likely to augment carbon assimilation and decomposition. Moreover, increasing temperature is anticipated to influence the balance between methane production and consumption through drivers interacting on multiple levels. Warming may shift species composition, alter primary productivity and consequently affect the metabolic activity of methane-producing and consuming microbes. On a global average, warming exceeds in Nordic regions and therefore studies including latitudinal gradients must be carried out. The Baltic system is characterized by several gradients that alter morphology and species composition of coastal marshes. Tidal and saline impact decreases with higher latitudes allowing reed-bed formation. Salt marshes develop when grazing is applied as management tool. To investigate plant communities as response to and regulator of climate change effects on carbon cycles coastal marsh blocks from three origins (Sweden, Finland, and Denmark) from two different management types (grazed and non-grazed) were brought to Hamburg, Germany, and treated with different warming scenarios. The feedback-controlled warming was applied in 1.5 °C steps with a maximum of +6 °C above ambient. For assessing carbon assimilation and decomposition a wide array of methods was applied such as loss on ignition for soil organic matter quantification, chamber measurements for studying methane fluxes or the Tea-Bag-Index to survey decomposition vs. stabilization. It is hoped that this study will contribute to a deeper understanding of the complexity of ecosystem responses to global warming, providing insights into the interactions between abiotic and biotic carbon cycles.

011

Understanding warming effects on soil microbial communities, redox conditions and their interactions along the elevational gradient of salt marshes

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Blue carbon ecosystems (i.e. salt marshes, mangrove forest, seagrass beds) play an important role in mitigating climate change, by their natural potential as highly effective carbon sinks. The disproportionally high carbon sequestration rates are the result of high net primary production and low rates of microbial decomposition in reducing soils. Soil redox potential and soil microbial functioning are interconnected in wetland ecosystems. Given the high potential of salt marshes to mitigate climate change, understanding the potential feedbacks to microbial functioning induced by global warming is vital. The MERIT (Marsh Ecosystem Response to Increased Temperature) experimental site provides a unique research infrastructure to assess *in-situ* warming effects on whole-soil profiles. MERIT combines passive aboveground warming with feedback-controlled active belowground heating down to a depth of 100 cm. Situated along the natural elevational gradient with differing tidal inundation frequencies, MERIT covers the two most important redox gradients of salt marshes, depth and elevation. Here, we present first results from the whole ecosystem warming experiment MERIT, coupling molecular methods (16S, metagenomic predictions, exo-enzyme assays) with soil redox measurements (redox sensors, IRIS sticks). Preliminary results reveal a response of active microbial communities to warming, assessed by analysing RNA (sequenced as cDNA). We found warming to have a negative effect on soil redox potentials, this effect was only present in higher elevated plots which are inundated less frequently.

EE3

P1

New insights into the habitat preferences of *Liparis loeselii* based on trait ecology

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Fens are one of the habitats in Europe that have undergone a great decline in the last century. Preventing the loss of fen-typical species and protecting them is therefore a major focus of international conservation efforts. One of these species prioritised by the EU within the Habitats Directive is the fen orchid *Liparis loeselii*. Continuously declining populations and an insufficient understanding of the site ecology of the species have led to an increasing number of new studies in recent years. However, comprehensive analyses of habitat preferences and resulting management strategies are hardly available, especially for populations in Germany. In our study, we aim to model the habitat preferences of *Liparis loeselii* based on selected traits in relation to a wide range of parameters. For this purpose, 17 extant populations of *Liparis loeselii* in Brandenburg (Germany) were investigated in 2021. We chose 4 plots per site with the occurrence of *Liparis loeselii,* in which 1-4 individuals were randomly measured for their traits (e.g. leaf length, fruit number, or inflorescence height). The Dataset was added by measurements out of random placed plots with the occurrence of the species. For data analysis we used GAM and BRT models under the addition of several environmental predictor variables (e.g. peat degradation, photosynthetically active radiation and several coverage parameters). The results provide new insights into habitat preferences, possible causes of decline and appropriate management strategies.

Benthic macroinvertebrate food web structures in ponds and ditches

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The basic principle of “you are what you eat (plus a few ‰)” (DeNiro und Epstein 1976) make stable isotopes a tool to understand food web structures and matter transport within systems and thus to understand and maintain ecological stability. To examine benthic macroinvertebrate food webs in small water bodies in the agricultural landscape of the region ‘Havelländisches Luch’ in Brandenburg, northwest of Berlin, Germany, we carried out sampling in four ditches and three small standing water bodies (ponds). Benthic macroinvertebrates from the different functional feeding groups (FFGs) present were analysed for the stable isotopes of carbon and nitrogen. Due to the proximity to agricultural production, the water bodies are prone to impacts by agricultural activities such as the use of pesticides or fertilizers, which can lead to declines of aquatic (insect) biodiversity. To understand how those agricultural activities could shape food web structures, this study, besides other parameters, included data on pesticide residues and nutrient concentrations of the water samples as possible explanatory variables for the food web structures described. We expected a simplification of food webs in water bodies strongly influenced by agriculture. However, no clear patterns regarding agricultural activity could be observed. Nevertheless, depicted food webs differ in their cluster structures, trophic niche width and trophic position for some FFGs. One explanation for the observed patterns is the water body type. Other explanations could be the long-term and ubiquitous use of pesticides and fertilizers and the strongly heterogenic characteristics of small water bodies.

Effect of floods on spider community in a floodplain mesocosm

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Floods play a vital role in rivers contributing to the morphological shaping of river and riparian areas. They can affect composition of arthropod and plant communities, as well as the productivity of ecosystems. Intensity and duration of natural floods are impacted by anthropization of river systems (e.g. diking, damming) and climate change and, in turn translate on cascading effects on aquatic-terrestrial communities. While it is known that natural flood regimes can shape spider communities in riparian area, there is a lack of knowledge on the impact of flood events on altered floodplains. We conducted a study on a field mesocosm, the Riparian Stream Mesocosm (RSM), in South-West Germany. The experiment was conducted implementing a full-block design using 16 independent mesocosm units. Each one include a 1m wide stream and an adjacent 4m grassland riparian area. RSM units were exposed to varying flood intensity (3, 7 and 14 days) or used as controls (i.e. no flood). The flooding design was repeated 4 times between May and September 2024 to consider seasonal variability. Spiders were collected before and after each flooding cycle using pitfall traps. We hypothesized that the flooding of the riparian areas would reduce abundance and species richness of spiders, and the effect to be positively related with the flood intensity. We also expected treatment-specific community shifts with riparian specialists favoured compared to generalist species. From May to July, after 14 days of floods spider species richness was reduced compared to before the flood. With shorter flood, richness wasn't affected. The number of spiders was not affected by any flood treatment. Spider community composition responded to seasonality while there was no difference related to the flood treatment. Species-specific analysis confirmed our hypothesis with higher number of spiders with high moisture preference (e.g. *Piratula latitans, Prinerigone vagans*) in flooded units than in the control.

EE3
P4

Development of reed canary grass on rewetted fen soil – agricultural and ecological insights on a potential fodder alternative

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As intact peatlands contribute positively to the global climate, rewetting of drained agricultural fens aims to reinstate their functions in water management, climate regulation and other ecosystem services. Brandenburg, Germany, is rich in degraded agricultural grassland fens most of which are currently rewetted to achieve climate mitigation goals. In this context alternative management practices and uses for biomass yield are needed. Reed canary grass (*Phalaris arundinacea*) naturally occurs on wet as well as rewetted fen soil, is suited also for temporarily flooded sites due to its very adaptive root system and is known to have a high biomass production capacity. Here we set up a lysimeter experiment on fen soil with a groundwater gradient up to the surface level and developed *Phalaris*-populations for the last two years. As extensive use of permanent grassland with temporarily high-water tables is seen as the most considerate management for wet fens, biomass was harvested and root samples were taken twice a year. We investigate the role of groundwater table height on reed canary grass biomass quality to evaluate its suitability as fodder alternative. We further analyse population root traits and the colonization intensity of AMF to study the belowground plant ecological responses to rewetting and to determine nutrient acquisition strategies of *Phalaris*. First results indicate different effects of groundwater level and harvest date on yield and root traits.

EE3
P5

Warming effects on soil microbial community dynamics in nordic salt marsh ecosystems

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Salt marshes are unique wetlands owing to their geographic location along coastlines and thus the dynamic biogeochemical fluctuations they experience. Salt marshes also play a critical role in climate regulation. They store large ¬amounts of carbon (blue carbon) and are at the same time directly affected by climate changes such as sea level rise. These climate change effects on salt marsh ecosystem functioning are controlled by complex interactions of plant and soil microbial communities. These interactions mitigate carbon fluxes, as well as storage and greenhouse gas emissions of the salt marsh system. However, the understanding of these plant- microbe interactions are still poorly understood. In this interdisciplinary study, we leverage an active aboveground and belowground salt marsh warming experiment, conducted at the Institute for Plant Science and Microbiology at the University of Hamburg. The experiment exposes soil sods and vegetation collected from a latitudinal gradient along the Baltic coastline of Denmark, Sweden and Finland. Sods are subjected to different warming treatments ranging from ambient conditions up to +6 °C, using a combination of soil heating pins and infrared heaters. In our analysis, we compare 16S amplicon sequences from soil samples of three different depths (0–5, 5–10 and 10–20 cm) to investigate the warming response of the microbial community structure at different redox conditions experienced at different depths, and how they relate to carbon dynamics and plant community structure.

Revealing hidden methane oxidation potential within wetland plant tissues

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Recent evidence shows that within-plant CH_4 oxidation attached to aboveground plant tissues exist in many terrestrial ecosystems, yet studies on wetland plant-based methanotrophy are scarce. Given CH_4 is a potent greenhouse gas (GHG), understanding additional drivers for wetlands CH_4 flux is vital. Thus, we ask: (i) Does aerobic CH_4 consumption occur in saltmarsh aboveground plant tissues? (ii) If so, how does plant-mediated oxygen availability affect such methanotrophic activity and how does such methanotrophic activity affect GHG dynamics? In a mesocosm experiment we expose two saltmarsh species (*S. anglica, E. athericus*) and unplanted controls to different soil oxygen concentrations as controlled by different hydrological conditions (waterlogged, groundwater, drained). Regular GHG chamber measurements are coupled with molecular microbial analysis. The ratio and location of methanotrophic to methanogenic microorganisms in the plant-soil system is determined by qPCR. To differentiate between total and active community, 16S sequencing on extracted DNA and rRNA is performed. Redox potentials are continuously monitored using multi-depth redox sensors. First results of qPCR reveal methanotrophic bacteria were detected within the plant shoots and in the rhizosphere, while methanogenic archaea were only detected in the rhizosphere. First results of GHG measurements show less CH_4 emission in the planted treatments than in the unplanted controls under waterlogged conditions. This could be attributed to the existence of methanotrophic communities in plant shoots. Our findings suggest a previously overlooked role of aboveground plant-associated methanotrophic microorganisms in saltmarsh GHG dynamics. To apply our findings to the larger saltmarsh ecosystem, we aim to conduct a complementary field study.

Peat formation potential of *Typha* spp. on a paludiculture pilot site

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Paludiculture is the productive usage of wet or rewetted peatlands. As part of the Paludi-PROGRESS project (Putting paludiculture into practice – Optimization of cattail and reed cultures, project period 2022—2025) 10 ha of a drained peatland in northeast Germany were rewetted and set up as a paludiculture pilot site for cattail cultivation (first project generation, Paludi-PRIMA, project period 2019—2022). In summer of 2019, the construction work was carried out to establish the site. In September, *Typha latifolia* and *Typha angustifolia* seedlings (25,000 per species) were planted on the field with a row spacing of 2 m and a planting density of 0.5 and 1 plant per m^2. To assess the peat formation potential of cattail, we examined the above- and belowground biomass accumulation and decomposition as well as the effects of water level and temperatures on it. We set up 20 plots of 4 m x 1 m (to cover more than one planting row) distributed over the pilot site to reflect the micro relief of the site and thus mirror different water levels. In February 2023 after a machine harvest of the site, ingrowth cores and litter bags were installed to assess the above- and belowground biomass decomposition and accumulation. The litter bags were filled with *Typha* plant material (roots, rhizomes and leaves), *Lipton* rooibos tea bags were used as standard material. The installations remained in the plots for one year, until January 2024. Aboveground biomass accumulation was examined by harvest in January 2024. The data are currently analysed and the results will be presented in September. The overall results of the project provide valuable information on the peat formation potential of cattail, which is not known so far.

Rice paddies can help amphibian populations in Swiss agricultural landscapes

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In Switzerland 90% of wetlands disappeared and were repurposed as agricultural land. Recently, trials cultivating paddy rice in Swiss lowlands showed the potential of rice paddies as habitats for amphibians. We investigate the impact of ditches within rice paddies on biodiversity and amphibian abundance, the potential role of rice paddies as additional habitat and the landscape features that promote amphibian presence and abundance. Our findings suggest that rice paddies are important habitats and breeding ground for amphibians and help alleviate fragmentation resulting from wetland loss.

Lighting up the landscape: Effects of artificial light at night on natural, agricultural and urban landscapes

Short title: Lighting up the night-time landscape

Chairs: Robin Heinen, Gregor Kalinkat, Eva Knop, Franz Hölker

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Humans are increasingly lighting up areas of the world that not too long ago used to be dark. The most obvious example is the illumination of the nightly hours, through street and building lights, advertisement lights, and vehicle lights. In the past two decades it has become increasingly clear that aside from giving people a sense of safety and security, it also often has devastating impacts on natural systems, including humans. Although critically vulnerable taxa have been identified, both in aquatic and terrestrial systems, there are still many open questions that remain, for instance about taxa that have not been studied in this context in great detail. Also, consequences for communities and ecosystem functioning through direct and indirect pathways are often still unknown, including the behavioural and physiological mechanisms driving the changes. Another challenge that scientists face when studying artificial light at night, is that it is hard to get a clear view on the actual light levels that natural systems are exposed to in the landscape, i.e. the lightscape. On the one hand, this is caused by the fact that light levels change with distance from the light source, which creates a hypervariable light environment. On the other hand, it is also highly dynamic, as new lights are constantly installed in previously dark areas. Old lights are also regularly replaced by new lights, and with novel light technology, with trends toward higher-intensity lights. In this session, we aim to bring together speakers that investigate light levels in natural, agricultural and urban landscapes, focus on different study systems and taxa, both aquatic and terrestrial, and changes of communities and ecosystem functioning to provide an overview of the breadth of impacts this often-overlooked form of pollution can have in ecosystems. Lastly, we also welcome input from applied scientists and industry to provide insights in potential solutions, and mitigation strategies that may pave the way to less light-dominated landscapes.

Light pollution of freshwater ecosystems: ecological impacts and remedies

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Artificial light at night (ALAN) is increasingly recognized as a major driver of global environmental change. Since emissions are rapidly growing and half of the human population lives within 3 km of a surface freshwater body, rivers and lakes are ever more exposed to light pollution worldwide. Although freshwaters are hotspots for biodiversity and crucial for human well-being, only a small proportion of studies conducted on ALAN focus on freshwater ecosystems. But the effects of light pollution on freshwaters are far-reaching and affect all levels of biodiversity. Thus, alleviating light pollution requires innovative concepts that include the protection of biodiversity and ecosystems as an explicit objective. With some progress in developing sustainable lighting concepts, the importance of reducing light pollution has indeed been increasingly recognized. However, despite evidence of effective and readily available mitigation strategies (e.g. light orientation, shielding, scaling of light levels to the intended use, spectral tuning), little attention has been given to measures that specifically address light pollution of inland waters and surrounding land. This presentation summarizes the effects of ALAN on freshwater biodiversity and ecosystems, and highlights innovative lighting concepts, strategies and specific measures to improve the protection of freshwater biodiversity and ecosystems from ALAN without foregoing the benefits of nocturnal lighting for humans.

Combining field and lab experiments: the impact of different streetlights on the flight behaviour of moths

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Artificial light at night has substantially increased in recent decades and can interfere with the orientation performance of moths, a key contributor to pollination networks. The global shift to light-emitting diode (LED) streetlights is currently driving the change of night-time light landscapes, particularly due to their high variability in spectrum and intensity. To understand how streetlights affect the behaviour of moths and hence their survival and reproductive success, it is important to quantify the light environment. Commonly used all-sky photometry focuses on one image facing the zenith, resulting in a limited resolution of the horizon. However, the horizon is of great importance for behavioural studies, as it contains light stimuli in the direction of movement. We therefore combined standard all-sky photometry with a robotic panorama head to retrieve full sphere measurements. Moreover, unlike animals moving exclusively on the ground, flying animals can move vertically in addition. Whenever an animal approaches a streetlight during flight, light intensities can be considerably high. To specifically investigate the impact of different LEDs with varying intensities, we took advantage of standardised conditions in the laboratory and conducted behavioural experiments using a flight tunnel. We found that the structure of the light environment is of crucial importance, as a heterogeneous light environment did not elicit the same behavioural responses as a homogeneous one. Moreover, LEDs with the lowest correlated colour temperature (CCT) did not result in the highest promise of mating success, indicating that the spectrum of an LED might have an optimum in terms of insect protection. As LED efficiency decreases with lower CCT values in addition, this finding is of crucial importance when considering the indirect effects of light pollution, such as the CO_2 footprint, for developing lighting strategies as minimally disruptive as possible.

Effects of artificial light at night on alien plant invasions

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Alien plant invasions pose a significant threat to biodiversity and ecosystem sustainability, with global environmental change significantly contributing to these invasions. While there is a well-established understanding of common factors associated with global change, the complex nature of environmental changes prompts further study into the impacts and mechanisms of overlooked aspects, such as artificial light at night (ALAN), on alien plant invasions. This presentation will share several case studies on how ALAN affects the invasion success of alien plants. Specifically, the case studies will include: (i) responses of common and rare aliens and natives to ALAN, (ii) mediated effects of trophic level organisms on the response of alien plants to ALAN, and (iii) interactive effects between ALAN and other global change factors (nutrient addition) on alien plant invasion. Finally, a conceptual framework for testing the effects of ALAN on alien plant invasion will be proposed.

EE4
04

Exploring a cryptic diversity of parasitoid wasps affected by Artificial Light at Night (ALAN)

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Artificial light at night (ALAN) attracts nocturnal insects, withdrawing them from their native habitats. This affects various aspects of ecosystem functioning, including biological control. Parasitoid wasps in this context represent a hyper diverse group with a wide range of undescribed species and host organisms. Although there is already evidence for mitigation strategies (e.g. light orientation, spectral tuning, shielding), uncertainty remains which approaches are best to reduce insect attraction. In our experimental setup, we wanted to test the effect of spatially confining the light emission. Over two years (2021–2022), we monitored the attraction effect of individual road lights (n = 28) at three municipal streets close to nature reserves in Southern Germany, representing different habitats and a gradient in skyglow (urban, peri-urban, rural). We found that tailored and shielded road lights significantly reduced the attraction of parasitoid wasps in terms of abundance and species richness compared to different conventional road lights (LED 4000K, high pressure sodium (HPS) 2000K). Combining molecular and morphological analyses, we identified 106 parasitoid individuals (62 morphotypes) of a minimum of 45 genera out of 13 families. Out of 21 identified species, eleven species were not reported for Baden-Württemberg elsewhere in the available literature and newly reported on a molecular basis. We conclusively think that tailored and shielded road lights will reduce the ecological impact of ALAN on parasitoid wasps in a large and undescribed number of taxa. Considering the different life-histories of attracted species, the potential impacts of ALAN may include an influence on nocturnal pollination and Lepidoptera populations via parasitism, biological control of invasive pest species and tritrophic interactions between primary and secondary parasitoids, with unknown consequences for ecosystem functioning.

EE4
05

Slugs hide in the dark: Impact of Artificial Light at Night on herbivory

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Artificial light at night (ALAN) is increasing and has deleterious effect on biodiversity. While disruptive effects of ALAN on predators are relatively well understood, we still know little on how it affects other functional groups and the ecosystem functions they provide, like pollinators and herbivores. Here we hypothesized that ALAN impacts the fitness, feeding activity, and herbivore damage caused of one of the most destructive herbivore slugs in Europe. To test the effect of ALAN on the amount of herbivory, we setup a field experiment in the Swiss lowlands, in which we experimentally illuminated eight independent wildflower strips and kept eight as dark controls, and we measured the amount of herbivory on three common plant species. In addition, experiments with captive individual feeding on plants with and without nocturnal lighting were conducted to investigate how ALAN affects the development and behaviour of slugs. We found less herbivory on illuminated sites compared to control sites, and the captive slugs bred with nocturnal lighting fed less on plants compared to the ones kept in natural conditions, had lower weights, respectively. It seems that ALAN negatively impacts the fitness and lowers the activity of the slugs, with consequences for herbivory damage caused in the field.

EE4
06

Exploring conservation approaches for nocturnal biodiversity

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The rapid increase of artificial light at night (ALAN) on a global scale means that ecological light pollution threatens sensitive organisms and nocturnal biodiversity almost everywhere. Fortunately, awareness about these downsides of ALAN are increasing while technological and legal mitigation measures are starting to be developed and applied in many countries. In biodiversity conservation, the concept of umbrella species that are targets for management measures and thereby can provide 'protection umbrellas' for co-occurring taxa has a decade-long tradition with multiple successful historical and current examples. In the field of ecological light pollution however, due to its very recent emergence, these and other classical concepts from biodiversity conservation have rarely been applied nor evaluated. In this presentation we explore (i) which taxa could be ideal conservation umbrellas for the protection of nocturnal biodiversity, (ii) how measuring the success of such approaches should be done, and, (iii) potential pitfalls of applying the conservation umbrella concept for the sake of nocturnal biodiversity.

Determining the reach of light pollution on arthropod communities: a campus case study

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In the past two decades, ecological consequences of artificial light at night (ALAN) have been recorded for many animal taxa, including arthropods. As light intensity varies with distance from the light source, it is likely that the impact of light on insect communities diminishes with distance from the light source. Because ALAN typically generates a mosaic of light intensities in the landscape, collecting real-world data on the effects of ALAN on arthropods and arthropod-mediated ecosystem functions is both challenging and urgently needed to fully understand impacts and optimize strategies to mitigate ecological impacts. In the spring of 2024, we selected a replicated set of a uniform type of LED street lights that were located across several extensively managed and mowed meadows on the green campus of the Technical University of Munich in Freising, Germany. From May to July, we recorded local insect communities using yellow sticky traps placed overnight, directly under the light source, randomly placed on a radius 5 m, or 10 m from the light source, respectively. Furthermore, we placed cohorts of dummy plasticine caterpillars in the same locations and assessed proportional attack rates, as a proxy for arthropod, slug, bird or mammal predation. We tested the hypothesis that particularly nocturnal flying insect taxa would be visually attracted to the light, leading to higher abundances closer to light in these arthropods. However, we expect more varied responses in soil-dwelling taxa and predation rates, as ALAN may on the one hand extend day length for diurnal predators leading to increased predation activity, but on the other hand reduce nighttime activity in nocturnal ones. The results of our campus investigation will serve as an important case study to help understand the impacts and reach of ALAN in green urban landscapes and will form the basis for future investigations that will extend their focus to include different light types and spatial and temporal scales.

Biodiversity Exploratories (BE): the value of long-term research platforms in the real world-land-use, biodiversity, ecosystem processes and services

Short title: BE: Long term biodiversity research platform

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The Biodiversity Exploratories are a long-term and large-scale research platform that investigates the effects of land use on biodiversity and ecosystem functions and services since 2006. With its broad range of research disciplines, the interdisciplinary consortium (over 40 projects) covers the entire spectrum of biodiversity, from botany to soil ecology, climate and animals to social-ecological research. A major advantage of this platform is that all studies take place on the same 50 grassland and 50 forest plots in each of the three Exploratories Schwäbische Alb, Hainich-Dün and Schorfheide-Chorin, which cover manifold land-use management types and intensities. This design, in which various aspects of the relationships between land use, biodiversity and ecosystem processes and services are studied through monitoring, comparative observation and large-scale experiments, enables well-founded conclusions and unique quantitative synthesis options. The session aims to present an overview of the most important research results of 18 years of biodiversity research from the BE and to illustrate the value of such long-term research platforms and provide future perspectives.

EE5
01

18 years Biodiversity Exploratories: Review, developments and future perspectives

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The interdisciplinary, DFG-funded priority infrastructure programme 'Biodiversity Exploratories' started in 2006 and holds particular significance in biodiversity research due to its long-term nature. Since then, the programme has investigated the influence of land-use on biodiversity and ecosystem functions, as well as how biodiversity impacts ecosystem functions and services. Significant progress has been made in the study of biodiversity in real landscapes in these past 18 years. This introductory presentation will provide a concise overview of the project's inception and design, its structure and coordination of over 300 project members and more than 40 research projects in the current phase (2023–2026). It will also highlight the development of key tools such as LUI, ForMI and outline future perspectives.

EE5
02

Data management within the BE – a key factor for enabling successful research

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In the DFG infrastructure priority program 'Biodiversity Exploratories' (BE), since 2006, several hundred researchers from close to eighty institutions and different disciplines have been working in more than 200 projects investigating the relationships between biodiversity, land use, and ecosystem services in Germany. All projects work on the same grassland and forest areas. This experimental design is the basis for analysis crossing regional, temporal and disciplinary boundaries. In practice, this will be successful only if data collected anywhere in the BE at any point in time by any project are actually available for research. This importance of data and its reuse in synthesis and long-term studies has been undisputed among those involved in the BE from the very beginning of the endeavour. Consequently, the creation and provision of FAIR data has been a goal in the BE, before the term was even coined. In our presentation, we will give an overview of the different aspects of measures taken to reach this aim: They range from the establishment of a data usage policy from the outset and its development towards more openness over time, training and hands-on, readily available support for scientists, to the implementation of a central database. This database, the Biodiversity Exploratories Information System - BExIS, is based since 2021 on the open-source software BEXIS2. The BE have contributed significantly to the development of this software. We will show the different data-related features of the new BExIS, but also many specially developed BEXIS2 modules that support the project, e.g. in fieldwork planning, research area managing, and event organisation. Furthermore, we highlight the data exchange between researchers and projects, as well as the provision of data to the public. We outline our services that support researchers with questions about data and how we provide high-quality, curated, and FAIR datasets and discuss success factors.

Effects of spatiotemporal variation of land-use intensity in grasslands

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Land-use intensity (LUI) in grasslands is highly variable in space and time and affects biodiversity and ecosystem functioning. In the three regions of the Biodiversity Exploratories, LUI in grasslands can range from extensive pastures or unfertilized hay meadows mown only once to fertilized, frequently mown or intensively grazed sites. We show the spatial and temporal variation in LUI, and how this affects biodiversity of arthropods. Besides aggregate measures of biodiversity, this includes an in-depth analysis of the distribution of each species along the LUI gradient.

EE5

04

Long-term assessment of the impact of mowing intensity on grassland biodiversity

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Over the past decades, grasslands transitioned from diverse, colorful hay meadows to uniform, species-poor multi-cut meadows, driven by technological advancements and agricultural efficiency. This shift has come at the expense of biodiversity, raising concerns about the sustainability of land management practices. Within the Biodiversity Exploratories, we have investigated the effects of mowing practices on grassland biodiversity. We present a novel compound index designed to estimate site-specific mowing intensity. This index incorporates different components such as the type of mowing machine, mowing height, conditioner usage, and the frequency of cuts per year. In addition to the fertilization and grazing index, the new mowing index can easily be incorporated and used in the well-known and established LUI (land-use intensity index). Notably, we observe that increased mowing intensity often correlates with heightened fertilizer usage, and that plants and arthropods decrease with higher mowing intensity. These findings underscore the complex interplay between land use practices and biodiversity. In another study, we applied a niche-model to consider the potential impacts of the mowing intensity on meadow-dwelling species, particularly focusing on grassland arthropods. Analysing data from 2008 to 2018, encompassing 1352 species across four arthropod orders (Araneae, Coleoptera, Hemiptera and Orthoptera), we explore which species are winners or losers in response to varying mowing intensities. Our presentation aims to contribute to the broader discussion on the importance of long-term research platforms like the Biodiversity Exploratories. By developing a new index and displaying the applications, we provide valuable insights into the intricate relationships between land use, biodiversity and ecosystem services.

From microscale to landscapes: the importance of nitrifiers and soil mineral associations for N storage in grasslands under different land use intensities

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Grasslands provide important ecosystem services and are critical to preserve biodiversity, but they may be affected by nutrient management, such as nitrogen (N). Thus, the extent to which land use intensity (LUI) modulates N storage in grassland soils may result from complex abiotic-biotic interactions. On the one hand, ammonium binds to soil minerals becoming unavailable. Also, soil minerals associate with organic matter storing organic N (MAON). On the other hand, nitrifiers, which oxidize ammonia to nitrate, undergo niche differentiation at increasing LUI and may decrease fixed ammonium. However, the interaction of nitrifiers and mineral-associated N under similar or changing LUI is not well understood. We hypothesize that the positive correlation of LUI to nitrifiers' abundance and potential activity strengthens over time if LUI remains stable, while extensification moderates nitrification, shifting mineral-associated N storage from MAON to fixed ammonium in extensive grasslands. Here, we analysed time series data (2014–2023) from 150 soil grassland plots across a LUI gradient in Schorfheide, Swabian Alb, and Hainich as part of the Biodiversity Exploratories in Germany. We analysed the interaction of LUI with potential nitrification, the abundance of ammonia and nitrite oxidizers, and the contribution of MAOM-N and fixed NH_4^+. First results demonstrate that the positive correlation between potential nitrification and LUI remains stable over 9 years for shallow developed soils, whereas ammonia oxidizers and total mineral-associated N weakly correlate with LUI at individual time points. Furthermore, we reveal a negative effect of extensification on potential nitrification over time for soils rich in organic matter, where, interestingly, ammonia oxidizers positively correlate with LUI before the extensification took place. Our study highlights the importance of abiotic-biotic interactions for N storage, therefore contributing to sustainable management of grasslands.

EE5
06

IntraFlor – How do grazing, mowing, and fertilization intensities affect floral cues and rewards of common meadow plants, their pollinator interactions and pollination outcome?

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Intraspecific trait variation is the cornerstone of evolution. Floral trait variation is often a result of environmental changes, such as the increase in *Curcubita* pepo pollen grain size due to increased soil nitrogen content, pale *Brassica rapa* flowers caused by sulphur deficiency, and a decrease in flower size and nectar content of *Epilobium angustifolium* in response to drought stress. These changes increase or decrease the attractiveness of a flower towards a pollinator, hence affecting cross pollination and ultimately the reproductive outcome of a plant individual. However, local intraspecific variation in floral traits may increase the resilience of a population, as differing traits can have differing levels of attraction towards pollinators, hence increasing the chance of a species' survival in an area where pollinators get attracted to particular traits. In this study, we aim to identify variation in the floral traits of *Ranunculus acris* and *Trifolium pratense* in relation to land use intensity and management– namely, different levels of mowing, grazing, and fertilization. We sampled flowers from differently managed grasslands in the Biodiversity Exploratories and analysed the quality and quantity of nectar and pollen from plants growing on different land use intensity plots. Furthermore, we examined the impacts of intraspecific variation in floral traits – especially colour, size, and floral rewards – on pollinator visits and pollination outcomes (seed set). Our results show a significant change in floral reward traits with varying flower morphology, particularly with fertilization.

Rethinking the quantification of land use in forests

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Almost all forests in Germany have been or are used by humans, e.g. for extracting timber. Land use in forests relates to species communities and ecosystem processes, which has been the subject of intensive research in the Biodiversity Exploratories. Any quantitative measure of land use in forests should be biologically meaningful, comparable across forest types, derivable from standard inventory data, and easy to understand and interpret. In the past, two indices of forest land use (or management), the Silvicultural Management Intensity (SMI) index and the Forest Management Intensity (ForMI) index had been developed in the Biodiversity Exploratories and have been frequently used in analyses. Both indices differentiate well between managed and unmanaged stands, but are difficult to interpret in an ecological context. Thus, we here propose a further measure advancing the original ForMI by blending (i) tree species composition, (ii) tree removal, (iii) deadwood availability, and (iv) stand maturity. All four components are calculated as deviation from the expectations in a natural old-growth beech forest, which would be the prevailing forest type in the largest part of Germany in the absence of land use. The components are scaled between 0 (no use) and 1 (theoretical maximum use) and can simply be summed to a new compound index. As the components are only weakly correlated, they capture independent aspects of land use and forest management. As the new index can be easily computed from standard inventory data, is comparable across forest types, and easy to interpret, it can readily be applied in any forest beyond the Biodiversity Exploratories.

Landscape structure and composition impact forest biodiversity and ecosystem services within the Biodiversity Exploratories

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Forest fragmentation and homogenization threaten biodiversity and the many ecosystem services (ES) forests provide, e.g. wood production, recreation and carbon storage. Past research on the impact of forest fragmentation and homogenization has predominantly focused on tropical forest ecosystems, leaving a noticeable gap in comparable assessments for temperate-zone forests. Here, local-level forest attributes like mean tree diameter, canopy cover, deadwood volume, and heterogeneity are known to influence local biodiversity and associated ES, but an understanding of how landscape factors, such as surrounding habitat amount and isolation, and the levels of surrounding diversity is largely missing. Accordingly, our study examined how large-scale landscape properties and surrounding biodiversity influence local diversity and ES measured across 150 European forest plots of the Biodiversity Exploratories project. Using comprehensive long-term multi-trophic diversity and ES data measured at the plot level, alongside recently acquired data on surrounding plant diversity and tree structure, we investigate how large-scale landscape context relates to within-plot forest diversity (i.e. alpha and beta-diversity), and the influence of these features on multiple ES (e.g. wood production, edible plant, carbon storage, soil processes). We show that both biotic homogenization of forest surroundings and fragmentation affect within-plot forest diversity (i.e. alpha and beta-diversity), and that this has repercussions for different ecosystem services. Our findings highlight the importance of forest heterogeneity and connectivity in maintaining biodiversity and ES, and in considering landscape level processes in temperate forest management.

The role of tree species identity, forest management and abiotic conditions for biodiversity in deadwood and wood decomposition – synthesis of the 14-year BELongDead Experiment

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Deadwood is a key structure for biodiversity and an important stock in carbon and nutrient cycles of forests globally. In Europe, deadwood stocks are much reduced compared to natural levels due to a long history of forest use and management. Acknowledging the importance of deadwood in forest ecosystems, it has become a central goal in forest conservation and management strategies to increase deadwood amounts. To restore deadwood habitats and processes efficiently, a detailed understanding is needed how deadwood characteristics and environmental conditions affect deadwood-inhabiting communities and processes. Starting in 2009 as part of the Biodiversity-Exploratories platform, the BELongDead Experiment is one of the longest still running deadwood experiment globally. More than 1100 freshly cut logs of 13 tree species were exposed on 30 sites in 3 regions across Germany representing a gradient in forest management intensity and different soil and climate conditions. Biodiversity of insects, fungi, bacteria, archaea and other taxa have been recorded repeatedly and variables associated with decomposition processes, such as enzyme activities and mass loss, have been studied at regular intervals. In this synthesis, we summarize previous results and present new analyses showing how species numbers of insects, fungi and bacteria over the complete time series differ between tree species and between different forest management categories. Moreover, we show how wood decomposition rates differ between tree species and how they correlate to abiotic conditions and biodiversity. The generated results provide a better ecological understanding of the mechanisms that drive biodiversity in deadwood and wood decomposition processes which can help to improve deadwood restoration strategies.

EE5

O10

Tree microhabitat dynamics at the stand and tree scale

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Forests are characterized by a highly variable compositional and spatial structure being extremely important for various ecological processes and the availability of resources and habitats. In the Biodiversity Exploratories forests differ in respect to tree species composition, developmental phase, age structure, layering, patchiness, and regeneration method. The managed forests cover the entire spectrum from planted, even-aged, single-layered, monoculture stands of conifers via naturally regenerated, even-aged, single or double layered monoculture stands of broadleaves of various developmental phases to even-aged man-made mixed forests and uneven-aged beech forests. Additionally, forests dominated by European beech which have been unmanaged since some decades are studied. Dynamics of forest properties, structures and management in the Biodiversity Exploratories plots were quantified using regular inventories of old and young trees, dead wood and silvicultural interventions. While these analyses are more or less standard, the dynamics of tree microhabitats has rarely been studied to our knowledge. We surveyed tree microhabitats such as cavities, dendrothelmes, bark pockets, large dead branches, epiphytes, cracks, sap runs, or trunk rot on all experimental plots in the year 2017 and in 2024. Of the 5985 trees (DBH >20 cm) surveyed in 2017 1620 carried microhabitats, resulting in 5409 microhabitats of 60 different types in total, with single trees carrying more than 20 microhabitats of ten types. We revisited the trees in off-season 2023/24 to quantify microhabitat dynamics at the stand and tree scale. Trees already carrying microhabitats tend to accumulate further microhabitats in abundance as well as in type. However, we also found that mortality is increased when trees carry a large number of microhabitats.

Canopy openness affects decomposer communities of carrion in forests

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Decomposition of necromass is a key ecosystem process in all ecosystems. Carrion is the kind of necromass considered with the highest nutrient quality and a relatively fast decomposition process. Numerous species of diverse taxa (vertebrates, invertebrates, microbes) play a role in this process. Compared to other kinds of necromass, such as leaf litter and wood, drivers of biodiversity patterns of carrion decomposers are poorly studied. In forests, canopy cover and other characteristics associated with forest management intensity are major drivers of biodiversity and decomposition processes in general, yet, their effects on carrion decomposers and decomposition are still largely unknown. To improve our understanding of these effects, we compared decomposer communities and decomposition rates of small carrion (dead rats) between paired sites of closed forest and forest gaps along a gradient of forest management intensity within the framework of the Biodiversity Exploratories. The carrion was exposed to (i) microbes only, (ii) microbes and invertebrates and (iii) microbes, invertebrates and vertebrates. We measured the decomposition rates and identified the decomposer communities of bacteria, fungi, insects and vertebrates. For all treatments, the decomposition process was faster in gaps compared to closed forest plots. The decomposition rates were twice as high when arthropods were present. The composition of the vertebrate decomposer community varied depending on canopy cover. The same was observed for the arthropod decomposer communities but overall, twice as many arthropod individuals were counted in gaps. Our results show that canopy cover is a major driver of decomposer communities and decomposition rates of carrion and highlight the importance of invertebrates for carrion decomposition. Increasing canopy openness due to forest management and natural disturbances will thus likely alter carrions decomposer communities and nutrient cycles associated with carrion decomposition.

Changes in moth communities along land-use intensity gradients in forests and grasslands

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The abundance and diversity of insect populations are under threat driven partially by land-use change and intensification. While forest management in Central Europe is transitioning towards more sustainable practices, the legacy of past intensive management still impacts forest communities. Additionally, the abandonment of seminatural grasslands in marginal areas, coupled with intensified land use in high-production grasslands, poses an increasing threat to biodiversity and ecosystem functions. Land-use intensification has been shown to have substantial effects on plant and insect communities, especially herbivores, which play a vital role in energy and nutrient cycling within ecosystems, yet the comprehensive understanding of herbivore-plant responses in the context of changing land-use intensity remains limited. We investigated the influence of forest and grassland management on the biomass, abundance and diversity of nocturnal butterflies by surveying a total of 150 forest and 150 grassland plots with different management in three regions of Germany. In total, we captured 62607 individuals of 449 moth species (forest = 390 spp, grassland = 334), and forest sites harbored on average more biomass (+385%), individuals (+79%), species (+ 58%) and had higher diversity (+16%) than the grassland plots. Regarding management intensity in grasslands, a higher level of management, associated with mowing, grazing and fertilization, was found to positively influence the diversity of moths but not biomass or abundance. Additional variables measured at the plot level showed that higher temperature and artificial light at night increased moth diversity in both habitats. On the contrary, a higher percentage of agricultural fields in the surroundings decreased moth biomass, but only in forests. Our results indicate that human management and activities can induce shifts in species diversity differentially in various ecosystem, with management necessary to mitigate potential negative effects.

EE5
P1

The impact of forest management intensity on multidiversity of deadwood-colonizing species in Central Europe

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Anthropogenic land use is causing a decline in species diversity worldwide and subsequently impacts the execution of ecosystem processes. Forest ecosystems cover large parts of earths terrestrial surface and harbor large carbon stocks, especially as deadwood. Deadwood-colonizing species are important decomposers, they are highly divergent and closely associated to each other. However, they seem to be differently sensitive towards environmental variables and thus to forest management. Yet, we still lack generalized approaches assessing the impact of forest management over a large number of biotic groups. For this purpose, we analysed data of vascular plants, bryophytes, lichen, fungi, bacteria, archaea and nematodes sampled in 2020 on a deadwood experiment across Germany (so called 'BELongDead'). We calculated multidiversity as mean diversity of the standardized alpha diversity of each biotic group, emphasizing rare, common and dominant diversity separately. We further calculated multicommunity dissimilarities for all three abundance levels. We then tested the impact of forest management on multidiversity, multicommunity and for each biotic group separately. Forest management intensity negatively impacted multidiversity. The amount of non-native tree species negatively impacted multidiversity significantly. However, alpha diversity was positively affected by harvesting intensity for several biotic groups. Multicommunity and single group community composition was always impacted by forest management intensity and the amount of non-native tree species. Overall effects of forest management on multidiversity were small. We attribute this to the diverging response of each species group, which cancels out overall effects not allowing for general conclusions to be drawn. Nevertheless, the consistent effect of forest management on community compositions highlights the anthropogenic influence on the deadwood-inhabiting biota.

EE5
P2

Influence of land use on mammal diversity and Lyme disease risk

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Global biodiversity is undergoing significant declines, with mammals being one of the most affected taxa due to habitat loss and environmental changes. These changes in diversity can have significant implications for disease dynamics. In Germany, as in many regions, the impact of forest management on biodiversity is under scrutiny. Utilizing a combination of innovative interdisciplinary methodologies, including small-mammal camera trapping, we comprehensively monitored mammalian diversity across 25 forest sites along a land-use gradient in the Schwäbische Alb Exploratory. Additionally, we assessed the abundance of *Ixodes ricinus* ticks and the prevalence of *Borrelia* infection. Our study aimed to identify the factors influencing mammalian biodiversity and tick-borne pathogens in relation to landscape structure, forest structure and management. We show how local and landscape factors affect the relative abundance of certain mammal species and address the hypothesis that higher mammalian diversity may mitigate tick-borne *Borrelia* transmission.

Effects of different land-use intensities on seed production of grassland species

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Plant regeneration plays a crucial role for the persistence and stability of plant populations and species diversity. Grasslands are mostly dominated by perennial, herbaceous species. These species can follow different life- histories. Perennial, herbaceous species mostly reproduce by sexually produced seeds, which often is complemented by clonal reproduction. In managed grasslands, plants have to cope with different disturbances, such as the removal of aboveground biomass, either by grazing livestock or mowing. Such disturbances alter biotic interactions and may limit opportunities for regeneration. Seed limitation in grasslands with high land- use intensity could occur because of early or frequent mowing, before seeds are produced or mature enough to successfully germinate. On the other hand, additional fertilization could increase seed production, especially in grass species. To investigate the effect of land-use intensity on the seed production of grassland species, we studied seed in the land- use experiment of the so-called 'Biodiversity Exploratories'. The Biodiversity Exploratories are three large-scale research areas in Germany, in which long-term biodiversity research takes place differently managed agricultural grasslands. Seed traps consisting of artificial grass patches were installed on a total of 45 grasslands with paired plots of 'normal' and experimentally manipulated land-use intensities. Seed traps remained on the plots from early spring to late summer 2023. Collected seeds were transferred to substrate for germination. After germination, seedlings were identified to species and counted. Preliminary results show a slightly higher number of seedlings emerging from seed traps installed on grassland plots with reduced land- use intensity and simultaneously additional fertilization, while species numbers did not vary dependent on land-use intensity.

Land use intensity effects on the biodiversity – ecosystem functioning relationship at the management unit scale in semi-natural grasslands

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Increasing land use intensity and the resulting homogenisation of grassland communities influence the relationship between plant diversity and the ecosystem function of aboveground biomass production. However, this biodiversity–ecosystem functioning relationship has not yet been elucidated at the spatial scale of uniform grassland management. In our study, we go beyond the plot-scale of 16 square meters and address the larger management unit scale with an area between 0.1–90 ha, using upscaled grassland vegetation data from two German regions. We aim to (i) understand direct and indirect effects of land use intensity on the spatial variability of biomass productivity mediated by species richness and its spatial variability, and to (ii) compare the strength of the biodiversity – ecosystem functioning relationship between the plot and the management unit scale. Statistical analyses were conducted based on prediction maps for plant species richness and biomass, upscaled with Sentinel-2 satellite images, as well as on upscaled land use intensity and spectral dissimilarity (Rao's Q) as a proxy for environmental heterogeneity. Our results showed that the spatial variability of richness, rather than the averaged richness within management units, buffers the effect of land use intensity on the spatial variability of biomass production. This highlights the importance of considering richness through space as biological insurance. Moreover, we found that the relationship between richness and the spatial variability of biomass production was stronger at the scale of management units compared to the smaller plot scale. Our study reveals new insights into land use intensity effects on the biodiversity–ecosystem functioning relationship at the spatial scale of farmer's management interventions. We deliver evidence that overcoming spatial mismatches is needed to better understand ecological processes in complex social-ecological systems, such as semi-natural grasslands.

Beyond — Learning from the Biodiversity Exploratories to make predictions beyond them

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The understanding and monitoring of spatio-temporal dynamics in biodiversity and ecosystem functioning at the landscape scale is a major challenge in ecological research. The Biodiversity Exploratories Project makes a significant contribution to this by intensively studying biodiversity patterns and ecological processes on field survey plots in three regions in Germany since 2006. However, for a landscape-scale understanding, spatial predictions of relevant biodiversity indicators are required. For this, machine learning offers great opportunities for predictive mapping, due to the ability to model non-linear and complex relationships between drivers and biodiversity indicators. However, recent research indicates considerable challenges when trained models are applied to make predictions beyond intensively studied areas. Further, complex machine learning models provide little insights into drivers and processes, hence initially do not support a mechanistic understanding of biodiversity patterns. The BEyond projects aims to overcome these challenges. With a focus on grasslands, we aim at learning from the Biodiversity Exploratories to make spatio-temporal predictions of biodiversity and ecosystem functioning variables on a landscape scale – beyond the experimental plots. We further aim at going beyond predictions and explore what models have learned and why local predictions were made. Here, we present predictions of grassland plant diversity patterns in the landscape Swabian Alb and their explanation. We further present the contributions of the drivers like terrain, soil, climate, land use and landscape structure to the predictions to contribute to a more mechanistic understanding of biodiversity and ecosystem functioning patterns. Preliminary results show moderate model performance (R^2 of ca. 0.3) when validated with 50 independent plots randomly distributed over the entire Swabian Alb. Land Use Intensity and soil variables were among the main drivers identified via explainable AI.

EE5
P6

ExploreNiche: using the oxygen stable isotopes approach to determine belowground niche partitioning in grasslands

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The 'ExploreNiche' project investigates the complex dynamics of belowground niche partitioning across various land-use gradients, aiming to illuminate the fundamental principles sustaining biodiversity and ecosystem productivity in temperate grasslands. This initiative seeks to fill critical knowledge gaps in our understanding of species coexistence, highlighting the essential role of belowground niche differentiation in promoting ecosystem resilience and integrity under varied land management strategies. Employing non-destructive methodologies such as the oxygen stable isotope analysis approach, this research enables the determination of plant species' water uptake depths from the soil. By analysing the stable isotope composition of oxygen (δ18O) in the plant's root crown xylem water and correlating these isotopic signatures with those in soil water across a range of soil depths up to a maximum of 50 cm, the research can infer the depth of water uptake by different species within grassland ecosystems and their water uptake overlaps. This comparison facilitates the identification of distinct patterns of resource use, providing detailed insights into how different plant species partition water resources spatially. The technique serves as a powerful tool for elucidating the belowground ecological niches of plants, significantly enhancing our understanding of species coexistence and ecosystem functioning. Conducted over 75 plots in three distinct regions in Germany within the Biodiversity Exploratories, the water uptake of targeted grassland species has been measured using this approach. Subsequently, the results from the hydrological niche partitioning will be integrated with an overall land use intensity dataset, such as mowing, fertilization, grazing, and leveraging extensive existing datasets on biotic/abiotic factors, species temporal richness to understand the dynamics of species diversity under varying conditions of resource availability, stress, and disturbance in grassland ecosystems.

Exploring the impact of soil silicon and calcium on plant functional types and community composition

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Grassland ecosystems, vital for biodiversity and ecosystem functioning, have garnered significant attention in recent decades, with contributions from initiatives like the Biodiversity Exploratories. Composition of plant functional types (PFTs), such as legumes, forbs, and grasses, strongly influences nutrient turnover and biomass production in these ecosystems. Since mowing and herbivory strongly mediate grassland functioning, the roles of silicon (Si) and calcium (Ca) in these systems have gained attention.Si and Ca act as defensive compounds against herbivores and influence fodder quality. Plants accumulate Si and Ca differently, with grasses being high Si accumulators and legumes being Ca accumulators. Soil availability of Si and Ca affects plant community composition and nutrient cycling, thereby impacting ecosystem processes. To understand how soil Si and Ca filter for plant functional traits and PFTs, we first investigated these effects independently of land-use factors. We hypothesized opposing effects along Si and Ca availability gradients, where legumes may dominate under low Si and high Ca, and grasses under high Si and low Ca availability. We discuss the observed patterns and their implications for the role of soil Si and Ca in shaping grassland communities. Methods involved measuring soil Si and Ca on a plot level, along with vegetation data analysis from each plot. Soil analyses utilized the Mehlich III method, followed by inductively coupled plasma with optical emission spectroscopy (ICP-OES). This research sets the basis for mechanistically disentangling the circular effects between land-use, soil, and plant Si and Ca, shedding light on their roles in mediating ecosystem processes in managed grasslands within the Biodiversity Exploratories.

Species interactions play a weak destabilizing role in biodiversity experiments: An integrated methodological framework for variability

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The performance of biodiversity in terms of temporal stability could simply benefit from the fact that population fluctuations are not perfectly synchronized among species. Thus, the idea that diversity can enhance the temporal stability of communities has gained general acceptance. However, apart from the differences in species' environmental responses, the degree of species asynchrony could also be affected by species interactions. Despite being recognized as one of the driving forces behind community assembly, the mediation of species interactions on the stabilizing effect of diversity is often blurred in empirical studies. We developed a methodological stability framework aimed at quantifying the relative stabilizing contributions of species' environmental responses and species interaction effects. Our stability framework also partitions species interaction effects into the average effect on all species, such as whether competitive interactions decrease synchrony among all species, and the selection effect for certain species, such as whether stable species come to dominate the community. We conducted an empirical analysis using grassland biodiversity experiments conducted across North America and Europe. Results reveal that the net interaction-dependent effects on community variability are weakly positive and distributed around zero. Species interactions did increase the average population variability while generally decreasing synchrony among species; moreover, the magnitudes of these two effects both increased with species richness. The selection effect accounted for less of the community variability. Our methodological framework not only provides an approach to quantify the relative contributions of interspecific interactions and the interaction-independent responses of species to the environment but also sheds light on a fundamental reason underlying the generally observed positive correlation between diversity and stability in empirical studies.

Community benefits – publicly available data and the options to request it

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In the DFG infrastructure priority program 'Biodiversity Exploratories' (BE), researchers from various institutions and different disciplines are investigating the effects of land use intensity in Germany. On the same grassland and forest plots, they are investigating common questions of biodiversity and the influence of land use. Since the start of the BE in 2006, projects have created a huge amount of diverse data reflecting the large number of scientific domains involved in biodiversity research. In the spirit of open science, the data from the BE are publicly available on the BExIS website after an embargo period has expired. This embargo period is set out in a data policy, which has been constantly developed over the years. For example, the standard time for the embargo has become shorter over time and has been entirely removed for the core projects. By now (as of early May 2024), more than 1800 datasets have been created, of which more than 1400 are publicly available under open licenses. That is more than 75% of the datasets in BExIS. On our poster, we show what data is publicly available, how to find it and which different possibilities there are to get this data. With this, we hope to foster the usage of this valuable data by the community beyond the Exploratories.

Beta diversity and beta ecosystem functioning: Landscape homogenization, new indices and the potential for beta BEF research

Short title: Beta diversity and beta ecosystem functioning

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Landscape homogenization is a major threat to both biodiversity and ecosystem functioning, especially affecting the turnover of species composition and provided ecosystem functions between local patches. In order to adequately predict biodiversity and ecosystem functioning of landscapes, it is essential to take the beta level into account. Recent developments in biodiversity indices offer new opportunities to decompose taxonomic, functional and phylogenetic gamma biodiversity into alpha and beta components. Analogously, beta ecosystem multifunctionality can be calculated. This represents novel possibilities for research on biodiversity and ecosystem functioning (BEF) on the beta level. With this session, we want to bring together the latest developments in new concepts and methodological approaches to quantify beta diversity and beta ecosystem functioning with insights from diverse ecological research on the beta level. We hope to cover a broad range of biomes, intensively used to undisturbed systems, theoretical, observational and experimental approaches, and various taxonomic groups. Our potential speakers' contributions already cover beta diversity research on birds, insects, seed plants, and multitrophic approaches, as well as study systems as different as tropical forests, oil palm plantations, temperate forests, and agricultural grasslands. We also want to bridge the gap to adjacent concepts like biotic homogenization, the meta community and meta food webs. Both contributions focusing on either beta diversity or beta ecosystem functioning, or contributions linking the two topics, are welcome.

EE6
01

BETA-FOR – Enhancing structural diversity in production forests – a blueprint for experimental beta diversity research in real world ecosystems

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Biodiversity-ecosystem functioning (BEF) research has provided strong evidence and positive contributions of biodiversity to ecosystem functioning, from single to multiple functions. However, most of this research has been conducted on the local alpha scale without consideration of the between patch so called beta diversity. In times of increasing homogenization of landscapes in the Anthropocene, this seems a critical knowledge gap, but both appropriate statistical tools as well as experimental field studies have been lacking until now. I will present a research platform manipulating forest landscapes to investigate the role of beta-diversity in forests together with new statistical tools to quantify BEF functions on alpha and beta-scale.

EE6
O2

Restoring structural beta-heterogeneity promotes diversity of higher trophic level taxa in a forest landscape

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It has been assumed that forest homogenization for timber production causes a loss of diversity at all trophic levels. However, there is a lack of experiments conducted at larger scales and under real-world conditions. We sampled bat and bird assemblages in eleven broadleaf forests in Germany where the structural heterogeneity within (alpha) and between forest patches (beta) was experimentally increased, and compared them to homogenous control forests. We are testing whether enhancing succession stages and deadwood types increases the gamma diversity of both taxa. Since foraging and maneuverability traits link bat and bird species to the complex 3D forest, we expect the most pronounced response in functional, followed by phylogenetic and taxonomic diversity. As many rare species are negatively affected by the biotic homogenization we anticipate the most pronounced response to rare species along the Hill numbers. The data was collected using autonomous recorders and automated species identification. A new meta-analytic approach was used for rarefaction-extrapolation curves standardized by sample coverage along the Hill numbers. The results showed higher gamma-diversity of bats in heterogeneous forests than homogeneous forests for all three diversity measures and Hill numbers. The same hypotheses will be tested for bird species. Contrary to our expectations taxonomic diversity was found to be a stronger driver than functional, and phylogenetic diversities, mainly for rare bat species. This study demonstrates, for the first time, that increasing beta-heterogeneity in forests, as is typical in natural forests, can be created in managed forests through disturbance or variable silviculture to enhance gamma-diversity of higher trophic level taxa.

Shifts in seed disperser communities in spring: The diversity of ants and gastropods, and slug-mediated seed removal in temperate forests with enhanced structural heterogeneity

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Over the past centuries, forest homogenization has emerged as a significant challenge to biodiversity and multifunctionality within forest ecosystems. One exemplary ecosystem function sensitive to forest management is seed dispersal. In spring, myrmecochorous geophytes rely on ants and gastropods for dispersal. Within the project BETA-FOR, where we used ESBC- (Enhancement of structural beta complexity) treatments to enhance the structural heterogeneity in temperate forests across eleven sites in Germany, we assessed the diversity of these invertebrate seed dispersers, along with the seed removal rate of slugs. To determine seed dispersal dynamics, we used elaiosome-bearing seeds (*Anemone nemorosa, Carex digitata*) and control seeds lacking elaiosome (*Allium ursinum, Linum* sp.) and followed the seed–slug interaction using camera traps in May/June 2023. Additionally, gastropod diversity was assessed across various habitats within plots, including deadwood, leaf litter, and pitfall-traps. The latter were also used for ant diversity assessments. Initial findings indicate that slugs preferred the seeds with elaiosome over the control seeds, but were unaffected by ESBC treatments, as evidenced by consistent seed removal rates. We found strong regional differences with the northern Steigerwald and Passau showing the highest slug activity, whereas in the Hunsrück national park, Saarland and Lübeck the interaction with the seeds was very infrequently. We identified 14 ant species, with highest diversity again in the northern Steigerwald and Passau. The diversity was higher on the gamma-level, and a positive trend was observed on the beta-level within ESBC-patches. Furthermore, we expect to find a shift in seed disperser communities in response to microclimatic variations and canopy openness. We aim to investigate whether gastropod and ant diversity fluctuates between more humid and shaded patches favoured by gastropods and drier, sun-exposed patches preferred by ants.

EE6
04

Beta complexity

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Species composition changes not only along environmental gradients but also randomly with spatial distance. While biodiversity studies have systematically described these changes as beta diversity, the question whether such turnover in species also causes changes in the community structure and functioning has received considerably less attention. We have tackled this question using data sets on meta food webs comprising multiple local food webs of the same type spread across different habitats of the same landscape. These data sets show substantial turnover in species composition but the structure of their food webs shows comparatively limited change. This result is highlighting that ecological communities have a remarkably robust energetic structure of their food webs that is maintained despite substantial changes in species identities.

EE6
05

The global human impact on ecological communities

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The world is facing an unprecedented decline of biodiversity due to anthropogenic activities. However, despite many studies and data available, the effects of global change on community composition across space (beta-diversity) in natural communities remains unclear. There is a real need for synthesis to generalize these results on a large scale. To address this, we conducted an ambitious and comprehensive meta-analysis to measure the magnitude of beta-diversity changes under anthropogenic pressure and to understand how these changes relate to different types of human activities. Summarizing the results from more than 2000 studies, our meta-analysis sheds new light on the impact of human activities on beta-diversity across ecosystems. In this presentation ye will show how beyond the change of species richness, communities shift in their composition and homogeneity across space, and how alterations in biodiversity vary in both direction and magnitude, contingent on the specific pressures, the type of organisms under scrutiny, and the scales of observation.

Environmental filtering, not dispersal history, drives global patterns of phylogenetic turnover in seed plants at deep evolutionary timescales

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Environmental filtering and dispersal history are two main processes that determine biogeographical patterns, but how their relative importance varies across evolutionary timescales is unresolved. Phylogenetic beta diversity quantifies dissimilarity in evolutionary relatedness among assemblages and might help resolve the ecological and biogeographical mechanisms structuring biodiversity. Here, we examined the effects of environmental dissimilarity and geographical distance on phylogenetic and taxonomic turnover for ca. 270,000 seed plant species globally and across evolutionary timescales. We calculated past and present dispersal barriers using paleo-geographical reconstructions and calculated geographical linear and least-cost distances, which account for the constraints associated with dispersing over water, mountains, or unsuitable climates. Environmental dissimilarity and geographical distance jointly explained most of the deviance in taxonomic (up to 86%) and phylogenetic turnover (66%). While environmental dissimilarity consistently showed strongly positive effects, the effect of geographical distance on phylogenetic turnover diminished when moving back in evolutionary time. Past physio-geographical barriers explained a comparatively low amount of the variation across all timescales, peaking slightly at intermediate timescales (20–50 Ma BP). Our results suggest that while old lineages have dispersed widely, the imprint of environmental filtering on range expansion persists, providing new insights into biogeographical and evolutionary processes underlying global biodiversity patterns.

EE6
07

Exploring the interplay of area and beta diversity in scaling the diversity-stability relationship

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Understanding how to manage biodiversity to maximize the stable provisioning of ecosystem functions and services in an era of climate change is imperative. Yet, current knowledge primarily stems from local scales, while management strategies are generally aimed at regional scales. This fundamental mismatch prevents us from effectively informing management decisions. Theory suggests that beta diversity, i.e. the variation in plant species composition among ecological communities, plays a pivotal role in scaling the diversity-temporal stability relationship from local (alpha) to regional (gamma) scales. This is because higher beta diversity may increase the spatial asynchrony of functions among local communities. That is, local communities with different plant species compositions may exhibit higher asynchronous functional responses to environmental fluctuations and thereby stabilize functions at the larger spatial scale. However, studies on how beta diversity and spatial asynchrony drive ecosystem stability have yielded mixed results. Importantly, beta diversity and spatial asynchrony determine how diversity and stability, respectively, change with area. Yet, the effect of area on the diversity-stability relationship has often been neglected. Our study aims to disentangle the contributions of beta diversity and area to spatial asynchrony and, consequently, to the stability of biomass production. We controlled and manipulated three central variables, alpha diversity, beta diversity, and area, by simulating landscapes using data collected from a biodiversity experiment. We find that as area increases, the maintenance of beta diversity becomes increasingly important for temporal stability, potentially rivalling the importance of alpha diversity. Furthermore, at low alpha diversity levels, the contribution of beta diversity to larger-scale stability becomes more important, highlighting the need for multi-scale conservation efforts to mitigate the threat to ecosystem stability.

Biodiversity at multiple spatial scales buffers ecosystem functioning against extreme climate events

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Extreme climate events, such as drought or wet events, are becoming increasingly frequent worldwide and threaten the stability of ecosystem functioning. A growing body of theoretical, experimental, and observational studies shows that biodiversity can increase the resistance of ecosystem functioning during extreme climate events, and also its resilience (i.e. the ability to recover after environmental perturbations) after climate events. However, most of the empirical evidence for this relationship comes from small scale-studies that ignore spatial biodiversity dynamics. Spatial biodiversity dynamics can be particularly important since, for example, the presence of functionally distinct species in the surrounding areas can maintain local plant diversity in the face of environmental change, through dispersal processes. Using a 14-years of plant productivity data from 150 permanent grassland plots and detailed multi-scale data on plant diversity, we examined how surrounding plant trait diversity (i.e. gamma- and beta-diversity) affects local functional composition (i.e. alpha-diversity), and the consequences of this for local ecosystem productivity resilience and resistance against extreme climate events. We show that gamma- and beta-plant trait diversity drive alpha- diversity and indirectly foster the resilience and resistance of ecosystem productivity against extreme climate events. More specifically, surrounding plant diversity promotes the resistance of ecosystem functioning to extreme climate events by enriching local level diversity. Promoting diversity, both within fields and in the surrounding landscape, can buffer the impacts of extreme climate events on livestock fodder production and food security.

EE6
09

Spatial factors influence beta-diversity patterns of invertebrate communities in water-filled tree holes more than small-scale environmental factors

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A fundamental question in ecology aims to understand which factors shape biodiversity and community composition at different spatial and temporal scales. Knowing how communities are formed and maintained is vital for managing natural resources and conserving biodiversity. We tested this question using water-filled tree holes (WHs) as a model system. WHs, ubiquitous in forests, are dynamic freshwater microcosms crucial for forest ecosystems. They serve as interconnected hubs, supporting biodiversity within and beyond forest boundaries. We investigated the relative importance of environmental and spatial factors influencing the beta diversity of invertebrate assemblages of WHs in near-pristine tropical and Mediterranean forests in Brazil, India, and France. We conducted standardized field surveys of 35 WHs in each forest during the rainy season. We assessed the physical and chemical parameters of each WH (used as small-scale environmental factors) and used Moran's eigenvector maps as spatial variables. To elucidate the importance of spatial and environmental factors for beta diversity and its components, we conducted distance-based redundancy analysis (db-RDA) and variation partitioning analysis. Our results suggest that beta diversity pattern in WH were consistent across forests. Spatial factors exerted a stronger influence on community assemblages than small-scale environmental factors, and differences in species richness dominated beta diversity. This suggests that in unstable environments like WHs, colonization and extinction dynamics are pronounced due to frequent disturbances. This should be particularly important in the Mediterranean forest with its pronounced seasonality. Preserving the integrity of WH and their interconnected ecosystems is essential for sustaining biodiversity in forests and necessitates coordinated conservation strategies at both local and regional scales.

Landscape complexity affects trap-nesting bee and wasp communities

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Landscape homogenization is known to lead to biotic homogenization and reduced resilience of ecosystems to disturbances. Conversely, increased landscape complexity promotes species persistence in agricultural landscapes. Trap nests, i.e. artificial nesting resources for cavity-nesting bees, wasps and their parasitoids, are an ideal model system to study small and well-defined communities of species from different trophic levels, from primary to quaternary consumers and with different grades of habitat and resource specialization in a standardized manner. Most studies using trap nests to date focused on single habitat types (e.g. forests or grasslands). Consequently, the extent to which different habitat types across landscape scales affect compositional turnover in trap-nesting insect communities (beta diversity) and communities at local (alpha diversity) and landscape scales (gamma diversity) remains unclear. Here, we studied trap-nest communities in 12 1-km^2 study landscapes in southwest Germany along a gradient of agricultural cover and landscape complexity. We installed 16 trap nests in each study landscape, following a grid-based design to sample all major habitat types in proportion to their area in a given landscape. Covering the full season from March to October 2022, we found >2500 occupied reeds and >10,000 brood cells. In my presentation, I will show how habitat specialization of bees and wasps affects their local diversity as well as turnover (beta-diversity) between habitat types. I will talk about how landscape complexity affects the community composition and parasitism rate of bees and wasps at different scales. In addition, I will show the role that floral resources play at a local scale over the course of the growing season. Our goal is to gain insights into the habitat requirements of these insects and how a landscape which benefits both food production and insect communities should look like.

Reconciling agriculture and biodiversity: high quality butterfly communities in Northern Italian agroecosystems

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The intensification of agriculture has often shown negative effects on local biodiversity. However, Europe has a long history of arable and livestock farming and 2/3 of the land is currently agricultural (cultivated or grazed). Thus, land sharing seems the only opportunity to guarantee biodiversity conservation as well as ecosystem services. To investigate whether agroecosystems play a role for biodiversity conservation, we used butterfly as bio-indicators of open and ecotonal habitats and providers of important ecosystem services, such as pollination. We analysed α and β diversity of butterfly communities in four agroecosystems in Piedmont (Northern Italy) from 2010 to 2019: orchards, pastures, rice fields and vineyards. We found that butterfly species richness was higher in pastures and vineyards, followed by rice fields and orchards. Interestingly, the four agroecosystems were characterized by high β-diversity, hosting differentiated and specialized butterfly communities. Several protected species were also recorded, in particular in rice fields. This study shows that, instead of acting as a filter for butterfly species and only hosting generalist species, agroecosystems can host high quality butterfly communities, in terms of β-diversity, thus playing a crucial role as surrogates of natural habitats. This implies that agroecosystems can have an important conservation value and appropriate management should be applied to preserve local ecological communities.

EE6
P1

Mapping spatial patterns of community assembly processes across multiple taxa reveals hotspots of trait filtering

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Despite growing effort to identify the mechanisms that drive community assembly processes from regional to local species pools, the spatial dynamics underlying these mechanisms remain largely unknown. This study aims to address this gap by quantifying and mapping the spatial variation in community assembly processes for butterflies and grasshoppers across Switzerland. Our dataset consists of large species occurrence and trait datasets along with high spatial resolution land use, climate, and vegetation data. The regional species pools for each community were dynamically defined through a co-occurrence-based approach. We quantified trait filtering by comparing the observed community-weighted mean trait and functional diversity values from the local communities to a null expectation derived from random sampling of the species pool. We then used random forest algorithms to model the spatial variation in trait filtering intensity as a function of land use, climate, and vegetation. Our analysis revealed consistent spatial patterns in community assembly across taxa, with elevation, climate, and land use emerging as a key determinant of filtering intensity across various traits. We also found strong filtering effects for traits related to mobility and environmental preferences. Taken together, our findings suggest the existence of hotspots of trait filtering across multiple taxa, which likely play a crucial role in shaping local and regional biodiversity. The spatial mapping of hierarchical trait filtering provides crucial insights into biodiversity and ecosystem dynamics, facilitating informed conservation planning and advancing ecological theory and models.

Increasing intraspecific plant chemical diversity at plot and plant level affects herbivorous, predatory, and pollinating arthropod communities

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Plant chemical diversity, or chemodiversity, encompasses within-species variability in chemical composition. This diversity profoundly influences interactions within plant-arthropod communities, yet gaps remain in our understanding of how intraspecific chemodiversity at the plot level influences arthropod occurrence and abundance. Over three seasons, we investigated the effect of intraspecific chemodiversity at the plot level on the occurrence and abundance of four arthropod groups (herbivores, flower visitors, predators, and ants) using tansy (*Tanacetum vulgare* L.) as our focal species. Manipulating chemotype richness (i.e. the number of different chemotypes present) and chemotype composition in tansy plots of six plants, we hypothesized that increasing plot-level chemotype richness would increase arthropod occurrence across all groups, decrease herbivore and ant abundances, and increase flower visitor and predator abundances. We separately tested the impact of specific chemotypes on arthropod occurrence and abundance in a plot. We used linear mixed-effect and zero-inflated negative binomial models to test those effects. Herbivore abundance decreased with increased plot-level chemotype richness, whereas flower visitor abundance increased, and predatory arthropods and ants were unaffected. The effects of specific chemotypes on arthropod groups varied over time; initially, positive correlations with herbivores turned negative, whereas flower visitors consistently responded positively. Our results show that the plant chemical environment shapes insect communities profoundly and predictably across the four arthropod groups, and it does over time. Understanding these intricate interactions contributes to understanding plant-arthropod relationships in natural ecosystems.

Carabid beetle communities exhibit distinct composition along rivers

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Rivers and adjacent riparian habitats are interconnected meta-ecosystems characterised by a high biodiversity. Water levels and flow regimes change along river courses and are known to shape aquatic communities. However, the natural longitudinal changes in river characteristics, as described in the river continuum concept, can also affect riparian communities. We aimed to investigate longitudinal changes in the diversity, community structure and trait composition of riparian carabid beetles. We sampled three different river sections (upstream, midstream and downstream) at five rivers each in Rhineland-Palatinate, southwest Germany. All sampling sites were surrounded by forest and characterised by gentle bank slopes. Carabid beetles were sampled with ten pitfall traps per sampling site during two time periods in May and September 2023. Standardised hand collections were also made. A total of 93 carabid species with 2636 individuals were recorded. The number of individuals and species richness of carabid beetles was highest in the downstream river sections and lowest in the upstream sections. The community composition also differed between the river sections. While forest generalists (e.g. *Nebria brevicollis, Abax parallelipedus*) dominated in the upstream sections, typical riparian carabid beetles increasingly occurred in the midstream (e.g. *Bembidion tetracoloum* and *Bembidion elongatum*) and downstream sections (*Bembidion semipunctatum* and *Bembidion dentellum*. Changes in community composition also resulted in different trait compositions. The proportion of autumn breeders and hydrophilic species increased from upstream to downstream sections, while the community weighted mean of body size decreased. Our results show that natural changes along the river course can strongly shape the riparian community of carabid beetles.

Effect of *Tanacetum vulgare* (tansy) chemo-diversity on ant aphid mutualisms

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Plant communication with each other and other organisms in the environment is mediated by chemicals known as secondary metabolites. Recently, attention has been drawn to the consequences of chemical diversity within plants of the same species (i.e. intraspecific chemodiversity) for ecological interactions, both at the plant and plot level. Although it is well-known that plant chemical profiles affect plant colonization by herbivores such as aphids, little is known about the effect of chemodiversity on ant-aphid mutualisms. *Tanecetum vulgare* (commonly known as Tansy) exhibits high variability in the blend and individual abundances of secondary metabolites, i.e. terpenoids. We used six predefined Tansy chemotypes to establish an experiment with different levels of plot-level chemotype richness in Jena, Germany, in which insect communities have been recorded regularly since 2021. In 2023, we observed that the occurrence of the ant-tended aphid *Metopeurum fuscoviride* was negatively affected by chemotype richness, but links with ants have not yet been adequately explored. We will therefore continue to observe the frequency and abundance of ant (*Lasius niger*) visitation and nesting frequency in the different plots over the summer season of 2024 to investigate relationships with the performance of the ant-tended aphid *M. fuscoviride*. This will give better insights into the role of chemotype richness as a partial driver of the ant-aphid mutualism.

EE6
P5

Human pressure homogenises species and traits globally

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Human pressures, in particular urbanisation and agricultural expansion, profoundly affect biodiversity and alter functional trait distributions, thereby impacting ecosystem resilience. However, the extent and strength of these effects across landscapes and ecosystems remain unclear. To address this, we analyse 160 datasets, encompassing over 13,000 unique local communities and nine major taxa in both freshwater and terrestrial ecosystems worldwide. Our study demonstrates that human pressure is a primary driver of compositional changes in both species and traits, surpassing the effects of climate and spatial distances. Overall biotic differentiation is the more common process. However, biotic homogenisation is also significant, with the composition in terrestrial systems being particularly vulnerable at the trait and in freshwater systems at the species level. Notably, human pressure effects were stronger in datasets undergoing biotic homogenisation compared to those displaying biotic differentiation. Species and trait replacement occurred along the human pressure gradient at similar rates with rates being particularly high from low to intermediate pressure and levelling off sharply thereafter, except in urban datasets where species replacement increased exponentially towards high human pressure. Our findings highlight the distinct challenges facing conservation efforts in terrestrial and freshwater ecosystems and emphasize the critical importance of preserving minimally impacted habitats to uphold ecosystem resilience and multifunctionality across spatial scales.

EE6

P6

Beta diversity at boundaries higher than in patch interiors

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With varying environmental conditions at the edges of habitat patches, due to and in concert with edge effects, the community composition should differ as well. This should lead to a peak in small-scale beta diversity across boundaries between habitat patches. So far there is, however, not much research on this fundamental pattern conducted and no unifying model has been formulated. Here, we present such a conceptual model on beta diversity across boundaries, derive patterns of underlying environmental parameters and responding functional traits, and test this framework on plant diversity at crop field – dry grassland boundaries in two German landscapes. We surveyed the vegetation and sampled soil parameters along twenty transects, extending approximately 30 m into both habitats. Ecological indicator values and species functional traits were also assessed. Across the boundary, we found a peak for plant beta diversity (for the turnover component, not nestedness) and a steeper gradient than in adjacent habitat interiors for most tested environmental parameters, indicator values and plant species traits. This confirms our theoretical framework. In our study, the peak of beta diversity was due to a replacement of species (turnover), not to additional (or missing) species without replacement (nestedness). In the landscape, visible boundaries are reflecting the underlying abiotic conditions, and are reflected by the deriving species functional traits. We provide a unifying model for the small-scale pattern of beta diversity across boundaries between different habitat types here. As the peaking beta diversity at boundaries increases the species diversity at the landscape level, landscape heterogeneity should be promoted for biodiversity conservation.

Forest Ecology (FE)

Reconciling forest conservation, forest protection and forest management in the climate crisis

Short title: Forests in the climate crisis

Chairs: Rico Fischer, Nadine Bräsicke, Daniel Magnabosco Marra, Felix Storch

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Forests are essential for livelihood and provide multiple services, like climate protection, biodiversity, water availability or recreational and cultural values. In recent years, severe droughts, heat waves, insect infestations, diseases and forest fires have caused unprecedented high levels of forest damage, threatening the provision of ecosystem services. This new situation has sparked debates on how to address these challenges. The strategies range from 'take no action' and leave forests alone, to active adaptation via gene flow or assisted migration. Since the late 19th century, conservationists and forest managers have taken opposite positions in debates on forest stewardship and the current crisis may have even fostered a certain dogmatism. Forest protection, whose task it is to prevent damage through preventive or curative actions, is now struggling with the ever-increasing insect infestation and complex diseases. From this perspective, the dramatic tree mortality and consequent changes that have occurred in our forests during the last few years call for synergistic cooperation and diversity of ideas, instead of dogmatic seclusion. In our session, we aim to discuss ideas, strategies and potential solutions to strengthen the resilience of forests against climate change and associated disturbances. We provide a stage for a variety of contributions, ranging from integrated or precision pest and disease management via biological or biotechnical control measures, and all the way to fostering functional biodiversity as self-regulatory mechanisms of forest resilience. We invite contributions presenting new concepts and methods in monitoring (terrestrial and remote sensing) forest biotic damages, experimental or observational studies on the biology and ecology of host-pathogen interactions. We also encourage the introduction of new concepts for developing strategies for shaping resilient forests under ongoing climate change, in particular via forest ecosystem modelling.

FE1
01

Forests in the climate crisis – are we protecting forests from themselves?

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Over the last decade, German forests have suffered large-scale damages from climate change-induced biotic and abiotic stresses. Rising temperatures and more frequent climatic extremes, like drought and heat, make trees more susceptible to infestation by domestic and invasive diseases and insects. This can bring forests to the edge of their normal functioning, often leading to forest decline and massive tree die-off. Recently, a public and scientific debate has emerged that centers on forest management practices as one of the primary causes of forest decline. Simplified forest structure, low tree species diversity or abusive canopy reductions causing low forest resilience against climate extremes and biotic threats are the main criticisms targeted at forest managers. In turn, low-intensity silvicultural treatments, greater diversity of mainly native tree species, or increased forest structural complexity are suggested as measures to improve forest resilience. In this intentionally provocative presentation, I argue that this view, despite its indisputable appeal and valuable short-term benefits, falls short of addressing the actual problems. It even poses the risk of deviating public and scientific attention away from the most important challenge of all – defining options for long-term adaptation of forests to climate change. I underscore that current climatic conditions already cause unexpected forest damages not only in Germany, but also across the entire globe. Because the climate trend is likely to accelerate at an unprecedented rate, current forests have to undergo severe transitions in structure, composition and appearance as a natural mechanism to acclimate to new climatic conditions. Setting the focus on measures to preserve the current forest state may be prone to failure, as this acts against forest acclimation mechanisms. Embracing the need for change will open new avenues for shaping resilient forests for future generations.

FE1

02

Bark beetles in mountain forests: challenges and opportunities

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Raising temperatures in mountain regions accelerate the development of the European spruce bark beetle (*Ips typographus*), while increased drought frequency reduces tree defenses, making mountain spruce forests more susceptible to infestation. This poses risks to their protective role against natural hazards and other ecosystem functions and services. Consequently, timely planning and effective implementation of control and adaptation measures are crucial. Our research in the canton of Grisons, Switzerland, focuses on these challenges. We are exploring methods for early bark beetle damage detection in mountain spruce forests using a combination of multispectral data, field observations, pheromone traps, and real-time data on new infestations. Additionally, we are examining the impact of bark beetle disturbance and subsequent management strategies on the protective effect of these forests against natural hazards, as well as the occurrence and diversity of tree-related microhabitats. Our results show that the presence of bark beetle-killed trees reduces the protective effect against rockfall by 2% on average (range 0–24% depending on disturbance severity), mainly due to a lower energy dissipation ability of dead trees. Salvage logging further impairs this protective effect (-12% on average, range 0 to -92%). A similar pattern is observed for the protective effect against avalanches, with salvage logging reducing the protective effect by 8% (range 0–83%). Despite the reduced protective effect, disturbed areas exhibit more tree-related microhabitats, with 82 microhabitats on average per study site, compared to the 42 in undisturbed sites. Galleries, holes, and bark loss are mainly observed after disturbance. Given the likelihood of increased bark beetle disturbances in mountain forests, understanding their impacts and implementing proactive measures are crucial for the sustainable management of these forests and preserving their essential ecosystem functions and services.

FE1
03

Drought resilience and legacy of a mixed beech-spruce forest – results from a 10-year throughfall exclusion experiment

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This paper deals with the responses of mature trees to five years of experimental drought, subsequent recovery and legacy effects, focusing on the physiological and morphological acclimation processes of trees. I summarize 10 years of research of the Kranzberg Forest Roof Project (KROOF), a throughfall exclusion experiment in a mature beech-spruce forest in southern Germany. We studied 70–80-year-old trees, accessible by canopy crane, growing in either monospecific or mixed situations. The study includes about 100 trees in 12 plots of about 150 m^2 each. The trees were exposed to experimentally induced summer drought for five consecutive years by throughfall exclusion during the growing season. In the first two drought summers, when both species were not yet acclimated, the most severe negative effects of drought were present, with pre-dawn water potentials of about -2.0 MPa. Both species showed severe reductions (up to 80%) in physiological responses (e.g. leaf gas exchange, phloem transport) and growth. However, growth in mixture ameliorated drought, in particular in spruce. Significant reduction of whole-tree leaf area led to successful acclimation in the following three years, resulting in alleviation of drought stress. After five consecutive years of throughfall exclusion, drought release was initiated in early summer 2019. In general, recovery was faster for physiological than for morphological parameters. Restored canopy-rhizosphere coupling significantly supported spruce root growth, which started to recover within a few weeks. In contrast, regrowth of spruce' leaf area was much slower, resulting in long lasting legacy effects. Even four years after the drought release, legacy effects were still evident. The reduced water use of the spruce – largely due to the still reduced leaf area – made spruce less susceptible to another summer drought, with parallel positive effects on neighbouring beech trees.

FE1
04

Investigating novel disturbance interactions among 33 tree species with simulated late-frost and drought events

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The frequency and duration of early spring and summer-time drought events is expected to increase significantly in Central Europe during the coming decades. At the same time, the risk of late-spring frost events (up to mid-May) remains. The resulting novel disturbance regime will likely have a profound impact on the future of Central European forests. The greatest practical challenge facing European forestry today is deciding which tree species to plant now to ensure future forests are productive, resilient, and supporting of biodiversity, even in the face of the most severe climate change scenarios. This will prove especially difficult in Central Europe, where the depauperating effects of the Plio-Pleistocene transition and subsequent glaciations have resulted in a much smaller species pool compared to the temperate zone in North America or Southeast Asia. Within the scope of a controlled ecological experiment, we test the responses of juveniles of 33 native and non-native tree species to simulated late frost and drought events. We utilize a gradient approach, exposing trees to different combinations of frost and drought to determine both species-specific stress and mortality thresholds. Stress was quantified through leaf chlorophyll content, elementary analysis (C and N), and extraction of total phenolic content (antioxidants). Using these responses, we investigate disturbance interactions in 2300 juvenile tree individuals. Finally, we present several candidate tree species that could be suitable for forestry under a novel disturbance regime in Central Europe.

European beech in times of climate change — Insights on tree growth, wood anatomy and leaf morphology from a provenance study along a north-south gradient in Germany

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Recently, we have experienced an increase in severity, frequency and duration of droughts induced by climate change. Given that observed trends are expected to continue, understanding how trees respond to climatic variability and extreme events is essential. European beech, one of Germany's ecologically and economically most important tree species, appears to be increasingly susceptible to droughts, as illustrated by recent reports about growth decline and tree dieback. As phenotypic plasticity and genetic variation play a key role in determining how trees may respond to changing environmental conditions, research in provenance trials provides a valuable means to quantify the intra-specific variability in growth responses of beech. Insights may help in assisted migration, which refers to the artificial transfer of more resilient and drought-tolerant provenances to mitigate climate change impacts. In contrast to previous studies that focused on single provenance trials or a limited number of provenances, we here present results on climate sensitivity of tree growth, quantitative wood anatomy and leaf morphology from 24 beech provenances planted at three trial sites in Germany, covering a climatic gradient from north to south. Trial sites are part of the International Beech Provenance Trial network. Our multi-parameter approach provides unique insights into intra-specific variability in growth responses and drought tolerance of beech. Overall, trait expression was found to differ substantially between trial sites and thus to depend upon prevailing environmental conditions, whereas provenance differentiation was relatively low.

Tree species classification for monitoring ecological succession and assessing forest resilience

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Remote sensing allows capturing area-wide and spatially high-resolution forest information. Knowledge about tree species composition is particular valuable for analysing the resilience of forest types. Here, we present a tree species classification map of Germany based on Sentinel-2 satellite data from 2015—2018, showing the main tree species pine, spruce, Douglas fir, fir, larch, oak and beech and less dominant tree species maple, alder, ash, birch as well as two mixed broadleaf classes. The classification was carried out independently in three landscape regions of Germany (Northern-Lowlands, Central- and Southern-Uplands) to take into account differences in phenological developments. The overall accuracy of the map is around 84%. We aim to repeat the tree species classification with satellite data from 2023/2024. This will allow us to compare forest areas before and after the major drought year 2018. In the following years, forest areas were severely damaged or died off due to water shortages and bark beetle infestation, especially in the German low mountain regions. Will tree species from the old stand regrow or will succession establish new species? Tree species compositional changes which will continue to be monitored over the coming years are important aspects for better understanding forest dynamics and assessing forest resilience to climate change.

FE1
07

Intraspecific variation in phenology of *Fagus sylvatica* – causes and implications for forestry

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The timing of spring leaf out and autumn senescence needs to be well adapted to the climate at the particular site to ensure precise alignment with the change of the seasons. From a tree species with a large distribution range covering wide parts of Europe, we would expect substantial variation the phenological characteristic between provenances. If climate is getting warmer and winters are getting shorter, the local adaptation might not fit future climate anymore, so that the trees cannot take advantage of an early start of the growing season or a late warm autumn. In a provenance trial with young beech seedlings, we quantified the differences between spring leaf out and autumn senescence of the provenances and individuals. We further asked which climate parameters were the evolutionary drivers for those phenological characteristics. And we investigated, if there is a correlation between phenological timing and growth, assuming that early flushing and late colouring individuals would utilize the growing season better. The difference between the earliest and the latest provenance in spring leaf out was 7 days and in autumn senescence 21 days. For spring leaf out, we tested for several climate parameters and found that the longer the winter with more days between 0 and 10 °C at the place of origin, the later the trees flushed in our common garden. This climate parameter reflects nicely the often-used quantification of chilling. So, at places were typically more chilling time occurs over winter, the trees developed higher chilling requirements. But also, the lower the minimum temperature in winter at the place of origin, the earlier they leafed out in our common garden, which is less intuitive. For autumn, eastern provenances coloured their leaves earlier than western provenances if grown under the same climate. The growth of the seedlings will be evaluated in relation to their provenances and to their phenological characteristics in the presentation.

FE1
08

Exploring barriers to silvicultural adaptation for resilient forests: Insights from a European survey

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In response to droughts and other disturbances caused by climate change, forest scientists and practitioners are looking for silvicultural adaptation options that enhance resilience in their forests. Within the RESONATE project, we created a survey to assess in how far adaptation options are seen as effective and/or already applied and which barriers may hinder their implementation. Firstly, we selected the main questions and potential implementation barriers for the survey in a workshop with stakeholder representing forest managers and forest owners across Europe. Secondly, we translated the survey into the languages of the nine different case studies of the project and disseminated them systematically. We observed that implementation of adaptation options was higher for those options which were perceived to be effective. Likewise, uncertainty about the effectiveness of adaptation options emerged as a major implementation barrier. The lack of social acceptance for certain adaptation options, however, was regarded as an even more important barrier. The participating forest managers and owners expressed concerns about potential public resistance to changes in current forest management practices and thus forest characteristics. Participants did not approve of cessation of management or shorter production times as adaptation options because they saw it in conflict with their current management objectives. Economic constraints also posed a significant barrier. While regulatory restrictions and shortages of skilled workers were considered less important, a substantial number of participants still viewed them as constraints. Lastly, we found a strong interest in this topic among the participants as indicated by the many and detailed answers in open text boxes. Therefore, we suggest embracing this motivation and conduct planning processes for forest adaptation in participatory ways, where it has not happened yet.

FE1
O9

Temperature buffering capacity of deadwood in temperate forests

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Extreme temperatures can be avoided by many organisms by using thermal buffers. Forests can have complex thermal characteristics on a relatively small area: on a higher resolution, forest gaps have different temperatures compared to closed forests; and on a fine resolution, dead or alive vegetation structures can buffer both cold and hot temperatures. In our study, based on 180 study sites and 3 forest structures, we focused on the thermal buffering capacity of deadwood. We found lower ground maximum temperatures near deadwood objects compared to open areas, especially in forest gaps. This ability to buffer temperature maximums has great implications in heatwaves, especially for ground-inhabiting organisms, however the buffering capacity of forest microhabitats are rarely quantified. As weather events become more extreme, especially in summer periods, the thermal buffering of forest microhabitats grow greater in importance for many organisms. Therefore, it is important to understand the capacity of natural forest structures as climate refugia in hot periods, and use this knowledge in applied climate protection.

O10

Influence of forest structure on above- and belowground microclimate

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Intensive recent periods of drought have led to an unprecedented surge of tree mortality throughout Germany. Next to diversifying forest tree species compositions, increasing forest structural complexity is considered a strategy to increase forest resistance and resilience to extreme events. Tree cover is known to affect the local microclimate, acting as buffer against climatic extremes, compared to open-land conditions. Amongst others, this is expected to create more favourable conditions during drought event with the potential to mitigate detrimental effects. However, there remains a notable gap in our understanding regarding the impact of varying forest structures on microclimate dynamics. In this project, 40 plots were established in a managed, Scots pine-dominated forest in Brandenburg, a region considered to be one of the driest in Germany. Plot selection was based around a structural gradient, ranging from single layered pure pine (*Pinus sylvestris*) stands to multilayered mixed stands (pine with various hardwood species). Stand complexity and individual tree metrics were computed from three-dimensional forest structure data. Air temperature and humidity, as well as soil temperature and moisture are continuously measured at all plots since June 2023. In line with findings from previous studies, we expect that increased forest complexity will positively impact aboveground climate buffering. However, belowground dynamics pose a more intricate scenario, as they involve contrary processes, leading to the second aspect of our study: Does the reduction in water loss due to decreased radiation complement the increased water consumption resulting from higher tree density? Contrasting aboveground and belowground microclimate dynamics based on forest structure complexity will not only support providing recommendations for enhancing aboveground biodiversity and promoting tree survival but also shed light on conditions conducive to mycorrhizal activity and carbon cycling.

FE1
O11

Forest temperature buffering in thinned stands and forest gaps

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Microclimatic buffering by the forest canopy is essential for many forest organisms and ecosystem processes. In times of increasingly frequent heat waves and tree mortality, quantifying the extent to which temperature buffering is maintained after changes in forest structure can help predict the impact of tree mortality and silvicultural interventions on biodiversity and ecosystem functioning. In a large-scale field experiment with 234 plots (each 0.25 ha) at eleven sites in Germany, we implemented the following silvicultural treatments: evenly distributed timber removal (thinning), clustered timber removal (gap), and no intervention (control). Equal proportions of the stand basal area (30%) were removed in the thinning and gap treatments. We measured soil surface temperatures and air temperatures at 2 m height at 30-min intervals for one year and compared them with open landscape reference temperatures, using the novel slope-equilibrium approach to determine the extent of microclimatic buffering. Forest gaps experienced higher temperature maxima than both thinned and non-thinned closed canopy stands, especially during summer. Furthermore, soil surface temperatures were spatially heterogeneous and differed from air temperatures at 2 m, suggesting that microclimate measurements at typical standardized heights are not necessarily representative of the conditions to which many forest organisms are actually exposed. Our results highlight the substantial impact of spatial patterns of stem loss on post-disturbance microclimate for a given reduction in stand basal area.

FE1

O12

Assessing the impact of multi-year droughts on German forests in the context of increased tree mortality

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Forests play a crucial role in climate regulation and societal well-being. The increasing frequency of droughts poses a severe threat to forest ecosystems, impacting carbon sequestration and forest stability. In Germany, the unprecedented 2018–2020 drought resulted in extensive tree mortality and damaged wood volume. As climate models project a continuation of such droughts, understanding the impact of droughts on forests becomes imperative. However, it is unclear how forests will evolve in the future if the drought duration continues to increase. This study employs a forest model to analyse the impact of droughts across various German forest types, focusing on the duration of drought periods and their influence on forest productivity. By utilizing an individual-based forest growth model and national forest inventories, the study addresses critical knowledge gaps regarding the effects of multi-year droughts on biomass and productivity across various forest types, including monocultures and mixed forests. The simulations consider a drought-induced large increase in tree mortality caused by factors such as pest infestations and diseases across Germany. Our simulation results reveal a declining aboveground biomass and gross primary production (GPP) for all simulated drought scenarios. GPP is reduced by 46% in the 3-year drought scenario and by 58% in the 6-year drought scenario. Monocultures and even-sized forests (mostly planted and managed forests) are more sensitive to drought than mixed and uneven-sized forests. The results provide valuable insights into forest resilience and ecosystem responses to increasingly frequent and prolonged droughts, highlighting the importance of understanding the effects of drought on monocultures and mixed forests to inform future forest management strategies. Modelling the influence of biotic factors on forest dynamics in a process-based manner remains a challenge that requires future research.

FE1
O13

Dynamic forest models and decision support tools for silvicultural decision-making in Swiss mountain protection forests

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Mountain forests provide multiple ecosystem services, particularly protection from natural hazards in regions with steep topography such as the European Alps. Forests with a protective function are actively managed to ensure resistance and resilience in the face of hazards such as avalanches, rockfall, or landslides. Various decision support tools (e.g. 'Tree-App' in Switzerland) are being used to assess the need and nature of silvicultural interventions at the stand level. They typically do not consider forest dynamics explicitly. Yet, dynamic forest models (DFMs) could provide support to forest practitioners by simulating future forest dynamics under specific management and climate scenarios. Using the DFM ForClim (v.4.1), we simulated the future development of multiple protection forests over the next 50 years. We analysed two cases: a) the absence of large-scale disturbances, and b) specific disturbance scenarios at the stand level such as droughts and bark beetle infestations. For the latter, we introduced a simplified bark beetle module to simulate shifts from endemic to epidemic phases under certain climatic and stand conditions. We also considered the proportion of spruce in the stands and their diameter at breast height (DBH) to identify susceptible stands. Simulations were conducted under scenarios of no climate change, moderate climate change, and extreme climate change. We evaluated simulated changes of species composition changes over 50 and 100 years as well as for a hypothetical future potential natural vegetation with the assessment provided for these same stands using the Tree-App DSS. We found that the direction and magnitude of changes often align well between ForClim and Tree-App, while in some cases strong differences are resulting. We discuss the reasons underlying the differences, pointing at conceptual differences underlying the two approaches. Our study demonstrates the potential of DFMs as Decision Support Tool.

FE1
O14

How to adapt forests? – Exploring the role of leaf trait diversity for long-term forest biomass under new climate normals

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Climate change is projected to bring substantial changes to forests, challenging their adaptability and sparking a larger discussion on how to respond. On one end of the spectrum, close-to-nature approaches have emerged, embracing biodiversity and natural competition as solutions. On the other end, researchers and foresters consider to actively plant climate-adapted tree species, aiming that forests remain productive and resilient in the face of ongoing environmental changes. However, focusing on a narrow range of climate-adapted species, poses the risk of reducing overall plant diversity within forest ecosystems. While actively planting climate-adapted trees may offer short-term benefits in terms of maintaining forest productivity, it may also lead to long-term ecological consequences if biodiversity is not adequately considered. Here, we explore the role of functional trait diversity for long-term forest resilience in European forests using the flexible trait-based vegetation model, LPJmL-FIT. We tested a set of simulation experiments ranging from full diversity ('let nature do‘) to model setups where only best performing trees were allowed to grow ('planting best adapted monocultures‘). We evaluate forest performance on long-term forest biomass under climate change. Moreover, we delve deeper into the simulation data to unravel ecological processes explaining changes in forest biomass. Our research highlights the role of functional diversity and competition for long-term forest biomass under future climate. We challenge the notion that planting only the most productive and climate-suited trees guarantees the highest future biomass and carbon sequestration.

O15

Inventory and tree-ring based estimates from young tropical trees of five species to identify climate extremes

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The resilience of tropical forests is declining with increasing climate variability and associated droughts, but the response of tropical trees to climate and species-specific differences remain poorly understood. This limits our ability to design effective forest adaptation strategies in the tropics, which are currently often implemented as young tree plantations and secondary forests on an increasing amount of land. To evaluate whether young trees have the potential to identify growth responses to climate variability and extremes, we used annual tree diameter measurements and stem discs from 139 16-year-old trees belonging to five native species planted in the Sardinilla tree diversity experiment in Panama. Radial growth series were calculated from three methods using inventory measurements, visual stem disk analysis, and wood density measurements to compare relative growth during wet and dry extremes and calculate climate-growth correlations. Our results show that annual radial growth data derived from wood density profiles are best suited for the identification of growth reactions to climate extremes, as they could capture a common growth signal within the high intraspecific variation of young trees to seasonal climate variables. For the quantification of growth responses during extreme drought, visual derived and inventory radial growth data are still useful. Among species, the ability to identify growth patterns during extreme events may be related to differences in seasonal water use when our results are compared with previous findings on leaf abscission, sap flow, and soil exploitation patterns. Cedrela odorata, a species with a pronounced decrease in water use and cambial dormancy during the dry season, showed the strongest climate-growth relationships. Therefore, stem discs from young trees planted in tropical forest plantations may be a suitable source for dendroecological analyses.

FE1

O16

Forest recovery patterns in managed and unmanaged forests in Central Europe

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The interplay between disturbance and recovery shape our forests. It is increasingly clear that disturbances will increase in the future. But how the recovery capacity of forests responds to climatic extremes, such as the drought years of 2018–2020, remains largely unknown. A particularly important question is how specific management decisions, such as setting aside areas to foster biodiversity, influence the recovery capacity of forests post disturbance. Here, our objective was to quantify recovery rates and patterns in managed and unmanaged forests of Central Europe. Our specific aims were (i) do rate of recovery and spatial recovery patterns differ between managed and unmanaged forests? (ii) Are differences in post-disturbance forest structure (i.e. disturbance legacies) driving rates and patterns of recovery? And (iii) has recovery capacity decreased in recent years affected by global change type drought, compared to disturbances occurring in the late 20th century? To address our research questions, we used a natural experiment in Bavaria (Germany), in which we carefully selected paired unmanaged and managed forest landscapes of similar topography, forest type, and climate (in total ~ 3000 ha per stratum). Using a sequence of Canopy Height Models (2017–2023) at 1 m spatial resolution we analysed the recovery signal and quantified post-disturbance residual structure in disturbed patches, identified via a Landsat-based European forest disturbance map. We used canopy height changes to fit a physiologically founded mathematical tree growth model, allowing us to compare post-disturbance recovery across disturbances and strata. Understanding how management decisions influence the recovery capacity of our forests is crucial for safeguarding forest resilience in the face of intensifying forest disturbance regimes. Our findings contribute to important questions of post-disturbance forest management (e.g. whether active management is strengthening post-disturbance recovery) and contribute to a better understanding of the impact of climate change on the forest recovery in Central Europe.

FE1

O17

LabForest – Consequences of disturbance management and silvicultural treatments on ecosystem services

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Climate change threatens forests in Europe, causing increasing variability in forest productivity and decreasing resistance of forest ecosystems, leading to changes in ecosystem services. This calls for adaptive forest management, accounting for economic and ecological well-being. Establishing long-term advance regeneration in forests may increase resilience to calamities and lead to more stable but lower income. In addition, common practices of sanitary felling and clearing of affected stands can be combined with planting and natural regrowth. In contrast, uncleared areas might provide improved ecosystem services, enhance biodiversity and regenerate more quickly but potentially increase labour volume. As the interrelation of criteria and their impact on decision makers of different levels (forest owner to society level) are not yet sufficiently understood, these topics need to be studied across disciplines. Here, we present the novel and interdisciplinary 'LabForest' project funded by the German Ministry for Education and Research, which compares effects of different management options within a living lab in the LMU-owned forest. The central methodological component links in situ measurements, remote sensing data, process-based hydrological models, dynamic vegetation models, economic models, timber engineering data and life cycle assessment models. Main objectives are to explore the different forest management strategies under changing environmental conditions and disturbances with respect to (i) ecosystem functioning (including ecological resilience), (ii) ecosystem services, and (iii) economic resilience (along the entire value chain). In addition, a (iv) multidimensional assessment matrix for decision support for forestry practice and a (v) 'Forum Zukunft Wald' as well as an educational centre 'LaborWald' for scientific and societal outreach shall be established.

FE1

O18

Forest protection measures in Germany only marginally rely on plant protection products

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Climate change is increasing frequency and intensity of abiotic and biotic disturbances in forests, making forest protection measures very difficult. Preventative silvicultural measures (e.g. increasing forest structure) aim to reduce risks of biotic forest damage, but during acute insect infestations, integrated pest management described in the Plant Protection Act (PflSchG) allows the use of chemical plant protection products (PPP). The public and nature/environment protection agencies raise concerns about potential side effects of PPP, while the media sometimes convey the impression that applications of PPP are common practice in forest management. Here we highlight that PPP are only a minor component in the management toolbox. We present PPP usage data from 2015 to 2020, based on annual reports from state ministries, which manage 3.3 of the 11.4 million ha of forest in Germany (BWI 3, 2012). Over the assessed period, which included the severest bark beetle calamities historically reported, log pile insecticide treatments against spruce bark beetles encompassed 7% (on av.) of the total timber harvest (127 million m3). During the 5 years, 16,329 ha of forest (0.49% of area, on av. 2,722 ha/yr) have been treated with PPP. Of these, 5,337 ha (0.16%, 890 ha/yr) had been treated with insecticides, half of the area via aerial applications to avoid total forest canopy loss. Although the data presented here cover only 29% of the total forest area in Germany, more than 80% of all German forests are managed under regulations of timber certifications (1.55 million ha to FSC, Dec. 2022; 8.27 million ha to PEFC, Dec. 2023), where the use of PPP is only possible in exceptional cases. While it is impossible to avoid completely all applications of PPP in the context of integrated pest management, the reported numbers show that are limited to a few necessary applications as a last means to control epidemic spread of pest insects or complete forest loss.

FE1

O19

Regeneration gap in climate-resilient tree species

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Available forest regeneration provides the basis for future forests and is of increasing scientific interest, particularly due to global change, associated disturbances, and the need for forest conversion. Nevertheless, spatial information on the currently available forest regeneration in terms of density and tree species composition is largely missing. Furthermore, the suitability of current regeneration for future climates is under-evaluated. Here, we assess the potential to map current species distributions in the regeneration using data of small trees from the national forest inventory of Germany. We calibrate and evaluate species-specific regeneration distribution models using current environmental information on topography, soil, climate, microclimate and stand structure, and interpolate the present tree species abundance in the regeneration across Germany. In addition, we combine the currently available regeneration with the future cultivation risk of tree species using maps by the Bavarian State Institute of Forestry. Our analyses reveal that tree species with a high future cultivation risk are still common in the regeneration, which underlines the need to promote the regeneration of climate-resilient species more strongly.

FE1

O20

Exploring climate change effects on Alpine forests: a Swiss case study from the Eco2Adapt project

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The Horizon Europe project Eco2Adapt aims to foster sustainable forest management by interacting with local stakeholders, forest owners and practitioners so as to maintain the functionality of ecosystem services (ES) under climate change. The project is based on case studies (Living Labs, LLs). LLs represent a network of climate hotspots across Europe. Data from LLs is used to refine dynamic models (DMs) to evaluate socio-economic pathways over time, analyse alternative adaptation strategies in multi-risk assessments, and study interactions among various ES bundles in different contexts. The DM LandClim is spatially explicit, process-based and considers disturbances (fire, wind etc.). We will present results regarding the Swiss LL, which is situated in Grisons (Swiss Alps), having an area >1200 km^2. This LL represents the Alpine environment, featuring multiple tree species and a wide elevational range (700 to 2500 m asl). The main species are Norway spruce (*Picea abies* (L.) Karst), larch (*Larix decidua* Mill.) and Swiss stone pine (*Pinus cembra* L.), with some broadleaves at lower elevations. The forests in this LL provide multiple ES, particularly protection from natural hazards (e.g. rockfall or avalanches). Using LandClim, we will assess how different scenarios of climate changes (e.g. RCP 4.5 vs. 8.5) and different management practices affect the provision of timber and the protective function of forests in the future, to eventually identify a sustainable balance between these two ES. Management practices are derived in close connection with local stakeholders. Natural disturbances and their changing regimes are also considered in the simulations. The results will be discussed with stakeholders to support the development of management guidelines and best practices. The insights gained from this study are expected to contribute to more resilient forest management strategies ultimately enhancing the sustainability of ES provision and climate change adaptation.

FE1

O21

Modelling of natural forest development under climate change in Europe

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Strict forest reserves, where any management is prohibited, have been established since multiple decades across Europe to protect the unfolding of ecological processes, or to preserve rare ecosystem types. Yet, anthropogenic climate change may be posing a threat to these original protection goals, as it will induce or has already induced changes in tree population dynamics in these reserves. This will lead to trajectories away from the originally protected forest structures, raising questions whether the original conservation goals can still be met. The aim of our study, which is embedded in the EU project WILDCARD (wildcard-project.eu), is to address these knowledge gaps and to analyse the potential for rewilding of forest ecosystems at the European scale, including the implications for carbon storage and biodiversity conservation. For this purpose, we will make use of the large and unique forest plot network EuFoRIa (www.euforia-project.org). We will employ a model of forest dynamics to evaluate the trajectories of a multiple strict forest reserves by initializing the model with individual-tree data from the first inventories. We are simulating plot dynamics until the last inventory to assess the quality of the model projections. Then, we continue the simulation into the future (i.e. until 2200) under widely varying climate change scenarios (particularly RCP4.5 and 8.5). Here, we will provide the blueprint for this analysis, focusing on 50 strict forest reserves in Switzerland with inventories back to 1955 and a very large environmental gradient from cold-wet (near upper treeline) to warm-dry (near the dry treeline). We show that while in some reserves few changes to forest structure, composition and carbon storage are likely to occur, in others strong changes to ecological processes, particularly mortality rates, are leading to a fast turnover and strongly different future forests. We will discuss the implications for forest conservation and reserve design.

FE1

O22

Assessing climate change adaptation gaps in Germany's forests using simulation of future potential natural vegetation

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Climate change poses a challenge for European forestry, requiring the selection of tree species adapted to future conditions. Analysing this for a heterogeneous country like Germany requires considering diverse regional environmental conditions about climate, soil, and management history. A promising approach is to utilize simulation models to derive potential natural vegetation (PNV) under climate change, which can help to identify robust candidate species for silviculture. We employed the process-based forest landscape model iLand to investigate: (i) the impact of climate change on PNV species composition and carrying capacity (total attainable live biomass) across regions in Germany, and (ii) regional adaptation deficits by comparing future PNV composition with current forest composition (derived from national forest inventory data). We identified 12 representative ecoregions via cluster analysis of climate, soil, and vegetation data. For each region, we created generic landscapes (20-30k ha) reflecting regional environmental gradients. We used these landscapes to simulate PNV with iLand under historical climate and nine climate change scenarios. Changes in equilibrium species composition (i + ii) and carrying capacity (only i) were calculated relative to historical climate simulations (i) and national forest inventory data (ii). Our landscapes cover 95% of Germany's forested climate and soil space. Simulations will identify regions particularly affected by climate change, as well as those with the greatest mismatch between expected PNV and current forests. To account for regional differences in species suitability is crucial for developing climate change adaptation policies at the national level within Germany.

FE1

O23

Identifying forest refugia under climate change in the central European mountains

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Ongoing climate change is altering the geographic distributions of plant species world-wide, shifting toward colder locations at higher latitudes and higher elevations. During the last decades, a progressive decline of cold mountain habitats and their biota has been observed. In this context, refugia of forest tree species may play a fundamental role to sustain long-term population viability and avoiding regional species extinctions. Therefore, we are aiming at predicting the location of forest refugia and characterize environmental factors leading to forest refugia occurrence under future climate change scenarios in central European mountains. To achieve this, we developed our approach in 1337 ha of the Berchtesgaden National Park (Germany) by using fine-scale spatial datasets combined with the advanced individual-based forest model iLand, allowing us to simulate future vegetation dynamics. We created an index to evaluate the refugia potential and investigated predictors for forest refugia. Our results in the Berchtesgaden National Park show the Swiss stone pine persists in a consistent area of 0.07 ha out of the initial 223.9 with an average refugia potential of 0.71 with our index. In comparison, the European larch persists in an area of 1020 ha (out of 1196 ha initially) and obtained an average refugia potential of 0.54 across this area. Current vegetation composition and abiotic predictors (i.e. climate conditions, current vegetation composition, topography and soil attributes) for future forest refugia occurrence in the Central European mountainous ecosystems will provide a ground to quantify the vulnerability of forest refugia to altered disturbances (bark beetles outbreaks and windstorms) on forest refugia and critical information for improving habitats conservation efforts in central European mountains.

O24

Observations of forest functioning following climate extremes and bark beetle infestation at the Wetzstein long-term study site

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In recent years, European forests have suffered extensive damage and mortality associated with biotic disturbances triggered by climate extremes. These combined disturbances drastically affected the vitality of trees, leading to large-scale mortality and to the loss of large areas of forests that can no longer provide timber and other ecosystem services. Norway spruce [*Picea abies* (L.) H. Karst.] forests in Germany were severely damaged following the droughts starting in 2018, and subsequent bark-beetle outbreak (ca. 40% crown damage and 4.4% mortality in 2022). Implementing strategies to promote forest resilience against biotic and abiotic disturbances requires long-term data on tree vitality and population processes. Detailed measurements of tree functional parameters before and after stress provide information on the physiological plasticity of trees to extreme weather conditions and indicates critical declines of tree vitality that can lead to biotic damage and mortality. In a >70 year-old spruce forest in Wetzstein, Thuringia, we will assess tree vitality parameters and forest population processes before and after the droughts starting in 2018. These led to a severe bark-beetle outbreak and massive tree mortality. The study site has been intensively monitored for >10 years (e.g. stem growth, sap flow, gas exchange, precipitation, radiation, air temperature and humidity, and soil moisture) and before the onset of these recent damage and mortality. Therefore, it now offers a unique opportunity to assess changes in forest functioning. In this talk, I will provide an overview of the site, our research aims, and give a general perspective of the necessity of such long-term observational studies for better understanding forest functioning under climate change.

O25

Risks and benefits of managing non-native tree species in the European alpine space

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The global discourse on forest management has emphasized the role of human-assisted movement of tree species and populations in adapting forests to climate change. Among other adaptive management strategies, planting non-native trees (NNTs) is also being discussed. However, with concerns for invasiveness, acceptance of NNTs faces socially and ecologically complex management challenges. Moreover, lack of awareness and prevailing negative attitudes towards NNTs, coupled with policies primarily emphasizing their invasive characteristics, risk overshadowing their potential role in climate change adaptation. We analysed the perceptions of multiple stakeholders, associated with the urban landscapes and traditional forests, on the risks and benefits of NNTs and their management in the European Alpine Space. We surveyed 6 countries of the Alpine Space and received 457 responses. We found that 90% of the respondents are aware of the NNTs in their region and most believe that the NNTs pose a risk to the environment. NNTs and invasive NNTs occur mainly in urban areas with a perceived increase in occurrence in the last 25 years. There was a clear relationship between the invasiveness of NNTs and their risks and benefits on ecosystem services. Respondents, who were not concerned about the invasiveness of NNTs, recognized a positive impact of NNTs on the provisioning ecosystem services such as timber. In contrast, respondents concerned about the invasiveness of the NNTs recognized a negative impact on regulating and cultural ecosystem services such as native biodiversity and landscape aesthetics, etc. Also, approximately 50% of the respondents believed that their understanding of the management policies of NNTs is inadequate.

FE1

O26

Douglas fir (*Pseudotsuga menziesii*) in European forests: consequences for wood decomposers and wood decomposition

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Douglas fir (*Pseudotsuga menziesii*) is considered a promising tree species for wood production in central European forests, particularly as a replacement for spruce, which is declining due to climate change. However, the effects of this non-native tree species on decomposer communities and processes mediated by them, such as decomposition and nutrient recycling have not yet been sufficiently investigated. To address this research gap, we exposed branch bundles of Douglas fir, spruce, and beech in a total of 40 pure and mixed stands of these tree species across Switzerland. Biodiversity of wood decomposers was measured by rearing beetles from the branches and metabarcoding of fungi based on drill dust. Wood decomposition was measured as wood density loss over 3 years. Douglas fir branches exhibited the lowest beetle species richness and abundance. Beetle community of Douglas-fir was characterized by a mixture of generalist species from both native tree species (beech and spruce). In contrast, no significant differences in fungal diversity were found between the tree species. The fungal communities of Douglas fir and spruce branches largely overlapped. Together with comparable decomposition rates observed for the three tree species, this indicates that fungi were the main drivers of decomposition. These results were not significantly affected by stand type. While decomposition as a proxy for nutrient recycling seems to be ensured with the current proportion of Douglas fir in Swiss forests, our results suggest that Douglas fir is not a substitute habitat for spruce-associated beetle species. Replacing spruce with Douglas fir therefore seems ecologically questionable and Douglas fir should be avoided, especially in near-natural forests with a focus on conservation.

O27

Assessing multiple dimensions of resilience to compounded disturbances and related management drivers in a mixed forest landscape

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Compounded disturbances are predicted to intensify under global change, potentially resulting in scarcely predictable forest recovery dynamics, especially when interacting with legacies of past ecosystem management, such as altered stand composition and wildlife, and post-disturbance interventions. We here investigated forest resilience to a compounded ice storm event and bark beetle outbreak in a sub-montane landscape in Slovenia, characterized by a gradient in pre-disturbances species composition ranging from mixed fir-beech forest with various share of spruce to spruce monocultures, which resulted in a severity gradient ranging from undamaged areas to complete canopy removal over patches of several hectares. We assessed multiple dimensions of resilience, such as forest structural and compositional heterogeneity, disturbance legacies and their growth resilience, and post-disturbance regeneration, by collecting field data on the residual tree structure and growth of surviving canopy trees across the disturbance severity gradient, on tree regeneration in patches with complete canopy removal across multiple inventories, and regeneration inside deer exclosures to quantify the impact of ungulates browsing. Our findings provide a variety of implication for forest ecosystem managers. In particular, we highlighted the low resilience of spruce monocultures, and how the presence of spruce negatively affects the structural and compositional heterogeneity of the recovering forests, once it is removed due to disturbances. We showed that canopy trees surviving the disturbances, even with substantial damage to their crowns, can sustain levels of growth resilience comparable to undamaged trees, which questions the convenience of salvage logging practices. Finally, we emphasized and quantified the detrimental impact of ungulate browsing on post-disturbances regeneration of palatable species.

FE1

028

Resilience and vulnerability: distinct concepts to address global change in forests

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Resilience and vulnerability are not new concepts to address the recent disturbances that caused unprecedented high levels of forest damage, threatening the provision of ecosystem services. Both are important concepts to understand, anticipate, and manage global change impacts on forest ecosystems. However, they are often used confusingly and inconsistently, hampering a synthetic understanding of global change, and impeding communication with managers and policy-makers. Here, we synthesize the similarities and differences of resilience and vulnerability in forest social-ecological systems, aiming to better define their scope in improving our understanding of forest responses to global change. In particular, we address the following questions: (i) What are the commonalities and differences between resilience and vulnerability, their respective contexts, and uses? (ii) What are the particular strengths of each concept for addressing forest change? (iii) And what can we learn from past studies on resilience and vulnerability for the next generation of global change assessments in forest social-ecological systems? Resilience and vulnerability are powerful concepts with complementary strengths, having different history, methodological approach, components, and spatiotemporal focus. Resilience assessments address the temporal response to disturbance and the mechanisms driving it. Vulnerability assessments focus on spatial patterns of exposure and susceptibility, and explicitly address adaptive capacity and stakeholder preferences. We suggest applying the distinct concepts of resilience and vulnerability where they provide particular leverage and deduce a number of lessons learned to facilitate the next generation of global change assessments.

FE1

P1

The effects of deadwood on tree regeneration and microsites: a systematic review

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Forests ecosystems have become increasingly exposed to large-scale disturbances like fire, bark-beetles and windthrow. The loss of the buffering canopy exacerbates temperature extremes, which impacts tree regeneration and seedling growth. Instead of salvage-logging after disturbance, deadwood retention could provide a nature-based solution to support reforestation. With this systematic review, we summarize the role of deadwood as microsites to facilitate tree regeneration and reveal the underlying mechanisms. We performed a literature search in English in the Web of Science and Scopus databases to identify corresponding articles. After the title-abstract screening, all studies that passed the eligibility criteria were categorized into three subtopics: deadwood as a) browsing protection b) abiotic shelter and c) substrate. Then, we used the literature search tool ResarchRabbit for a subsequent backward/forward search (snowballing). After full-text screening, we used all eligible studies for a qualitative synthesis of the results. In total, 216 studies were included (n = 35 for browsing protection, n = 65 for abiotic shelter and n = 116 for substrate). Most studies were located in temperate broad-leaf, conifer and mixed forests in Europe and North America. We have identified three ways how deadwood can support tree regeneration: A large number of lying logs and fallen trees with dense branches acted as natural exclosure against ungulate browsing. Lying logs, snags and dispersed logging slash provided abiotic shelter. Deadwood lowered temperatures and increased moisture. Finally, rotten logs and stumps are a favourable germination substrate, mostly for conifers. We advocate to include deadwood retention in post-disturbance forest management to increase the resilience of tree regeneration. Future studies should investigate combined retention and the effects of dispersed slash for different forest types.

P2

Fire risks and boreal forest management

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Forests face mounting pressures from natural disturbances and human activities like fires, logging, and land-use changes. This is further exacerbated by climate change-induced phenomena such as heightened droughts and more frequent fires. In the boreal region, fires rank as a significant factor shaping forest dynamics, only surpassed by human intervention. Despite millions of hectares burning annually, our grasp of how forest management influences wildfires remains limited. Intensive forest management practices, including tree planting, thinning, and clearcutting, contribute to uniform forests in terms of species and age, often disconnected from the underlying landscape. These practices, along with landscape augmentation methods such as ditching, enhance wood production but also increase the susceptibility of spatially homogeneous forests to large fires. As wildfires are projected to become more frequent and severe in Eurasia due to climate change, comprehending fire dynamics in these forests becomes increasingly important. We use a cellular-automata model to simulate fire spread, combined with eco-physiological modelling for environmental factors such as fuel moisture. We consider fire spread through small regions (1–10 km), and focus on two management aspects, the structuring of forest stands by logging and tree planting, and the impact of ditching on fire dynamics via soil moisture. We find that stand management, and its effect on the spatial organization of the forest landscape, greatly affects fire spread, and that small stands can be used to mitigate fire risk. This behaviour interplays with other aspects of landscape management, such as augmenting the landscape to control soil moisture, and diversifying stands with different tree species. Overall we find that management practices has a substantial impact on fire risk in boreal forests, with preferable choices depending on the scale at which management choices are made.

FE1

P3

Mixed forests maintain ecosystem functions under drought

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In Germany, many economically relevant Norway spruce stands have been lost in recent years following droughts. The impact of drought is expected to increase in the future, therefore solutions to improve forest drought resistance and resilience is needed. One of them is to favour mixed over monospecific forests, as they have shown to be more productive, to provide more ecosystem services, and to be more resistant to drought. One of the most interesting mixture is the one with native European beech and non-native Douglas fir. However, there are concerns about drought resistance of Douglas fir, and about its negative effects on ecological processes, such as N leaching. The aim of this study is thus to investigate the provisioning of ecosystem functions by different forest types under the impact of drought. We hypothesized that mixed forests with beech and Douglas fir maintain higher ecosystem functions under the impact of drought, compared to other forest types. To test this, we synthetize the data about diameter growth (collected with high-resolution dendrometers), soil microbial biomass and seed survival, collected from non-drought years and drought years, as proxy of forest ecosystem services: tree growth, nutrient cycling and regeneration. We compared them in different forest types: pure beech, pure Norway spruce, pure Douglas fir, mixed beech-spruce, mixed beech-Douglas fir. The drought event of summer 2022 led to an extreme reduction of soil water content in our forest plots, regardless of forest type. As a consequence, the preliminary results show that tree growth was particularly reduced, especially in pure Norway spruce stands. Similar trend for the other ecosystem services is expected. In conclusion, this study shows that under drought tree growth is negatively impacted but this effect could be mitigated in mixed forests with native beech and non-native Douglas fir, maintaining ecosystem functionality.

FE1
P4

A nationwide database on forest damage: challenges, opportunities and outlook

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Forest damage in Germany has increased in recent years. Climate change is the driving factor, which weakens forest ecosystems and favours the development of various forest pests with sometimes dramatic ecological and economic consequences. This makes it even more important to have a comprehensive picture of current forest damage in Germany. However, there is no nationwide database on forest damage that summarizes all relevant information such as extent and cause of damage. This is due to the fact that forest protection and forest damage reporting is assigned to the federal states of Germany, which limits the possibility of analysing forest damage across several federal states and Germany as a whole. The Forest Protection Institute of the Julius Kühn Institute is setting up a novel database to collect information on the extent of damage and the volume of damaged wood by various forest pests in Germany. The challenge is to harmonize the different reporting systems used by the federal states and to integrate them into a nationwide system. The potential of such a unique database is enormous, especially when combined with remote sensing, modelling and artificial intelligence. Remote sensing can provide information about forested areas, such as private forests, that are not committed to report on forest pests. Georeferenced information on forest pests can be used in combination with remote sensing and AI to explore causal relationships with the goal of semi-automatically detection. Forest modelling can also be used to simulate the future spread of pests with the aim to identify potential risk areas. This would allow an early planning and coordination of management interventions and support policy decisions related to forest protection in Germany.

Can natural dynamics increase resilience and multifunctionality of floodplain forest ecosystems?

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Floodplain forests fulfil many ecosystem functions and provide numerous socio-economic and ecological benefits that are important to mitigate biodiversity losses and climate change impacts. Thus, an extensive area along the Middle Isar between Munich and Landshut in Bavaria, Germany has been designated as a 'natural forest' to address the challenges faced by degraded forests. The interdisciplinary project A-DUR is studying the impact of such natural forests to provide recommendations for future management. The collaboration between universities (TUM, HSWT), administrative bodies (Bavarian State Institute of Forestry (LWF), Authority for Nutrition, Agriculture and Forestry (AELF), Bavarian State Forest Enterprise (BaySF)), NGOs (Bavarian Nature Conservation Society (BN)), and private companies (Green-Solutions, SCIMOND) is a key element to reach this aim and to develop practical solutions while promoting young scientists. Five sub-projects focus on C-storage, forest dynamics, species conservation, natural processes, climate impacts and the social value of peri-urban forests. Based on the results of these topics, the project will develop strategies for the revitalization and regeneration of these forests. To provide answers, the field design covers the most important site factors and gradients. It was stratified with 120 plots, based on the inventory network of BaySF. The selected forest types represent the most relevant tree species of the floodplain including near-natural stands as well as relicts of forest management. To represent the dynamics of the floodplain, the potential impact of flood events is included, while small-scale diversity is captured by a combination of substrate type and height above water table. By using a common design for all sub-projects, data sharing and a deeper understanding at different levels of focus is provided. The research is expected to render findings that are also relevant for similar forest ecosystems throughout Europe.

FE1

P6

Mountain pine health and ecological consequences in a protected forest landscape

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Mountain pine (*Pinus mugo*) is an important forest and woodland species. In Central Europe, it is a keystone species in the ecotones from forests to bogs and from forests to the alpine vegetation belt, as well as in frequently disturbed areas. In the Alps, they provide ecosystem services like carbon sequestration, protection against gravitational hazards and erosion, as well as habitat for other species. However, mountain pine health is under pressure by novel pathogens. *Lecanosticta acicola* is an invasive fungus causing brown spot needle blight, a pine tree disease that leads to premature defoliation, declining vitality, and ultimately death. Until recently, the pathogen has mainly been recorded in wetlands at lower elevations in Germany. Now it has spread to the montane and subalpine zones of the Bavarian Alps, potentially due to alleviated environmental conditions caused by climate change. In 2022, the pathogen was first detected in Berchtesgaden National Park, with potentially far-reaching consequences for the ecosystem dynamics in this protected landscape. The mountain pine is a key species in the park and accounts for 15% (1,700 ha) of its forest and woodland cover. A large-scale dieback of mountain pine could have serious consequences for the national park and for mountain ecosystems throughout the Alps. We investigate the effects of mountain pine health on ecosystem dynamics along an elevational gradient. Our foci lie on the impacts of pine health on microclimate, soil, tree regeneration, and biodiversity. We analyse microclimatic variables, soil depth, and soil contents over a gradient of mountain pine health. We experimentally investigate germination, growth, and mortality of four tree species beneath mountain pines to assess implications for forest dynamics. Our results will provide insights into the ecological role of the mountain pine and into the possible consequences of their reduced health on mountain ecosystems.

P7

Preventive measures: Limited impact of soil amendments to mitigate high mortality of replanted trees

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The intensifying effects of climate change have increased the challenges of forest restoration, particularly regarding seedling survival and drought resilience. Our project focuses on the potential of preventive technical measures to address these issues. In particular, we were investigating the potential of hydrogels and fertilizers as soil amendments to mitigate seedling mortality under realistic planting conditions. In this study we monitored the growth and survival of over 40,000 seedlings at 24 field sites from continental eastern Lower Austria to mountain forests in Carinthia. We applied different types and rates of soil amendments during planting, namely two types of hydrogels and two types of fertilizer. Our study included three widely planted species (oak, larch, spruce) in Austria, manual (rows or groups) and tractor-based planting methods, spring and autumn plantings, and bare-root and potted seedlings. Our results indicate that hydrogels and fertilizers cannot significantly improve seedling resistance to drought. While marked differences in mortality rates between bare-root and potted seedlings persist, our data suggest that 'preventive technical measures' such as soil amendments are not realistic ways to improve forest restoration outcomes under changing climate conditions.

P8

Regulating outbreaks of the European spruce bark beetle (*Ips typographus*): Economic and ecological implications for forest management

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The interplay and coupling effects of increasing biotic disturbances (i.e. windstorms, droughts), climate warming, and outbreaks of the European Spruce Bark Beetle (*Ips typographus*) are fundamentally transforming the appearance of European forests. Unprecedented amounts of Norway spruce (*Picea abies*) have been damaged in recent years. Up to now, damaged or weakened Norway spruce trees are either extracted by salvage logging or, when quantities are low, made unsuitable for breeding by manual debarking techniques. Both pest control interventions are costly and involve negative impacts on forest biodiversity. In order to quantify the economic costs, pest control efficiency and influence on the diversity of saproxylic beetle assemblages, an experiment was conducted across Germany in a variety of management situations with five mechanical bark treatments aimed at pest control. The results of the study confirm, that the traditional methods of (motor-) manual debarking are highly effective for the reduction of bark beetles. The repeated handling of logs with the harvester for bark removal and perforation, indicates efficient reduction in bark beetles, which is especially important for the treatment of large amounts of calamity wood. Similarly, motor manual bark gouging is effective and particularly suited for inaccessible terrains, like alpine protective forests. As the intensity of bark removal increases, the saproxylic biodiversity and species assemblages are compromised. Our results provide guidelines for bark beetle reduction interventions based on a variety of management and infestation scenarios to assist practitioners in forestry for small to large-scale disturbance management.

P9

Prediction of European spruce bark beetle mortality based on tree radial growth and response to past drought in mountain forests of south-eastern switzerland

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Drought and bark beetles interact in forests, potentially causing widespread mortality of trees. The processes underlying bark beetle-induced tree mortality, particularly regarding predisposing factors and memory effects of past droughts, remain poorly understood. However, understanding these processes is key to develop efficient and timely management strategies. We used tree rings to investigate *Picea abies* mortality following European spruce bark beetle infestations in spruce-dominated mountain forests in south-eastern Switzerland. Two contrasting zones were investigated: one area influenced by bark beetle disturbance, another one in a neighbouring undisturbed area. In each zone a circular plot of 12.6 m radius was established, where we recorded individual tree and forest structural characteristics and collected two increments cores at 1.3 m height from 10–12 healthy or dead trees based on the analysed zone (disturbed or undisturbed). We determined the influence of climate and competition on growth in trees that died and that were not affected by the insect attacks and examined growth resistance and resilience to past droughts to derive regression models of growth-mortality risk. Our preliminary results show that dead trees and trees in an early stage of the bark beetle infestation were larger and taller than healthy trees. We observed that in the last two decades the healthy trees recorded lower but more stable radial growth than dead trees. In addition, dead trees displayed higher radial growth resistance during the drought of 2018. Although still preliminary, our results suggest that accounting for individual tree characteristics and past growth patterns may be important for improving predictions of bark beetle-associated mortality. The present study could represent an important step for the definition of sustainable management strategies in spruce-dominated mountain forests to reduce important forest ecosystem services losses, e.g. protection and production.

P10

Global insights on insecticide use in forest systems: patterns, impacts and perspectives in a changing world

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Forest ecosystems are increasingly vulnerable as climate change and international trade bolster biotic invasions and outbreak intensity while negatively impacting tree health. In this context, insecticides have remained a staple in the integrated management of forest insects despite efforts to phased out their use. A scoping review was conducted to provide a global perspective on insecticide use patterns, impacts and alternatives in forest protection. Aerial applications of microbial insecticides are used to suppress defoliator outbreaks across North America, Europe and Asia. In the USA, systemic insecticides are an integral part of nation-wide strategies to curb the spread of invasive pests that drive the decline of keystone species such as ash and hemlock. In Southern-hemisphere exotic tree plantations, the rise of introduced pests and local herbivores adapting to non-native trees have intensified pressures on timber production, increasing reliance on insecticides. In this context, the regulation of insecticide use is an essential stake. The lists of active substances approved by governmental and certification agencies have consistently decreased over the last decades. In Africa and South America, the lack of viable alternatives for the control of root-eating beetles and leaf-cutting ants has led many certified plantations to depend on products under temporary derogation and stalled the progress of forest certification. Likewise, the limited number of registered products in the EU risks developing insecticide resistance in nurseries. Our understanding of the non-target impacts of insecticide treatments varies with the ecological value attributed to the focal system. While the side effects of aerial spraying in secondary forests are well documented, the environmental impacts of treatments in nurseries and exotic plantations remain poorly understood despite their higher potency and frequency. This lack of ecological data hinders the adoption of a more system-specific approach to regulating insecticides. Research is ongoing to find alternatives to insecticides as rapid, direct control tactics in the forest IPM toolbox. Botanical insecticides are promising but lack sufficient biosafety data for streamlined approval procedures. The rapid development of RNA interference as a basis for species-specific insecticides shows promise although significant progress in delivery technology will be required before operational implementation can be considered.

Silviculture beyond the climax phase: Adaptation strategies for a dynamic forest management in times of change

Short title: Silviculture beyond the climax phase

Chairs: Peter Annighöfer, Rupert Seidl

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The traditional forestry and silviculture are facing new challenges due to climate change, increased disturbance events such as storms, pest infestations, and wildfires, as well as changes in land use. These developments are leading to dynamics that might require moving beyond the classic concepts of single-tree selection and late successional forest stages as management references. The session 'Silviculture Beyond the Climax Phase' aims to present and discuss innovative, pragmatic, and generally new approaches and strategies aimed at strengthening the resilience and adaptability of forests and enabling sustainable management in times of change. The session can evolve around adaptive silvicultural concepts, silvicultural challenges in growing and regenerating new tree species, silvicultural concepts for early successional stages, management of a highly diversified tree species portfolio, and creating and maintaining structural diversity. All of what might be required for silviculture in the future. We invite case studies and other research, as well as practical applications and on-site experience to be shared. The session is intended as a platform for constructive dialogue on the future of forest management.

FE2

01

Promoting diverse forest landscapes: How landscape structural complexity affects forest understorey vegetation

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Forest understory vegetation plays an essential role for multiple ecosystem functions such as primary productivity, nutrient cycling and floral resource provision and has a strong impact on tree recruitment processes. Current management approaches, however, often result in structurally homogenous forests. Such structural homogenisation is expected to negatively affect the diversity of understory plant communities. Thus, novel approaches are needed to counteract floristic homogenisation in forest understories. In the BETA-FOR project, treatments to Enhance Structural Beta-Complexity (ESBC) were established in 2016, 2017 and 2018 in 11 managed, beech-dominated forests in Germany using different patch-scale manipulations of light availability and deadwood structures, thus altering resource availability and enhancing structural complexity between patches. Each of the study regions consists of an ESBC district and a managed control district. Vegetation surveys were conducted using a standardised protocol in the vegetation period of 2023. Functional traits and phylogenetic relatedness of the observed species were obtained from databases, allowing us to analyse the effects of ESBC treatments on different facets of understory diversity (taxonomic, functional, phylogenetic) at landscape scale. Here, we will present results from a meta-analysis to reveal how an enhancement of structural complexity among forest patches impacts diversity of understory vegetation, while correcting for differences in sample coverage (as a measure of sample completeness) at the different study regions. For our meta-analysis, we will use coverage-based rarefaction and extrapolation of species diversity at different Hill-Chao numbers ($q = 0$, 1 and 2) to account for differences in plant species abundance. We expect that a higher resource availability in the ESBC treatments, especially those with higher light availability, will increase understory diversity across study regions and diversity facets.

Impacts of forest management on the spatio-temporal variability of forest microclimates

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Developing climate-change adapted forest management strategies requires an in-depth understanding of forest management impacts on forest microclimates. Forest canopies buffer within-stand microclimates from weather conditions outside the forest, whereby the buffering capacity of forest canopies strongly depends on forest structure. Forest management shapes forest structures and is thereby likely affecting the spatial and temporal variability of forest microclimates. In our presentation, we will explore the spatial and temporal variability of forest microclimates based on a 11-year time-series of temperature measurements taken on 150 forest plots in three different regions of Germany. We thereby cover a large gradient of management intensity (even-aged, uneven-aged and unmanaged forests), forest structures (from low to high structural complexity), and macroclimatic conditions (from sub-atlantic to continental climates). Our results show that forest management strongly determines the spatial variability of forest microclimates, resulting in a higher stand- and landscape-level microclimate variability in managed forests compared to unmanaged forests. However, we find only weak evidence that current management practices affect the temporal variability of forest microclimates. Over the 11-year period of observations, forest microclimate anomalies did not differ between managed and unmanaged forests and were rather determined by weather anomalies than by silvicultural interventions. Our results suggest that current management approaches do not counteract the maintenance of forest microclimates, as long as management interventions remain at low to medium intensity. However, as microclimate anomalies are rather linked to weather anomalies than to forest management, climate change-related weather extremes will likely result in microclimate extremes, even within closed-canopy forests.

FE2
03

Restoration of coniferous monocultures towards mixed broad-leaved forests in Central Europe – Dynamics of stand structure, tree composition, and understorey vegetation

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Planted monocultures of even-aged coniferous tree species are abundant worldwide but increasingly damaged by abiotic and biotic stressors and disturbances. In Central Europe, a fundamental goal of forest management is thus the conversion of such stands into structurally more diverse and mixed broad-leaved forests. To describe the *status quo* of conversion and derive implications for forest management, we investigated changes in stand structure, tree composition, and understorey vegetation in the Bavarian Spessart mountains in southwest Germany. We conducted a resurvey of 108 semi-permanent plots in four different coniferous stand types of Norway spruce, Scots pine, Douglas fir, and European larch about 30 years after the initial survey. We found significant differences in stratification and cover of respective forest layers that indicated an increase in stand structural heterogeneity since the 1990s. The forest understorey shifted from typical coniferous and generalist species towards mixed broad-leaved and specialist species. While species richness of the overstorey remained constant, species diversity of the herb, shrub, and lower canopy layer increased significantly. Regenerating 'winner' tree species included late-successional broad-leaved (e.g. European beech, sessile oak), pioneer broad-leaved (e.g. silver birch, rowan), and shade-tolerant coniferous (e.g. silver fir, Douglas fir) species. Although Norway spruce was significantly reduced in the overstorey, it regenerated extensively in the understorey. We conclude that forest conversion in the Spessart mountains was overall successful in terms of diversifying forest structure and tree species. Its effects are, though, still emerging and the stands are in a transitional phase. Besides the preferred natural regeneration of target tree species, forest management may consider active measures to guide the facilitated diverse tree community of previously pure and even-aged coniferous stands towards stand maturity.

FE2
04

Drought risk spreading through admixtures of Douglas fir and silver fir with European beech

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Temperate forests face unprecedented challenges due to climate change driven growth decline, mortality, and species turnover. The summer drought events between 2018–2020 particularly affected the widely cultivated Norway spruce in Germany. The non-native Douglas fir is considered as a drought tolerant alternative to Norway spruce. Despite its high productivity levels , its introduction is debated due to potential negative impacts on native forest biodiversity. Silver fir, a native alternative, has uncertain growth projections under climate change. Both conifers are currently planted in mixture with European beech. Studies show positive relationships between tree species diversity and productivity, yet it remains uncertain whether mixed forests are in fact more resilient to frequent and severe droughts. In the Spessart region of northern Bavaria we compared resistance, recovery, and resilience of beech radial growth to the 2018/19 drought event in trees that grew in direct neighbourhood with Douglas fir or silver fir. In total 94 plots were established in mixed stands of Douglas fir/ beech (38) and silver fir/beech (31), alongside pure beech stands (25). To compare individual neighbourhoods, target trees and surrounding forest structures were recorded via mobile laser scanning. From this data, metrics relating to morphology and stand structure were extracted. Dendrochronological analyses over the past 20 years allowed for assessing the individual tree response to drought. We found all studied species responded to recent drought by a decrease in basal area increment, with Douglas fir being the most resilient, followed by beech and silver fir. Yet, the resilience of beech in conifer mixtures and pure stands did not differ significantly despite varying levels of competition. Hence there was no positive effect of admixture for drought resistance of beech, at least in mixtures with conifers. Our results rather suggest that Douglas fir is a drought resilient species in Germany.

Sustainable management of forests on poor soils and in increasingly drier and hotter climate

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International agreements aim at creating forests that are productive, resilient to climate change, and that store carbon to mitigate global warming. However, these aims are challenged by increased tree mortality rates and decreased tree growth rates in response to severe droughts and heatwaves, and ongoing soil acidification with high nitrogen deposition. Our aim is to understand and quantify effects of management-controlled tree density on forest dynamics under those conditions. We setup a forest experiment in the Netherlands covering 15 1-ha plots (five for beech, Scots pine, and Douglas fir, respectively) on poor, acidified soils, with 4 stand density treatments (control, 20% trees removed (high thinning), 80% trees removed (shelterwood) and clear-cut) in each plot. We show that forests faced ongoing soil acidification due to nitrogen deposition and legacies of sulphur deposition. In control or high thinning forests, acidification was buffered owing to nitrogen uptake by trees and nitrogen immobilization reducing base cation leaching. Moreover, effective capture of atmospheric base cations, being c. 100% higher compared to forest clearcuts, mitigated soil acidification here. In contrast, in shelterwood system and clearcut, N mobilization enforced acidification. During summer droughts and heatwaves, trees were less dehydrated at intermediate forest density, and implications for growth are still explored. Mycorrhizal communities were also modified by droughts and drastically dropped in the shelterwood system and clearcut. All these impacts were consistent — but differed quantitatively — across the species. Our results imply that continuous cover forestry fosters the most productive, resilient forests on poor soils. We still analyse data required for testing the forest model for different management and climate scenarios. The potential contribution to the development of operational tools for climate resilient forest management practices warrants further discussion.

Safeguarding reforestation efforts on former spruce plantations: Exploring forest irrigation to mitigate drought stress

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The increasing frequency of drought events poses significant challenges to reforestation efforts, particularly evident in regions with large areas of disturbance-induced forest loss like Northern Bavaria, Germany. Despite being essential for ecosystem restoration, reforestation projects face setbacks due to prolonged drought conditions exacerbated by climate change, especially on sites with south-facing, steep and unshaded slopes and shallow soils with little water holding capacity. In response, the regional government of Bavaria has allocated resources to fund irrigation initiatives aimed at enhancing reforestation success. However, the lack of practical and scientific knowledge regarding optimal irrigation strategies presents a critical gap in implementation, given historically irrigation was not a common technique in this area. In this context, optimal timing for the irrigation of saplings is a crucial aspect, to avoid excess irrigation and thus risk maladaptation of the saplings for surviving future droughts without irrigation. In a greenhouse experiment, irrigation thresholds have been determined based on ecophysiological and environmental measurements for four tree species commonly planted in our study region in Northern Bavaria. Using the tree water deficit derived from dendrometers as well as plant water potential measurements, along with environmental indicators such as soil moisture and climate parameters, we establish thresholds for irrigation scheduling. In summer 2024, these thresholds will be tested for practical use at intensively monitored pilot sites. If successful, the implementation of a threshold-based irrigation approach will help to mitigate tree water stress and boost reforestation efforts in drought-prone regions. Our findings therefore contribute to the sustainable management of forest ecosystems while offering insights into optimizing water usage for reforestation efforts.

Management as a driving factor of forest ecosystem vulnerability and resilience

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Forest managers have traditionally aimed to exert control over natural forest variation to achieve their desired targets. Nowadays, this approach is increasingly confronted with strategies that promote natural dynamics and foster ecological resilience through enhancing species diversity and structural and functional complexity. Nevertheless, our understanding of the consequences of these two strategies for ecosystem vulnerability and resilience remains incomplete. To address this gap, we developed a conceptual framework that depicts the ecological effects of broadly used management operations in temperate Europe, encompassing planting, harvesting, regeneration protection from ungulates, non-intervention, and forest pest control; and how these effects are modulated by climate change. We identified the main process chains initiated by these operations, their influence on forest structure and composition, and subsequently on forest vulnerability and resilience. To demonstrate this concept, we formulated five management narratives relevant to European temperate forests and evaluated them in a model forest landscape by using a simulation model. The tested narratives were aligned along the gradient of anthropogenic input, from an increased emphasis on biomass production to the low-intensity management promoting natural dynamics and addressing carbon and biodiversity objectives. These simulations served to examine how processes affected by management within these narratives interact and influence the forest`s sensitivity to climate change and resilience. This experiment proved that the proposed theoretical framework is applicable as a roadmap for managing forests for resilience under climate change. The framework's utility is highlighted by different non-additive interactions between management operations and environmental drivers, which can be challenging to anticipate but should be considered in management planning.

P2

Pioneering future forests: The Harz living laboratory as innovative approach for climate resilient management

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Forests play a multifaceted role by simultaneously meeting ecological, economic, and social demands. Given the current and projected challenges posed by climate change, it is of utmost importance to develop sustainable forest adaptation concepts to maintain this multifunctionality for the coming decades. To address these challenges, the Julius Kühn Institut establishes in cooperation with an array of different partners and stakeholders a forest living laboratory (FLL) in the Harz region. This spruce-dominated mid-mountain region has been severely affected by climate warming and extreme weather events in recent years that caused severe forest damage by bark beetles. The large-scale forest cover loss poses enormous challenges for economic, ecological and societal considerations, but it also provides a fantastic opportunity to develop and test innovative and alternative management practices to increase future forest resilience. The FLL Harz will be one of the first implementations that uses mechanistic digital twins as a tool for forest management strategic planning. FLLs conduct management experiments under real-world conditions and evaluate them. An essential component is the collaborative involvement of a practical network. The FLL in the Harz consists of three central components: (i) experimental plots, (ii) digital representation and modelling, and (iii) transdisciplinary research-practice network, including co-creation approaches with stakeholders. In contrast to traditional, past-oriented approaches, this project initially envisions diverse expectations for forests at the end of the century. Through modelling-driven vegetation forecasting, and assuming different climatic trajectories, we identify societally accepted silvicultural measures that are necessary for increasing forest resilience at the end of the 21st century. This backward planning methodology allows for the testing of currently non-existing forest structures and species compositions. Our goal is to develop site-specific recommendations that promote climate-resilient forests while simultaneously meeting their multifunctional requirements and societal acceptance.

P3

Linking climate and social changes for identifying adaption pathways in Alpine forests: stakeholder perspectives on Alpine Forest ecosystem-services

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Climate change (CC) is inducing rapid shifts and complex patterns of change in ecology and society in Alpine regions. Extreme warming is coupled with altering weather patterns, specifically increased incidence and severity of droughts, thus Alpine forests are experiencing increased and novel stressors. Alpine communities rely on ecosystem services (ES) supplied by Alpine forests, however under CC flow of ES may be disrupted. Understanding CC impacts alongside management response will dictate resilience of social-ecological systems (SES). Integrating the SES concept into ecosystem modelling requires collection of data on stakeholder perceptions for current ES and visions of the future (VOF) in Alpine forests. Through a series of semi-structured interviews of expert stakeholders and use of software NVivo 14 to analyse themes and connections between participants, I will identify and develop understanding of stakeholder perceptions, VOF, and thresholds for change (TFC). I will utilise stakeholder participation methods to engage different types of forest users to instigate constructive dialogue on future forest management. These outputs will be integrated into the already parameterized i-Land model for the Stubai Valley. I hope to present analysis of these stakeholder perspectives in this session, looking at two different aspects: current views and VOF. Using semi-structured interviews with expert stakeholders, I will identify preferences, attitudes, and perceptions of current ecosystem services, as well as VOF and TFC. Research questions around these aspects will be used to inform the subsequent modelling process and integrate stakeholder preferences into the landscape-scale process-based model for the Stubai Valley. Modelling process outputs will be used to identify different management strategies and preferences for construction of adaptation pathways. Ultimately, I will develop pragmatic adaptation pathways to build resilience for forest SES in the broader Alpine arc.

FE2
P4

Application of climate-smart forestry in long-term experimental plots to analyse the management effects for forest resilience and climate adaptation

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In recent years, Climate-Smart Forestry (CSF) has emerged as an innovative approach for sustainable forest management, aiming to enhance forest resilience, mitigate greenhouse gas emissions, and balance the provision of ecosystem services in the face of climate change threats. This study employs a composite Climate-Smart Index (I_{CSF}) to assess CSF in long-term experimental plots in Bavaria, characterized by Norway spruce and European beech with different silvicultural treatments (e.g. low thinning, strong thinning, no thinning) and species mixing. Using historical data and the I_{CSF} index allows us to compare these management options in terms of mitigation and adaptation over time. The study aims to answer the following questions: (i) how do different management options affect the I_{CSF} over time? and (ii) what are the impacts of the historical climatic trend on I_{CSF} for each management options? The approach includes the (i) selection, (ii) normalization, (iii) weighting, and (iv) aggregation of CSF indicators. Eight indicators were selected and assessed for each plot (i.e. carbon stock, growing stock, diameter distribution, tree species composition, slenderness coefficient, forest damage, increment and felling, and regeneration). The Analytic Hierarchy Process was employed to weigh the indicators according to the preferences of CSF-expert stakeholders at both indicators and criteria levels. The expected results include a deeper understanding of how different silvicultural approaches influence forest resilience and their capacity to adapt to climate change. This study will provide valuable insights for forest managers and policymakers, helping them to implement more effective strategies for the sustainable management of forests in the context of climate change.

P5

Understanding forest dynamics under climate change: Insights from strict forest reserves in Bavaria

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Increased frequency of drought years with alarming forest decline is challenging forestry and society in Central Europe. The longevity of forest ecosystems as well as the extent and ecological diversity of forest areas hinder the attribution of causes and effects of the decline. Foresters, forest owners, conservation organisations and public are struggling for adequate responses to the crisis. While strict forest reserves (SFR) have often been perceived in terms of biodiversity conservation, climate change calls for reconsidering their role as a reference for forest management. In Central Europe, SFRs are the only forests, where mortality of trees and stands and their effect on vegetation can be observed without interference of timber harvesting. Further, they are indispensable for deciding whether managed or natural forests exhibit higher resistance and resilience towards climate change and to what degree silvicultural adaptation measures can be replaced by self-organised forest dynamics. An integrated analysis of the development of 14 SFRs in conjunction with adjacent managed forests along a climatic gradient in Southern Germany, ranging from subalpine spruce forest to colline mixed oak woodlands promises answers to these questions. Our contribution reports on preliminary results on the reaction and dynamics of the investigated forest ecosystems, particularly the response of vegetation and tree growth to different and changing conditions.

FE2
P6

A framework to measure mountain forest resistance and resilience: Application of aerial images and field data

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With global change, natural disturbances in forests are occurring with increasing frequency and intensity, altering forest characteristics with corresponding consequences for ecosystem services. To evaluate the uncertainties resulting from rapidly changing forest growing conditions, many researchers and practitioners are attempting to use metrics for forest resistance and/or resilience as adaptive management tools. But these metrics have proven difficult to define and monitor across landscapes, particularly in mountain forest regions. Here we present a framework for identifying and analysing how different management strategies and measures can influence forest resistance and resilience against natural disturbances. The study objective is to develop a catalog of key (i) forest stand structural characteristics to evaluate resistance and (ii) metrics on the amount and structure of regeneration to evaluate resilience against disturbances such as bark beetles and windthrow in Norway spruce-dominated mountain forests. In 21 forest sites in the Swiss Alps, time series of aerial images (1954–2022) were combined with field assessments of stand and regeneration characteristics (2022–2023) to evaluate: (i) how management and/or natural disturbances affected stand development and (ii) how stand and regeneration characteristics can be improved to better mitigate risks related to future disturbances. We show how the proposed framework can help to identify management strategies and measures to achieve climate-adapted forests. Furthermore, we show how selected measures can be upscaled and integrated into forest planning – a particularly important issue given the extent of Norway spruce-dominated mountain forests currently being under risk in the context of climate change. This study is being carried out as part of the WSL-program EXTREMES, research project MountEx (2021–2025).

Development of *Abies alba* seedlings during the years 2023 and 2024 in relation to microclimatic variables

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Forests in Germany dominated by Norway spruce (*Picea abies*) are vulnerable to the effects of climate change. Therefore, the conversion of those monospecific stands into mixed species forests is crucial for the establishment of stable forest ecosystems. The direct seeding of climate-tolerant species, such as silver fir (*Abies alba*), under closed canopy forests represents a method of introducing species that do not occur in the stand at the moment in a natural-like way that is distinct from traditional planting. The IntegSaat project aims to assess the influences of abiotic factors on the success of the direct seeding of A. alba and other species in a low mountain forest in Thuringia, central Germany. Over a period of two years, seedling rates and microclimatic variables were recorded on newly seeded forest sites under the shelter of Norway spruce. The study plots reflect the heterogeneity of the area, particularly with regard to light availability. Half of the plots were left in their original state and the seed rows of the other half were enriched with deadwood. The plots were equipped with soil moisture/soil temperature loggers as well as humidity/temperature loggers. During the vegetation period, the seed development was recorded at regular intervals. In 2023, the overall success of silver fir seedling establishment was low. Following the initial seedling survey conducted during the 2024 vegetation period, it is evident that by now the germination rate is much higher. We will present the results of the comparison of the two years in terms of seedling rates and relate these to the recorded microclimatic variables, weather conditions as well as the deadwood enrichment.

FE2

P8

Management of large-scale disturbances in the past as a historical guide for future silvicultural strategies

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For centuries, forests in Germany have been characterized by intensive human use. The forest management of the past can still be seen today in the mostly uniform age and stand structures. This applies to the extensive Norway spruce forests of the low mountain ranges, which are currently under pressure due to storms, wet snow, and drought, which are exacerbated by bark beetle calamities. With the introduction of regulated forestry in the 19th century to reduce timber shortages and ensure reforestation, the continuous influence on the composition of tree species and their standardization through thinning, harvesting and artificial reforestation also began. Despite major successes in the realization of sustainable timber production, the historical records of the last 200 years show recurring large-scale disturbances, the frequency of which has increased with global change and associated weather extremes. From today's perspective, these precise records of forestry activities form an extraordinary historical fund. In addition, many of the regional meteorological measuring stations, which are still used today for the continuous recording of the climate and weather forecasts, were originally initiated, and supervised by foresters. In our 'RetroWald' project, we analyse the silvicultural management of disturbances in various model regions, e.g. in the Thuringian Forest, using archive material and specialist forestry literature of the time. A historical review illustrates the close interaction between silvicultural measures and the occurrence of climatic and anthropogenic disturbances. The individual events analysed (e.g. early years with extreme drought in 1800, 1893, 1904 and 1911) also show that the social demands on the forest in certain periods, technical progress and silvicultural knowledge had a decisive influence on the treatment of the areas. Phases of near-natural forest management have alternated with highly mechanized and schematic methods in silviculture.

Effects of deadwood management strategies on topsoil functions in disturbed spruce areas in the Harz mountains

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The impact of extreme weather events such as droughts, heat waves, storms and the associated intensification of bark beetle outbreaks in spruce forests in recent years has led to a significant loss of spruce stands in Thuringia and other regions in Germany. There are several options for the management of disturbed areas, yet the relative merits and drawbacks of each remain undetermined. The ResEt-Fi consortium established a supra-regional field trial with the objective of evaluating the impact of specific practices for deadwood management on the ecological conditions and subsequent reforestation dynamics. Briefly, a nested experimental design integrates different silvicultural strategies for dealing with disturbed areas. These include clearing, high stumps and dead wood patches, which are compared with undisturbed sites as a control. In three regions of the southern Harz Mountains the different management variants were sampled to assess the impact of reforestation strategies on topsoil functions. Of particular interest is the turnover and storage of organic matter. The soil ecological status is evaluated using various soil properties, such as carbon concentration and soil biological characteristics such as microbial carbon (Cmic) and nitrogen (Nmic). Basal respiration was quantified over a seven-day incubation period. As sampling approach, the fine subdivision of the organic floor into several sublayers and the mineral soil layers allows a soil-ecological gradient to be displayed in fine scale from the surface to the subsurface. This provides insight into the vertical distribution of these soil properties in relation to vegetation dynamics and silvicultural practices.

P10

The CARBON project: Management strategies to optimize the carbon balance of forest ecosystems in a dry region of Germany

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German forests sequester about 62 million tons of CO_2 per year, and are thus playing an important role as nature-based-solution to climate change. However, with the rapid progression of climate change, it is expected that water stress and disturbances will occur more frequently, likely depriving this sink its potential. Knowledge gaps hinder the derivation of optimal management strategies for enhancing the carbon balance of forests. We address this gap by comparing the effects of active and passive management strategies, including (i) coppice-with-standards, (ii) managed high forests and (iii) unmanaged forests, on the total *in* and *ex situ* carbon balance. We hypothesize that carbon sequestration is greatest in coppice-with-standards, followed by high forests, and unmanaged forests, while we expect the reverse order for carbon storage. We will re-inventory the forests of Bad Windsheim, a dry region in Germany, and collect soil samples to derive *in-situ* carbon sequestration and storage for each management strategy. Life cycle assessments of harvested firewood and wood products, including their substitution effects, will determine *ex-situ* carbon storage. After empirical assessments, we will use the individual-based forest landscape and disturbance model (iLand) to simulate carbon dynamics under changing climate disturbance regimes for each forest management type. By considering both the *in-situ* and *ex-situ* carbon balance for three fundamentally different management strategies, our assessments will go beyond prior research investigating the climate change mitigation function of forests. Moreover, coupling empirical research with process-based simulation modelling will enable us to derive robust management recommendations for the region to optimize the forest carbon sink in a changing world.

Understanding the impacts of climate and land Use change on tundra and northern boreal forest ecosystems

Short title: Northern ecosystems under change

Chairs: Ramona Heim, Stefan Kruse

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Tundra and boreal forest ecosystems are increasingly impacted by climate change and the growing influence of human activities. These high latitude ecosystems are tightly coupled with climate and the significant temperature increase at northern latitudes is thus expected to have strong impacts on ecosystems and ecosystem functioning. Key land use changes in these areas stem from the development of infrastructure for oil and gas extraction, forestry, or reindeer herding. Climate and land use changes in these regions can directly lead to alterations in the ecosystem structure and functioning but also to changes in disturbance regimes, which are for example increased fire activity and pest outbreaks. Far reaching consequences of climate and land use change in tundra and northern boreal forest ecosystems can therefore encompass changes in vegetation, permafrost thaw, habitat reduction, changes in animal migration patterns, and ultimately loss of biodiversity. The consequences are not limited to the local ecosystem level, but they also have social and cultural dimensions related to indigenous and local communities. In addition, global consequences are to be expected, e.g. through greenhouse gases emissions from thawing permafrost, which form global feedback loops. A better understanding of the impacts of climate and land use changes and their interaction on ecosystems is essential for precise predictions but also for conservation, and management strategies. Solid and resilient conservation and management strategies are urgently needed to ensure the stability and ecosystem functioning of tundra and northern boreal forest ecosystems. This session aims therefore to bring together the latest study results, visions, and perspectives on the topic of northern ecosystems under climate and land use change. We encourage contributions from all fields including modelling, remote sensing, experimental, survey, or conservation planning approaches.

FE3
01

Determining drivers of boreal mountain treeline ecotone responses in changing climates

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Elevational treelines may respond to climate warming with an upward shift, particularly in the rapidly changing Arctic. The expansion of forests threatens pristine alpine tundra habitats and their cold-adapted species. This threatens to reduce or eliminate these habitats, thereby reducing albedo and contributing to regional temperature increases. However, the rate of climate change may outrun a treeline advance, and the factors, constraints, and time lags involved remain unclear. To address these uncertainties, we investigate the driving forces and the constraints that influence the response of the mountain treeline. In this study, we present the extended version of LAVESI (*Larix* vegetation simulator), an individual-based and spatially explicit model, that simulates the life cycle of boreal tree taxa. In order to take into account the particularities of high-altitude treelines, the latest version of LAVESI for the first time includes precipitation in winter months allowing computation of snow processes. As part of the adaptation of LAVESI to mountain treelines, various effects of snow on treeline migration speed have been implemented in the new snow module of the model. To test and compare the influence of different factors on the migration rate of the mountain treeline, a sensitivity analysis was performed in which a number of factors were increased and decreased compared to an average reference value.

Differential sensitivity of sub-arctic peatland versus tundra heath CO_2 fluxes to drought

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Drought events are becoming more frequent and severe due to climate change, which causes lasting impacts on plant communities and ecosystem functioning. In the sub-arctic, climate is changing at a rate above the global average. Given the vast stock of soil organic carbon in these ecosystems, of which parts are expected to be released in the future, drought-induced shifts in the CO_2 balance might have important implications for climate change feedbacks. Here, we test how the two important but contrasting ecosystem types peatland and tundra heath, respond to experimental drought. Mesocosms were exposed to a full precipitation exclusion of 7 weeks resulting in a decrease of gravimetric soil water content by 71 and 59%, respectively. On average, drought reduced Gross Primary Productivity by 47 and 64% for peatland and for tundra heath respectively. Similar patterns were observed for Ecosystem Respiration (40 and 53%), and for the resulting Net Ecosystem Exchange (57 and 98%). Concomitantly with the mesocosm fluxes, leaf assimilation of the three most abundant vascular plant species per ecosystem type were suppressed by 40 to 77%. The drought led to high plant mortality: up to 54 and 73% of plant shoots died in the peatland and tundra heath respectively. Overall, tundra heath was more sensitive than peatland indicating that the feedback strength to drought differs between the two ecosystem types which is important to include in ecosystem models. Considering that tundra heath covers a large area, drought events might cause significant reductions in summertime net CO_2 uptake. This in turn would leave a gap in the yearly carbon balance of the Arctic and further push it towards a carbon source. Additionally, our findings highlight the need for climate change studies to include the most prominent ecosystem types under multiple global change drivers.

Impacts of climate change on ecosystem functions of moss and lichen communities at high latitudes

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Mosses and lichens are a key component of tundra and boreal Forest ecosystems. In some regions, they substantially contribute to carbon input into the soil through productivity, particularly in peatlands, and they have been suggested to provide a large fraction of nitrogen input in boreal forests through their associations with cyanobacteria. Moreover, mosses and lichens at high latitudes often form carpets at the soil surface that act as insulating layer, leading to a net cooling effect on the soil. They may thus be crucial for the protection of permafrost carbon under climate change. This effect not only depends on the fractional coverage of mosses and lichens, but also on their functional traits, including height, water storage capacity, and albedo. So far, both empirical studies and modelling approaches have focused on effects of current moss and lichen communities on ecosystem functions, and studies on the response of functional traits to changing environmental conditions have been limited mostly to the individual level. Hence, it is largely unclear how climate change and associated stressors, such as tree invasion in the tundra, will affect the distribution of functional traits in communities of mosses and lichens. Here, we apply a process-based numerical simulation model of mosses and lichens at large scale to estimate how the community-weighted mean values of several key traits depend on changing climatic conditions. We present first estimates of the impacts of climate change on community composition of mosses and lichens at high latitudes and the consequences for their associated ecosystem functions, focusing on soil temperature and carbon content.

Using remote sensing data in arctic tundra conservation planning

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The advancement of forests and the expansion of economic activities associated with global warming will lead to an displacement of the Arctic tundra. The impact of the expansion of the Arctic tree line, intensifying land-use changes, and economic changes on the loss of the unique tundra biodiversity and ecosystem functions have not been adequately documented. Currently, we lack a spatial, qualitative, and quantitative assessment of the current status, especially regarding the dynamics of forest expansion and the biodiversity regions of the tundra. As part of the inter-institutional project SQUEEZE, we plan to capture the current dynamics of the Arctic tree line and the biodiversity of tundra regions using circum-arctic Earth observation (EO) data with a spatial resolution finer than 50 m x 50 m. Existing operational EO products are insufficient in quality and temporal and spatial coverage for a targeted description of dynamics in the Arctic. Therefore, we will create new time series for (i) the spatio-temporal dynamics of expanding forest cover in tundra areas, (ii) the spectral characterization of functional tundra properties, and (iii) an analysis of the spatio-temporal patterns of selected aspects. In the session, we plan to present the concept of our subproject and discuss the very first, preliminary results. – The SQUEEZE project aims to systematically plan a circumpolar, sustainable, and acceptable network of tundra conservation areas. To address potential land-use conflicts and guide management decisions in nature conservation, feedback from stakeholders and rights-holders is considered. Putative protection areas are envisioned to maintain tundra biodiversity and associated ecosystem services, including permafrost protection, to withstand future warming.

Monitoring progress towards adequate and representative protection of the Arctic tundra

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The Arctic tundra is a unique and diverse ecosystem that provides key social-ecological benefits, such as permafrost protection, wildlife habitat and livelihoods for indigenous communities. However, the tundra is under immense pressure and is expected to shrink due to climate change-induced forest expansion and economic development. Protected areas play a key role in safeguarding its biodiversity and ecosystem services, but current coverage falls far short of the 30% target called for in the Convention on Biological Diversity's Strategy to 2030, known as the 30x30 target. We present a transparent and replicable method to analyse the past and current conservation status of the Arctic tundra using spatial information on the coverage and distribution of terrestrial protected areas, ecoregions, and threatened species. Our findings show that both the coverage and the number of protected areas in the Arctic tundra have increased substantially, especially after the 1970s and during the Aichi Targets period. However, the current coverage of 25% is still below the 30x30 target. The protected areas are biased towards several ecoregions, such as Wrangel Island Arctic desert and Kalaallit Nunaat High Arctic tundra, while others, like Arctic coastal tundra, are minimally covered. We further assessed the representativeness of protected areas in conserving threatened species to identify those that are under-protected. This gives a first impression of which ecoregions and threatened species warrant further consideration. Our method allows for rapid monitoring of progress in Arctic tundra protected area coverage and ecological representation towards the 30x30 target. The comprehensive assessment of protection levels in individual ecoregions and species, together with ecological targets, rightsholder views, and opportunity costs, can inform systematic conservation planning and help identify priority areas for fulfilling conservation targets in the Arctic tundra.

Trends and advances in forest ecology: Ecological patterns and processes

Short title: Patterns and processes shaping forests

Chairs: Lisa Hülsmann, Bettina Ohse, Jonas Stillhard

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Forests are one of the most important ecosystems on Earth. Characterized by the dominance of long-lived individuals, forests undergo change at relatively slow rates, presenting unique challenges and opportunities for ecological research. This session will cover ecological processes in forest ecosystems and their effects on ecological patterns at all spatial scales, including both local processes and large scale gradients. The session invites a broad range of studies dealing with issues related to forest ecology and natural forest dynamics. Possible topics are tree demographic processes, dynamics in community composition, tree species diversity, structure, equilibria and continuity in forest ecosystems, tree species characteristics, life history strategies and traits as well as tree species distributions. Studies may be based on (longitudinal) data from both unmanaged and managed forests at all spatial scales, but can also be based on simulations and dynamic forest models.

FE4

01

Creating biodiversity rich forest landscapes in Europe: What we know and what we can do

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Forest ecosystems are quite important for biodiversity. Yet, only minor parts of the European forests are protected and most of them are managed for wood production. As we are nowadays facing a biodiversity crisis, with exacerbated extinction rates due to e.g. land use and climate change, it is of utmost importance to find sustainable compromises between forest management and biodiversity conservation. Ecologists have long tried to evaluate impacts of forest management on biodiversity and suggested solutions on how to create biodiversity rich forests where management still is possible. Yet, our understanding on how forest management is affecting biodiversity is hampered by a confusing large amount of different forest management systems and inconsistent terminology. We reviewed the existing literature and now compiled an all-in-one overview of different forest management systems, their effects on forest structure and on biodiversity. In addition, we are giving an outlook how a combination of different forest management systems theoretically can be used to create heterogeneous landscapes that provide habitats for biodiversity-rich communities.

FE4

O2

Historical land use effects on biodiversity: A case study from southern Germany

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The landscapes of southern Germany (Baden-Württemberg) have been formed by centuries of human activity interacting with natural ecosystems. These interactions have shaped biodiversity and created areas rich in species of conservation interest. Historical land use, particularly the use of forests as open land, has left a lasting imprint on the composition of plant communities. Current ecological assessments often overlook these long-term effects, leaving a gap in our understanding of how historical land use still influences contemporary biodiversity. Here, we show that historical land use over the last five centuries continues to shape the current vegetation structure in southern Germany. Historical land use significantly influences the biodiversity of forests in Baden-Württemberg. We found that areas with frequent deforestation in the past have richer plant species diversity, reflecting a history of frequent land use. In contrast, areas with a less frequent history of land use maintain a more stable and less species-rich composition. Historical land use data were collected from local archives, including maps, paintings, postcards and engravings, to reconstruct the deforestation history of the study forests. An ecological survey of 100 vegetation records from forests around five historic castles in the Swabian Alb was carried out. We used non-metric multidimensional scaling (NMDS), generalized dissimilarity modelling (GDM) and cluster analysis to analyse species composition in relation to historical deforestation scenarios and environmental variables. Our results highlight the importance of considering historical land-use patterns in assessing ecological dynamics and interpreting current biodiversity.

How long does it take? – Comparing the structure of beech forest reserves and virgin beech forests using the Development Stage Index

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Former managed forests that have been left to develop naturally are often referred to as the 'virgin forests of tomorrow'. The length of time it takes until age-class forests develop structures comparable to virgin forests is largely speculative and difficult to quantify. As part of the natWald100 project, forest structure surveys were carried out in 69 beech-dominated stands (nine circular sample plots of 500 m² each) along a gradient in time since abandonment (TSA). With the help of the Development Stage Index (I_{DS}), that assigns trees to one of three development stages (initial, optimum and terminal) by size (dbh), the structure of the study stands was analysed and compared with those in Slovakian virgin beech forests. Overall, the I_{DS} draws a plausible picture of the forest structures and their development along the time axis. The investigations make it clear that beech age-class forests still differ significantly from virgin beech forests even with a high TSA and stand age. On the one hand, this is due to the long time it takes to develop elements of the terminal stage, and on the other hand, tree establishment seems impeded in the age-class forest over a long period. While virgin beech forests have balanced proportions at the stand level and a more intensive mix of the three development stages at the plot level, one or two stages usually dominate in the former managed forests. The I_{DS} proves to be a suitable and clear method for comparing forest stands in terms of their structure and for depicting the structural development. It reveals that the structure of beech age-class forests that have been set aside only approaches that of virgin beech forests very slowly. The results highlight the importance of virgin beech forests as reference areas with regard to the classification of the structural development status of forests and can contribute to assessing the effects of passive and active restoration efforts.

Community assembly history of initial decomposer insects can explain later-successional communities and deadwood decomposition

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Assembly history — the order and timing with which different species join an ecological community — plays a fundamental role in shaping community structure and ecosystem processes. We manipulated the colonization of initial deadwood decomposer insects to understand: (i) How does the assembly history affect communities of later-successional insects and microbes? (ii) What mechanism(s), particularly niche preemption and niche modification, drives community assembly? (iii) What is the consequence of differences in assembly history and subsequent community establishment on deadwood decomposition? We set up a factorial experiment with 190 mesocosms (mesh cages) in the Bavarian Forest National Park. Each mesocosm consisted of two spruce logs each where we introduced one or more species of saproxylic beetles such that we obtained a gradient of species richness (0–8 species) and functional diversity across mesocosms. We maintained the mesocosms for two growing seasons and ensured that no other insects colonized the deadwood. After that, we selected one log per mesocosm to measure microbial diversity, insect activity, mass loss, and chemical parameters. We then opened the mesocosms, allowing insects to colonize the second log for another year before we sampled insects and microbes. We found that abundance and functional groups of early-successional beetle communities in deadwood had far-reaching effects on microbes and later-successional insect communities. Fungal biomass and bacterial diversity increased with beetle species number and the abundance and diversity of beetles and spiders colonizing the deadwood at the later-successional stage (post-opening of mesocosms) were positively related to the initial species richness of beetles. Initial insect treatments and their effects on microbial communities translated into differences in wood decomposition rates. Our results highlight the importance of assembly history for insect and microbe decomposer communities and their effects on wood decomposition.

05

Elevation modifies associations between aboveground and belowground communities in forests across different climatic regions

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Associations between aboveground and belowground communities are pivotal for biodiversity conservation and the maintenance of ecosystem functioning amid global environmental changes. However, the dynamics of these associations along environmental gradients in forest ecosystems, and whether patterns are consistent across different climatic zones, remain insufficiently explored. Here, we examine how associations between alpha and beta diversity of plant and soil microbial communities change along elevational gradients in unmanaged forests and test the generality of observed patterns and conclusions by comparing elevational gradient transects from different climatic regions. Using data from 186 permanent forest plots spanning three climate zones – from subtropical Asia to temperate Europe – we assessed the linkages in species diversity and composition between plants in different forest strata (i.e. tree, shrub and herb) and soil microbes (i.e. fungi and bacteria). Further, we examined the effects of environmental factors (i.e. elevation and edaphic factors) on the strength and direction of the linkages between aboveground and belowground communities. Across landscapes, plant alpha diversity showed weak correlations with soil fungi and bacteria, but plant beta diversity (species compositional dissimilarity between plots) was significantly correlated with the beta diversity of bacterial and fungal communities. Structural equation models indicate that elevation and edaphic factors indirectly affect the composition of soil microbial communities via plant community composition. Effects of elevation on correlations between alpha diversity of plants and soil microbes were inconsistent across landscapes, but significant effects of elevation on community composition associations. Our findings indicate consistent patterns of composition association between aboveground and belowground communities across forest landscapes and were affected by elevation, highlighting the need to incorporate these associations into biodiversity conservation strategies and ecosystem management practices.

FE4

06

Do forest fires have an impact on moth communities?

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Over the last years, the number of forest fires in Germany strongly increased due to drought and heat, especially in the eastern parts of the country. While fires belong to many ecosystems world-wide, they are no natural part of any ecosystem in Central Europe. Fires in Germany therefore are increasing challenges we are facing due to climate change. Consequently, little is still known about the impact of fires on forest ecosystems in Germany. In particular, we need information on the possible management strategies to establish a healthy post-fire forest ecosystem resilient to drought and fires in the future. We are using moths as indicators to assess how communities change after a fire and how to manage the burned sites. Moths depend on plants and are important food resources for birds and bats in forest ecosystems. Furthermore, they are species-rich and taxonomically as well as ecologically well-known. On sites burned in 2018 and 2019, different post-fire forestry treatments were established to assess which of these perform best to obtain a healthy forest ecosystem more resistant to heat and drought in the future. Moths were collected by standardized automatic light interception traps at 15 different sites from March to November in the years 2021 and 2022. We analyse the impact of forest fire on moth communities. Therefore, we analyse ecological traits as well as community composition on burned and unburned sites. This presentation showcases the most important results.

Quantifying the impacts of lightning-induced tree mortality using a dynamic global vegetation model

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Lightning is an important yet often disregarded disturbance agent in forest ecosystems, with ecological impacts that are likely underestimated. Recent findings in tropical forests suggest that a single lightning strike typically results in the death of multiple trees, potentially making lightning the primary cause of mortality of large trees in this region. Lightning is also assumed to be an important cause of tree mortality at least in some coniferous forests. Given that lightning activity is expected to increase in a warmer climate, lightning-induced tree mortality may become even more important in the future. However, lightning damage and mortality are not represented in state-of-the-art dynamic global vegetation models. This could cause biases in simulated forest structure, composition, carbon storage, and ecosystem services and challenges the reliability of future projections. We will present findings from the implementation of lightning-induced tree mortality into the dynamic global vegetation model LPJ-GUESS. This implementation is driven by local lightning frequency and incorporates the dependency of lightning mortality on tree size and density derived from field observations. The model will be evaluated using data from forest sites where estimates on lightning-induced mortality exist. Simulations for the entire tropics will provide insights into the role of lightning in shaping forest ecosystems across different regions and will facilitate to assess the importance of lightning-induced tree mortality relative to other causes of mortality. Preliminary results suggest that lightning kills more than 100 million tropical trees each year and accounts for around 5% of the overall mortality of mature trees. Incorporating lightning into LPJ-GUESS will provide valuable insights to support informed decision-making concerning forest management strategies aimed at tackling climate mitigation, adaptation, and conservation targets amidst environmental change.

Exploring future disturbance scenarios for Europe's forests

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Climate change challenges forest ecosystems and amplifies forest disturbances and their wide-ranging impacts on ecosystem services, biodiversity, and carbon storage. While forest disturbances belong to the most climate-sensitive processes in forest ecosystems and are therefore expected to show a strong response to climate change, it remains unclear how different disturbance agents will be affected and how vegetation feedbacks (e.g. amplification by CO_2 fertilization) will shape disturbance regimes. Here, we used the scaling vegetation dynamics (SVD) framework to upscale forest dynamics from stand- and landscape scale simulations to the continental scale based on a deep learning approach. SVD simulates high-resolution (100 x 100m) trajectories of forest development and dynamic disturbances for Europe until the end of the 21st century. Disturbances are simulated with process-informed statistical modules that are calibrated on remote sensing-based products and interact dynamically with changing vegetation. Our simulation results show a strong increase in disturbed area until the end of the 21st century, particularly under high-emission scenarios. We found that the increase in disturbances is mainly driven by forest fires and bark beetle outbreaks. Finally, we show that Europe's forests will likely experience strong shifts in structure and demography, which in turn bear significant implications for ecosystem services and biodiversity. These insights underscore the urgency of incorporating both direct climate change effects as well as the interaction between forest development and disturbances into models that inform decision-making and management strategies for forest ecosystems in the face of climate change.

Beyond resilience: Responses to changing climate and disturbance regimes in temperate forest landscapes across the Northern Hemisphere

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Climate change has profound impacts on forest ecosystem dynamics and could lead to the emergence of novel ecosystems via changes in species composition, forest structure, and potentially a loss of tree cover. Disturbances further modify ecosystem change in two fundamental ways: First, the prevailing disturbance regime of a region determines the variability of a system and hence its basin of attraction. Second, climate-mediated changes in disturbance regimes could accelerate ecosystem transformation. We used the individual-based forest landscape and disturbance model iLand to investigate the resilience of three temperate forest landscapes on three continents – selected to represent a gradient from low to high disturbance activity – to changing climate and disturbance regimes. In scenarios of strong global warming, natural disturbances increased across all landscapes regardless of projected changes in precipitation (up to a seven-fold increase in disturbance rate over the 180-year simulation period). Landscapes with historically high disturbance activity had a higher chance of remaining resilient in the future, retaining their structure and composition within the range of variability inherent to the system. However, the risk of regime shift and forest loss due to a climate-mediated increase in disturbances was also highest in these systems. Resilience generally decreased with increasing severity of climate change. Novelty in tree species composition was more common than novelty in forest structure, especially under dry climate scenarios. Restructuring was the dominant pathway of forest reorganization close to the upper tree line across all three study systems. Our results highlight common patterns and processes of forest change, while also underlining the diverse and context-specific responses of temperate forest landscapes to climate change. We conclude that past and future disturbance regimes are crucial determinants of forest ecosystem dynamics in a changing world.

FE4

O10

Effect of climate change on the recovery capacity of *Fagus sylvatica* after a severe disturbance event along its productivity gradient in Central Europe

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Given the widespread distribution of the common beech (*Fagus sylvatica* L.) in Europe, the recent escalation in disturbance dynamics has raised questions about the capacity of beech forests to recover from severe perturbations. Understanding the resilience of forest carbon stocks across the species range and its sensitivity to climate change is crucial for enhancing the climate change mitigation potential of forest ecosystems. We examined the recovery capacity of pure beech stands using the process-based model Biome-BGCMuSo at 87 sites spanning from the Adriatic to the Baltic Sea. We evaluated the recovery rate and the time to the full recovery from the prescribed disturbance affecting 80% of the aboveground carbon stock. The simulations were run for 80 years covering a period 2021—2100. Climate change effects were represented by ten climate projections driven by two Representative Concentration Pathway scenarios (RCP 4.5 and 8.5). Under the reference climate conditions, i.e. without the effect of climate change, the slowest recovery was identified at temperature-limited sites followed by the production optimum zone characterised by the fastest accumulation of aboveground carbon stock. Different levels of climate change affected the recovery along the whole studied gradient, while the recovery was substantially accelerated under conditions colder than the current beech optimum, whereas the effect in water-limited environments was marginal. This was due to the trade-off between the aggravating climate change and the compensatory effect of the increased CO_2 concentration. The results indicate that beech can preserve its recovery capacity across its current distribution even under the aggravating climate change.

FE4
O11

Quantifying the pace of succession: Turnover rates of tree functional composition after disturbances

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Forest disturbances, such as windthrow, insect outbreaks, or fire, can have long-term effects on the richness and the functional composition of tree species communities. Theory predicts and empirical data have shown that rates of change in species richness generally decrease over the course of succession. However, our quantitative knowledge of turnover rates of tree species abundances and functional composition is still limited, despite increasing recognition that functional composition, rather than taxonomic diversity, drives many ecosystem processes. Here, we used longitudinal data on tree species abundances derived from long-term monitoring of unmanaged temperate forests in central Europe. We related abundance data (stem number, basal area) to functional trait data in order to derive time series of functional composition (community weighted mean traits, CWM, and functional diversity indices) and to calculate functional turnover rates. We expect that functional turnover will change significantly with time after disturbance, and that direction, magnitude, and rate of change will differ depending on the specific trait and disturbance severity. Specifically, we expect that e.g. CWM wood density and seed mass increase during succession after disturbances, while mean leaf traits might not change profoundly. Rates of turnover are expected to be high within the first few years after disturbances, but may not change significantly thereafter. Higher disturbance severity will likely increase functional turnover rates. Our insights on disturbance-driven temporal variations in tree functional composition may also help understand and predict temporal fluctuations in related ecosystem processes in the face of accelerating disturbance regimes. This study is part of 'TempTurn', a project that aims at a thorough and systematic assessment of multi-decadal trajectories of tree functional biodiversity turnover in temperate forests after major disturbances.

FE4

O12

Enhancing reforestation success through scale-adapted spatiotemporal coordination of natural and artificial regeneration: insights from simulation experiments with the iLand model

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The forest ecosystems in Thuringia and other regions of Germany, especially the large areas of spruce forests there, are threatened by extreme climatic events and disturbances such as bark beetle outbreaks. This caused the massive losses of spruce trees and suitable management strategies are required for developing multifunctional forests in these disturbed spruce forest sites. We used iLand, the individual-based forest landscape and disturbance model, to first simulate how the density and diversity of seed trees in still intact neighbouring stands is defining the spatiotemporal patterns of natural regeneration in disturbance areas of varying size. We then defined and simulated different spatiotemporal planting schemes for artificial regeneration to identify the most suitable silvicultural support measures in each case. The results of the study suggest that a mix of natural and artificial regeneration in specific spatial and temporal configurations can significantly improve reforestation success, thereby helping forests to recover more quickly from disturbances and continue to provide ecosystem services. Importantly, the effectiveness of these combinations is related to the size of the disturbed areas, thus emphasizing the need for tailored forest management strategies. Such tailored strategies can also address challenges such as the limited availability of seed and planting material, which is often a significant constraint to artificial regeneration in large, disturbed areas. This study offers scientific support for forest management decisions, provides insight into the interactions between ecological patterns and processes, and informs the development of management and restoration strategies for similar ecosystems. It also shows the value of practical applications of forest models such as iLand in the development of sustainable forest management strategies.

FE4

O13

Increasing frequency of drought years threatens the viability of beech forests in Central Germany

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Recent recurrent drought years have imposed water and heat stress on trees across Germany. However, it is unclear how demographic rates of broadleaved tree species were affected by the drought. Moreover, it is likely that climate change leads to an increasing frequency of drought years and associated changes of demographic rates, and it is unclear whether current forests will still be viable in the future. To explore these questions, we carried out a forest inventory in 2023 in a 28-ha beech-dominated forest in the Hainich National Park that had previously been surveyed in 1999, 2007 and 2013. We calculated growth, mortality, and recruitment rates for the four most abundant tree species (beech, ash, sycamore maple, and hornbeam, ≥1 cm diameter) before 2013 (1 drought year/decade) and after 2013 (four drought years/decade) and projected forest dynamics for both climate scenarios until 2100 using a demographic forest model. Growth rates were similar across census intervals. However, mortality rates were increased after 2013 for all tree species, especially strongly for small trees, as compared to mortality rates before 2013. As an example, the annual mortality rate of beech was ~0.5% higher. Model simulations using demographic rates from before 2013 predict that the forest could increase in above-ground biomass from 410 t/ha to >500 t/ha until the end of the century. However, when using demographic rates from after 2013, the forest was predicted to decline to 280 t/ha, i.e. to nearly half the expected biomass. These simulations also suggested that all four species would decrease in biomass. We conclude that an increasing frequency of drought years threatens the viability of beech-dominated broad-leaved forests in Central Germany.

Drought resistance of *Abies alba* seedlings of different provenances to simulated drought

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The conversion of monocultures into diverse forests stands with climate-tolerant species is one of the primary goals in siviculture to mitigate global change. In practice this is often done by planting or seeding species currently not occurring in a specific area. Silver fir (Abies alba) is one of the climate-tolerant species, which recently received increasing attention in research and forest practice. While the intra-specific variation of adult trees has been more and more studied, here we explore the potential of Abies alba-seedlings to withstand summer drouths. In a climate chamber experiment silver fir seedlings from four provenances representing a geographic West-East gradient in Europe were examined, testing their resistance to and recovery from drought by exposing them to two 30-day drought scenarios of differing severity. Three of the four provenances originated from the Central European lineage, while one belonged to the Balkan lineage of the species. Measurements describing biomass allocation pattern and individual fitness, revealed that seedlings from all provenances can withstand intermediate droughts in both resistance and recovery. It was striking that the Balkan provenance had the largest seedlings in terms of biomass in all treatments. The severe drought treatment significantly affected photosynthetic potential of the central European provenances, but not the Balkan lineage. However, central European provenances very well recovered from drought, while the Balkan provenance performed significantly worse and being highly variable between individuals. Our findings show, that while the tested provenance of the Balkan linage had the largest overall growth it was inferior to studied provenances of the Central European lineage in terms of drought resistance and especially recovery after drought.

FE4
O15

Deciphering the future dynamics of temperate montane forest: Early snowmelt's influence on winter herbivory and seedling drought resistance

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In the face of ongoing climate change, understanding the dynamics of montane forests is crucial for predicting their future trajectories. Our research aims to address this complexity, focusing on how early snowmelt, driven by future warming temperatures, could reshape fundamental ecological interactions within these ecosystems. Specifically, we investigate the cascading effects of early snowmelt on tree seedlings winter herbivory patterns and the subsequent responses to drought of the browsed seedlings. To explore these dynamics, we conducted both a field and a climate chamber experiment with seedlings of nine different tree species. In the field, we implemented a snow removal and herbivory exclusion experiment at the ecotone between montane and sub-alpine forests in the Northern Alps. Simultaneously, we complemented this study with a climate chamber experiment, simulating the combined effects of winter browsing and drought on seedling performance under various warming temperature scenarios, using the current climate of the field study as a reference. Our preliminary findings highlight the complexity of these interactions, revealing species-specific responses to the earlier snowmelt timing effect on winter herbivory. Notably, winter herbivory rises as a critical factor increasing seedling resistance to drought, underscoring the interconnectedness of these drivers (warming temperatures, shifts in snowmelt timing, shifts in winter herbivory and resistance to drought). The next step involves the use of landscape simulation models to unravel the long-term implications of these interactions for temperate montane forest ecosystems.

FE4
O16

High nitrate and sulfate leaching in response to wetter winters in temperate beech forests

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Winter climate drives many ecological and biogeochemical processes in temperate forests. We investigated the effects of winter climate change on temperate beech forests at their north-eastern distribution range at nine sites along a natural gradient in mean winter temperature of >4 °C. In a large-scale field experiment from 2021 to 2023 we simulated future climatic conditions during winter by increasing the amount of total precipitation and excluding snow. Nutrient availability and leaching, decomposition, radial growth and root growth of mature European beech trees were analysed. We found an increase in topsoil nitrate and sulfate availability during winter in response to rain addition, likely as a consequence of atmospheric deposition. Surprisingly high leaching rates of >80% of the additionally available nutrients occurred, what can be explained by water-saturated conditions and limited nutrient uptake by plants during winter. For the subsequent early growing season, no difference in nutrient availability could be observed anymore. Winter greentea decomposition slightly increased with increasing winter precipitation and higher soil temperatures, while redtea decomposition was only affected by the latter. Interestingly, our results also show a significant interaction effect of winter precipitation and soil temperature on green-tea decomposition during the subsequent summer, what indicates a microbial community shift. These biogeochemical changes in response to wetter winters seem not to have a strong influence on the beech trees themselves, because radial tree growth and root growth during winter and the following growing season were not influenced. Instead, additionally available nutrients in the topsoil result in a high risk of groundwater pollution during winter.

017

Impacts of a thermohaline circulation shutdown on European tree-species distributions

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Recently, several studies provided model-based insights on how climate change may alter European tree-species distributions. Yet, none of those have considered the implications of a thermohaline circulation (THC) shutdown, even though recent research indicates an already declining THC and a significant chance of a complete shutdown within the 21st century. Since a THC shutdown results in cooler and drier climatic conditions across Europe that differ significantly from current climate model projections we need to increase our understanding of the impacts of a THC shutdown on European forests. Under this framework, we projected future tree-species distributions across Europe for various CMIP6 and THC-shutdown scenarios. We trained climate envelope models for the 24 most abundant European tree species and performed model simulations with quantile-mapped climate projections at an unprecedented spatial resolution of 1 km^2. To quantify the effects of a THC shutdown, we compared projections based on regular CMIP6 scenarios (SSPs 1-2.6, 2-4.5, 5-8.5, 10 different models) with such including a THC shutdown. These were created by superimposing changes in temperature and precipitation associated with a THC shutdown on the CMIP6 scenarios. In our statistical evaluation, we emphasized on relative changes in abundance probability, redistribution of species-specific core areas, and the diversity of forest's tree-species portfolios. Our results show a stark contrast between the scenarios that account for a THC shutdown and those that do not across all considered SSPs. Specifically, we observed an increase in abundance probabilities of selected tree species in Central Europe, while abundance probabilities in Scandinavia decreased substantially and indicating local extinction of the dominant tree species Norway spruce and Scots pine. Taken together, our study highlights potentially catastrophic impacts on Europe's boreal forests in case of a THC shutdown.

FE4

O18

Diversity-enhanced canopy space occupation and canopy leaf trait diversity jointly promote overyielding in tropical tree communities

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Understanding the mechanisms that drive biodiversity-productivity relationships is critical for guiding forest restoration. Although complementarity among trees in the canopy space has been suggested as a key mechanism for greater productivity in mixed-species tree communities, empirical evidence remains limited. Here, we used data from a tropical tree diversity experiment to disentangle the effects of tree species richness and community functional characteristics (community weighted mean and functional diversity of leaf traits) on canopy space filling, and how they are related to overyielding. We found that canopy space filling was largely explained by species identity effects rather than tree species richness effects. Communities with a high abundance of species with conservative leaf traits were those with most densely packed canopies. Overall, a higher canopy space filling translated into an enhanced wood productivity, with communities associated with a high functional diversity dissimilarity in leaf traits being the most productive. Importantly, most communities (83%) produced more wood volume than the average of their constituent species in monoculture (i.e. overyielding). Our results show that overyielding increased with leaf functional diversity and positive net biodiversity effects on canopy space filling, which mainly arose due to a high taxonomic diversity. These findings suggest that both taxonomic diversity-enhanced canopy space filling and canopy leaf diversity are important drivers for overyielding in mixed-species forests. Consequently, restoration initiatives should promote stands with functionally diverse canopies by selecting tree species with large interspecific differences in leaf nutrition, as well as leaf and branch morphology to optimize carbon capture in young forest stands.

FE4

O19

The interplay of carbon stocks and biodiversity in European managed forests and underlying mechanisms

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Under human-induced climate change and biodiversity loss, forests can play a major role in mitigating both crises. In tropical regions the potential to mitigate both is explained through the positive effects of natural forest succession on carbon storage and biodiversity. In contrast, many European forests are influenced by human-activities. Therefore, it is important to understand the impacts of management practices — which shape forest characteristics — on the simultaneous mitigation potential of forests. We analysed data on a wide range of temperate European managed forests to understand the interplay of forest characteristics, carbon stocks and the richness of different taxonomic groups. Using structural equation modelling, we investigated which forest characteristics should be promoted to increase aboveground carbon storage and to conserve a high diversity of organisms at the same time. We found that stand age and tree diversity underlie changes in forest characteristics and have positive effects on the carbon stocks in deadwood. Increasing stand age leads to an increase in carbon stocks in living wood, while these carbon stocks are decreasing with a higher tree richness. There were no negative effects of stand age and tree richness on the richness of different taxonomic groups. An increasing diversity of deadwood has positive effects on the carbon stocks in deadwood, the richness of birds, saproxylic beetles and saproxylic fungi. Larger trees positively affect the carbon stock in living trees and the richness of birds, but with increasing carbon stocks in living wood the richness of birds and vascular plants is decreasing. Our finding that forest stand age plays a role in mitigating both crises highlights important similarities between tropical and temperate forests. This can help us in understanding changes in the mitigation capacity of forests in the future.

FE4

O20

Overyielding in a mixed deciduous forest is driven by both above- and belowground adaptation, and influenced by ontogenetic changes in allometry

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Mixed forest plantations are increasingly recognised for their role in mitigating the impacts of climate change and enhancing ecosystem resilience. Yet, there remains a significant gap in understanding the early-stage dynamics of species trait diversity and interspecies interactions. This study aims to explore the timing and mechanisms by which trait diversity of deciduous species and interspecies interactions influence yield, carbon allocation, and space occupation in mixed forests above- and belowground. A forest inventory was conducted in planted monocultures, 2-species, and 4-species mixtures of European *Acer, Tilia, Quercus*, and *Carpinus*, representing a spectrum from acquisitive to conservative tree species. Competition effects were assessed with linear mixed-effects models at the level of biomass and space acquisition, including leaf, canopy, stem, and fine root traits. Early aboveground growth effects were observed six years post-planting, with significant biomass accumulation after eight years, strongly influenced by species composition. Most diverse stands, especially with acquisitive *Acer*, exhibited aboveground overyielding, 1.5- to 1.9-times higher than monocultures. Fine roots showed substantial overyielding in high diversity stands. Biomass allocation and trait plasticity were highly species-specific and varied markedly at the level of diversity. No root segregation was found. Our findings underscore the critical role of species trait diversity in enhancing productivity in mixed plantations. Allometric changes point towards the significance of root competition despite being planted on a nutrient-rich site, and consequences of competitive interactions for the functional relation between organs of individual trees. This study highlights the significant contributions of both above- and belowground components to overall forest productivity in mixed-species settings, emphasizing the need to increasingly consider effects at a whole plant level.

Experimental canopy nitrogen deposition effects in temperate forests: The case of *Quercus petraea* L. and *Fagus sylvatica* L. ring width and wood density

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As an essential nutrient, nitrogen (N) availability is fundamental in monitoring forest productivity, and as such, understanding the effects of changing atmospheric N inputs in forest ecosystems is of high significance. While most field experiments have been employing ground fertilization to simulate nitrogen deposition, two experimental forest sites in Italy have adopted the more advanced canopy N application approach. Here we present findings from a case study of wood core analyses of predominantly pure, even aged, Sessile Oak (*Quercus petraea* L.) and European Beech (*Fagus sylvatica* L.) forest stands, treated with either below or above canopy N fertilization, comparing between the two simulation pathways of increased N deposition. The potential effect of elevated N availability on total ring width, mean ring density, and their corresponding earlywood and latewood fractions are examined. Our results indicate inconclusive effects of the treatments on the ring widths of both *Q. petraea* or *F. sylvatica*, although basal area increment patterns appeared to be affected divergently between the species and treatments. Mean and earlywood, but not latewood, densities exhibited a decrease in certain years of treatment in *Q. petraea* following the above canopy N application only, whereas *F. sylvatica* wood density showed no clear response to any of the treatments. Thus, we are describing distinct reactions of the two broad-leaved species to the different experimental N deposition approaches, discussing potential growth patterns under increased N availability, and emphasizing the importance of considering wood density in assessments of tree biomass accumulation and essentially carbon storage capacities.

FE4
O22

Forest Informed Neural Networks (FINN) – Combining deep learning and process-based models to improve inference and prediction of forest dynamics

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Numerous forest models, ranging from data-driven to dynamic process-based, have been developed to predict forest ecosystems and infer forest dynamics and patterns using both process knowledge and observational data. Dynamic vegetation models (DVM) have become the main tool for understanding forest dynamics, but are often too large to be calibrated with observational data. On the other hand, correlative models that use observational data to learn predictive patterns from the data are often criticized for their inability to extrapolate due to their lack of mechanistic understanding. In response, the integration of Deep Learning, as the state-of-the-art tool for data-driven modelling, and process-based models, particularly through Physics-informed Neural Networks (PINNs), offers new avenues for enhancing forest ecology research. We introduce Forest-informed Neural Networks (FINNs), which aim to synergistically blend the complex dynamics of forest ecosystems with Neural Networks to improve the inference capabilities of DVMs. Specifically, we use Neural Networks within a DVM to estimate the ecological niches based on observational data thereby combining process understanding and the flexibility of NNs to enhance the robustness of ecological predictions. However, deploying Neural Networks within DVMs is complex, requiring dedicated efforts to effectively address research questions and overcome technical challenges. Here, we discuss the development, advantages, limitations, and potential of FINNs, positioning them as an important complement to existing forest modelling frameworks, thereby enriching our ability to understand and predict forest dynamics.

Dynamic water balance modelling for Bavaria's forests

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With a view to changing environmental conditions such as rising temperatures and droughts, the Bavarian Forestry Administration has used the deterministic water balance model LWF-Brook90 to model the site factor water balance for forestry practice in a realistic, spatially high-resolution and dynamic manner. The basic parameterization of the selected model was tested, improved and supplemented with tree species-specific information with the help of validation sites of forest environmental monitoring (forest climate stations). Suitable indicators for drought stress risk and waterlogging were identified and implemented in the model outputs. Temporally and spatially high-resolution climate data for the years 1961–2020 and selected climate scenarios were used together with site information, soil analyses and digital terrain models for deterministic and site-specific water balance modelling. In Bavaria, the forest site mapping was used in the Nürnberger Land project region, while information from the Bavarian Site Information System BaSIS was used for Bavaria as a whole. The results provide a good representation of site differences, hydromorphology and climate dynamics in the current and predicted climate. The predicted climate changes will lead to a general, but site-specific deterioration in the water supply for forest trees in Bavaria. In a next step, the water balance for the forest soils in Bavaria will be mapped in high resolution in the now and forecast, a method that allows a daily assessment of the water supply of forest stands and is being developed into a soil moisture monitor.

Impacts of increased frequency of extreme droughts on structure and traits of high- and low-diversity forests in Brandenburg

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Forests in Brandenburg are experiencing the detrimental effects of droughts, exemplified by the severe conditions of 2018. With climate change, such extreme events are expected to become more frequent. Previous work suggests that biodiverse ecosystems exhibit greater resilience towards disturbances compared to monocultures. Our study aims to investigate the impact of increased frequency of extreme droughts such as those seen in 2018, on biomass, structure and traits of forests in Brandenburg. Utilizing the flexible-trait Dynamic Global Vegetation Model LPJmL-FIT, we conducted simulations for both natural, biodiverse forests and monoculture Pinus sylvestris forests by artificially increasing the frequency of 2018's drought year in the climate forcing data. The simulation period was 800 years allowing us to analyse the short-term impacts as well as the long-term adaptation of the forest to those new climate-extreme normals. Our findings reveal that in monocultures, increased drought frequency led to a reduction in biomass and system stability, characterized by greater variance. Conversely, in biodiverse forests, biomass initially declined in scenarios drier than the baseline but recovered and even exceeded baseline levels after 100–150 years. However, if the drought frequency was increased, biomass was lower compared to scenarios with less severe drought frequencies, suggesting a threshold beyond which adaptation capacity diminishes. This highlights the capacity of biodiverse forests to adapt to changing environmental conditions, with mechanisms such as increased wood density and higher tree count contributing to biomass recovery in drier scenarios. However, there appears to be a limit to this adaptability, as indicated by reduced biomass in the driest scenarios. These results underscore the importance of considering biodiversity in forest management strategies especially given the challenges posed by increasing frequencies of extreme droughts in Brandenburg.

FE4

P3

Linking annual tree ring growth to high resolution vegetation indices within the new WALD-Puls monitoring network

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When do we detect tree stress from space? Here we introduce the new WALD-Puls monitoring network, a forest condition monitoring system that gathers real-time, spatially distributed data on secondary tree growth and forest climate, enhancing risk assessment and long-term projections. For more than 25 sites and 13 species across Mecklenburg-Vorpommern (Germany), we established a data cube encompassing hundreds of dendrometers, sap-flux sensors, minirhizotrons, micrometeorological, and tree ring data, which are complemented with remotely-sensed vegetation indices from the German Forest Condition Monitor. Overall, we seek to establish statistical links between ground-truth and remotely sensed canopy condition, that will allow for extrapolation of point-based monitoring into space. As part of the project, we seek to combine annual measurements of secondary tree growth (tree ring width) with remotely sensed vegetation indices. We sampled and analysed deciduous and coniferous tree species both in pure and mixed stands representative of large areas in Germany. Using Sentinel-2 satellite imagery, we computed the monthly vegetation indices NDVI (Normalized Difference Vegetation Index) and DSWI (Disease Water Stress Index) for the period 2017–2023. Tree cores were obtained from the sampled tree species and aggregated into tree groups/chronologies per site. Similarly, Sentinel-2 pixels (10 m x 10 m resolution) corresponding to each tree crown were selected and aggregated into groups/chronologies per site. Tree ring chronologies of each tree species and the computed vegetation indices were then analysed for correlation and tested for synchronicity. Preliminary results are promising, especially the drought year 2019 is detectable for many tree species such as European beech, European larch, and Douglas fir. Canopy water content (DSWI) appears to be more sensitive to drought conditions than canopy green cover (NDVI), making it more useful for future drought events.

The abundance of oak trees in turkey oak-silver fir mixed stands has a profound impact on the overall resilience of forest to late frost and drought stress

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There is concern that the capacity of forest ecosystems to withstand or adapt to stressors may decline, leading to significant adverse repercussions on the provision of ecosystem services. It's expected that drought and late frost events will become more frequent and intense in the Mediterranean basin. Since climate conditions and stand structure can influence stand responses to stressors, it is challenging to generalize how mixed forests will respond to climate stressors. To this aim, we examined radial growth responses in stands with varying abundances of silver fir (*Abies alba* Mill.) and Turkey oak (*Quercus cerris* L.) along a latitudinal gradient in Southern Italy. In drier conditions, both species were more resistant to drought than to late frost. The interspecific response, however, varied between sites, with Turkey oak being less resistant than silver fir to late frost in xeric conditions, and vice versa in moist conditions. Stand characteristics, particularly basal area and diameter heterogeneity, had a more pronounced impact on radial growth responses to stress events in drier conditions. The effect of the presence of Turkey oak on resilience components mirrored the different interspecific responses observed. Comparing patterns of radial growth among the two climate conditions, we found that water balance had a greater impact on silver fir radial growth in moist conditions, while accumulated growing degree days had a negative impact on Turkey oak in drier conditions but a positive impact in moist conditions. Our results highlighted different intra- and inter-specific responses related to climate conditions and the relevance of different interspecific strategies for stand-level resilience components. Additionally, we highlighted the importance of density management and diameter heterogeneity in xeric conditions as adaptive silvicultural measures to enhance stand resistance to climate stressors.

The influence of environment on the development of *Abies alba* and *Quercus robur* seedlings

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Converting Norway spruce stands in Central Europe towards mixed species forests is one of the currently most demanding tasks to ensure the stability of forest ecosystems. Recently, direct seeding as a method of artificial regeneration and introduction of species in current monocultures is gaining increased attention in forestry practice. As environmental conditions have a large impact on the establishment success of plants originating from direct seeding, we examined how differences in soil and environment drive establishment success of *Abies alba* and *Quercus robur* seedlings in undisturbed and disturbed Norway spruce stands (canopy removal) in a low mountain forest in central Germany (Thuringia). Our data suggests that the growth performance of *A. alba* and *Q. robur* seedlings (4-year-old) is mainly influenced by the level of photosynthetically active radiation (PAR), while the soil pH and available soil moisture had no effect on their performance. *A. alba*'s photosynthetic performance described by Fv/Fm appeared to be mainly negatively correlated with PAR with an optimum at around 20% of open field PAR. For *Q. robur* growth performance increased linearly with higher light availability. Because of this relation, the abrupt cutting of shelter trees, one year after germination had a strong negative impact on the growth of *A. alba* and resulted severe diebacks, while *Q. robur* appeared to benefit from the increased light availability. The results suggest that *A. alba* reacts very sensitive to a sudden change in the light regime in this development stage, making the establishment success strongly dependent on the longevity of the canopy cover. *Q. robur* on the other hand appears to be well suited for sites that are under a high risk of losing its canopy to disturbances, or potentially even where the canopy already has been removed.

P6

Forest fire intensities matter for the post-fire development of moth communities

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Over the past years, Germany was facing an increasing number of forest fires. Thus, 750 ha of mostly pine forest burned in south-western parts of Brandenburg (Germany) in 2019. Since fires are not natural part of German forest ecosystems, little is known about the development of burned sites. In our project, we studied the development of such sites in an area without post-fire human management. However, forest fires are not consistent in temperature and fire intensity. We therefore not only looked at changes of communities after the fire, but also at differences in communities regarding fire intensity. We used moths as indicators organisms since they are well known, species rich and an important part of forest food webs. Moths were collected by standardised automatic light interception traps on five different sites from March to November of the years 2021–2023. Besides community composition, we analyse functional, morphological and ecological traits. This poster presents relevant results.

Unveiling hidden worlds: A dive into the impact of forest management on tree-hole ecosystems

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Water-filled tree holes represent isolated and ephemeral aquatic microenvironments in forests worldwide. They are embedded within terrestrial ecosystems, providing a niche for diverse aquatic insect assemblages. These systems are convenient models as they are small, can be treated as discrete units, are very tractable and can be mimicked with artificial analogues. However, the communities inhabiting them are still largely unknown. In this context, we studied artificial tree-hole macroinvertebrate communities in and around two Austrian national parks. Forest areas that serve as steppingstones outside the national parks were compared with areas inside the national parks. Two artificial water-filled microhabitats were installed in each of 35 plots and their naturally colonizing communities were analysed after three months. The artificial microhabitats were filled with standardized litter bags to measure decomposition and temperature loggers for daily temperature curves. Our goal was to understand the environmental effects driving their community structure, for example local and regional conditions such as water chemical parameters and connectivity to other forests. We found that artificial tree holes in Gesäuse national park were inhabited by a greater number of macroinvertebrates than surrounding steppingstones, however, this was not significant in Kalkalpen national park. The most common species was by far *Dasyhelea incisurata* (Ceratopogonidae). We found a low species richness (13 species in 70 microhabitats). Our results also show a bottom-up control in the tree-hole food web with a positive effect of detritus content on abundance, and a positive effect of canopy cover suggesting a higher habitat colonisation in canopy-dense forest. Spatial autocorrelation of community abundance for two artificial tree holes in the same plot was stronger in previously unmanaged plots than in previously managed ones, suggesting increased habitat connectivity in unmanaged forests.

P8

Nutrient availability and habitat filtering shape saproxylic beetle community patterns along deadwood decomposition

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Fresh deadwood is nutrient-rich but full of species-specific secondary metabolites, while advanced structural decomposed wood is inflated by fungi and other microbes. This exerts high evolutionary pressure, particularly on early colonisers of tree species with high C:N ratios, which should lead to functional adaptations and shifts in community patterns until decomposition is complete. However, as most deadwood studies focusing only on the early stage (i.e. three years), the ecological principles driving saproxylic communities over time are not fully understood. Here, we tracked saproxylic beetles from experimental exposed wood of three dominant species in Central Europe, *Picea abies, Abies alba* and *Fagus sylvatica*, over the course of a decade. In specific we tested the two fundamental hypothesis explaining local diversity, the species-energy and the habitat heterogeneity hypothesis for beetle communities along decomposition. Specifically, we predicted stronger habitat filtering in tree species with higher C:N ratios, with a rapid decline in abundance and species number in the early stage of decomposition after the nutrient-rich phloem and cambium layers are depleted (species-energy) and an increase in species number and richness in the advanced stage of decomposition (habitat heterogeneity). We found consistent patterns of decreasing abundance and species numbers, but not of richness along decomposition in all tree species supporting the species-energy hypotheses. Community patterns switched non-linearly from habitat filtering, which was more pronounced in spruce with highest C:N ratio, to a random pattern in the end of the early stage. Although community patterns showed a slight hump shaped curve, they remained within the boundaries of random assemblages, indicating that communities of saproxlic beetles within a tree are mainly driven by decreasing nutrient availability.

P9

The diversity of nucleation techniques determines the richness and abundance of regenerating plants during tropical forest restoration

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Human activities have triggered a global biodiversity crisis, with serious consequences for ecosystems and human societies. Therefore, restoration of degraded areas is imperative and offers a promising solution for restoring the diversity and functioning of ecosystems. Among the priority areas for restoration is the Brazilian Atlantic Forest, recognized as a global biodiversity hotspot. Over the past 500 years, this biome has suffered extensive damage from agriculture, deforestation, and urbanization. From the different measures applied for the restoration of tropical forests, nucleation techniques propose to accelerate ecosystem recovery and promote the establishment of resilient and biodiverse systems. Such techniques aim to recover degraded areas by establishing clusters of native vegetation and other habitat elements to facilitate colonization by other plant species. We assessed how the application of nine different nucleation techniques in a gradient of 1, 3 and 9 techniques combined affected native plant regeneration in abandoned pastures within the Brazilian Atlantic Forest. We tested nucleation techniques related to fauna (3), flora (3), and soil restoration (3). Using linear mixed-effects models, we demonstrated that the diversity of nucleation techniques applied in interaction with the distance to forest fragments determines the richness and abundance of regenerating plants in abandoned pastures in the Atlantic Forest. Mostly techniques related to topsoil transposition and direct seeding. Furthermore, we observed that the interaction between the identity of the nucleation technique and the distance to the forest also affected the richness of regenerating plants. Combining nucleation techniques proved more efficient than using a single technique. Hence, the type of nucleation technique, their combinations, and the proximity to existing forests can significantly influence the success of ecological restoration efforts in abandoned pastures.

FE4

P10

Drivers of forest structural complexity

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Forest structural complexity influences ecosystem processes and functions by determining microclimatic conditions, light environment and habitat availability. Globally, forest structures can range from simply structured, single-layered forests to complex structures with multiple canopy layers, spanning up a gradient of forest structural complexity that creates unique within-stand environmental conditions depending on the level of complexity. The patterns and processes involved in shaping forest structures of different levels of complexity remain largely unexplored. Here, we present a theoretical framework of how abiotic and biotic factors constrain forest structural complexity. Thereby, we aim to support an improved understanding of the interaction between forest structure, ecosystem processes and functions. Using a global dataset of three-dimensional forest structures derived from terrestrial laser scanning data, we test our theoretical framework and show how abiotic (climate, soil, disturbances) and biotic factors (tree species and functional diversity) affect the spatial patterns of three-dimensional forest structures, resulting in different levels of forest structural complexity. Our results suggest that -on a global scale- forest structural complexity increases with increasing water availability, but that these global patterns of structural complexity covary locally with tree species diversity, functional diversity, disturbance level and successional stage. Using exemplary case studies, we provide an outlook on the influence of forest structural complexity and its changes over time on selected ecosystem processes and functions, and how the presented theoretical framework can support biodiversity and ecosystem functioning research.

P11

The influence of forest structure on the nutrient distribution in the vegetation layer in the Saale Elster Sandstein Observatory (SESO), Thuringia

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Nutrient cycling in forest ecosystems is mediated by the climate, location, abiotic factors (such as topography, parent material), and biotic communities. Nutrient cycles are noticeably modified by tree species-specific controls over the efficiency of resource use. Nutrient mineralization and decomposition are governed by temperature and moisture conditions, and by the chemical and physical nature of the litter. The forest canopy has a large influence on nutrient mineralization and decomposition which in turn influence nutrient cycling. Another important phenomenon is the formation of forest gap and reduced canopy density which leads to environmental heterogeneity within different forest ecosystems. Environmental factors such as moisture, net radiation, and temperature get affected by the size of the gap. Furthermore, gaps induce changes in the microclimate which dramatically influence local biogeochemical cycling. To understand the influence of canopy and canopy gaps on leaf and moss nutrients, herbs and moss samples were collected from the seven forest sites (a pair of beech forests, a pair of spruce forests, a pair of pine forests, and one clear-cut). NIRS was used to predict nutrients in the plant samples. With this research, we wanted to answer (i) How does the small-scale environmental gradient induced by forest canopy influence the nutrient variation in different forest stands? (ii) How does the nutrient content differ between the herbaceous plant layer and moss layer along the environmental gradient? (iii) How does the nutrient content differ intraspecifically along the environmental gradient in the most dominant herbaceous and moss species?

P12

Niche convergence and biogeographic history shape elevational tree community assembly in a subtropical mountain forest

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Niche convergence or conservatism have been proposed as essential mechanisms underlying elevational plant community assembly in tropical mountain ecosystems. Subtropical mountains at higher latitudes, compared to tropical mountains, are likely to be shaped by a mixing of different origin of species and remain somehow unclear. Here, we used 31 0.1-ha permanent plots distributed in subtropical forests on the eastern and western slopes of the Gaoligong Mountains, southwest China between 1498 m and 3204 m a.sl. to evaluate how niche-based and biogeographic processes shape tree community assembly along elevational gradients. We analysed the elevational patterns of taxonomic, phylogenetic and functional diversity, as well as of individual traits, and assessed the relative importance of environmental effects on these diversity measures. We then classified tree species as being either tropical affiliated or temperate affiliated and estimated their contribution to the composition of biogeographic affinities. Species richness decreased with elevation, and species composition showed apparent turnover across the aspects and elevations. Most traits exhibited convergent patterns across the entire elevational gradient. Phylogenetic and functional diversity showed opposing patterns, with phylogenetic diversity increasing and functional diversity decreasing with elevation. Soil nutrients, especially phosphorus and nitrogen, appeared to be the main abiotic variables driving the elevational diversity patterns. Communities at lower elevations were occupied by tropical genera, while highlands contained species of tropical and temperate biogeographic affinities. Moreover, the high phylogenetic diversity at highlands were likely due to differences in evolutionary history between temperate and tropical species. Our results highlight the importance of niche convergence of tropical species and the legacy of biogeographic history on the composition and structure of subtropical mountain forests. Furthermore, limited soil phosphorus caused traits divergence and the partitioning for different forms of phosphorus may explain the high biodiversity found in phosphorus-limited subtropical forests.

P13

Comparison of distribution, productivity and mortality models as a means for tree suitability prediction for European Beech

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Higher temperature and extended drought periods considerably affect tree growth in European forests. In order to sustain healthy and robust forests ecosystems, the site suitability of particular tree species need to be revisited. A commonly used tool for this are species distribution models which take environmental variables into account to predict the presence probability of a tree species. Another aspect of tree species suitability is productivity that we model using a site index model which delivers tree height as a productivity measure. A third aspect is mortality risk that we obtain from survival analysis. As all models are based on different environmental input parameters and different statistical algorithms we investigate, if there is a correlation between occurrence probability, productivity and mortality risk. We analyse the spatial patterns in the relationship between these three measures of tree species suitability with particular focus on the warm and dry distribution margin of beech. This explorative work provides the foundation for a concept that formally combines the investigated tree species suitability measures in one single suitability index.

P14

LeafArea: A Python package for efficiently measuring leaf areas from photographs

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Computer Vision (CV) and image processing techniques hold great promise for facilitating ecological research, by providing efficient tools for data analysis. We introduce LeafArea, an open-source Python package designed for precise and rapid measurement of leaf area from smartphone or camera photographs. Our software offers several advantages over existing methods, including the ability to batch process images, correct for perspective, and measure multiple leaves per image, while requiring minimal user input. Featuring an intuitive Graphical User Interface, LeafArea caters to users of all expertise levels, eliminating the need for advanced computer skills. This makes it accessible and appealing even to those with limited background in informatics. It employs classical CV algorithms to accurately recognize leaves and various types of scale markers, allowing to calculate leaf areas without the need to manually provide a scale for each image. In contrast to traditional flatbed scanner approaches, the perspective correction provided by our software allows the user to take pictures of the samples non-destructively and in the field. Compared with other applications to measure leaf area, our software requires less input from the user, increasing the reproducibility of the data analysis, while still offering the possibility to manually correct errors if necessary. By harnessing efficient CV algorithms, LeafArea enables scientists to streamline the measurement of leaf areas, thus facilitating data collection for ecological research, addressing a key challenge in the study of plant systems. We will present the algorithms employed by the software, the intended workflow for the user, and a case study on how we employed the LeafArea software to measure leaf samples originating from a provenance trial experiment.

FE4

P15

Enhancing forest genetics: Advanced amplification methods and marker comparisons in spruce

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Forest genetic resources play a crucial role in understanding and managing biodiversity, yet the complexity of genetic information often challenges conventional methodologies. Our study introduces a novel amplification-based method designed for high-throughput sequencing to enhance the acquisition of genotypic data in forest species, specifically spruce. This method not only refines existing genetic analysis techniques but also provides a framework for the development of new genomic markers. In this presentation, we will detail the implementation of our method, highlighting the introduction of several new markers. A comparative analysis will demonstrate the efficacy of these markers against traditional microsatellite-based genotyping, particularly in the context of gene duplication — a prevalent issue in spruce that may induce homoplasy in genetic analyses. Furthermore, we explore the potential of integrating intron-derived markers linked to candidate genes for functional traits. Although optional in our current study, this approach offers significant insights into the genetic architecture and adaptive potential of forest trees. Our preliminary findings underscore a fundamental truth in genetic research: the deeper we probe into the genetic fabric of organisms, the more intricate the emerging patterns appear. This presentation will discuss these complexities and propose a path forward for developing an effective analysis pipeline and experimental design to handle them.

P16

Evidence-based cultivation recommendations for tree species in a changing climate

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Choosing the right tree species in forestry planning is preceded by a complex decision-making process. At a time when the range of suitable tree species needs to be adapted to keep pace with a rapidly changing climate, selecting the right species for establishing future forests is becoming increasingly difficult. The approach presented here, combines different 'climate sensitive' aspects that are relevant in forestry and seldomly combined in one scheme: We are using species distribution models (SDMs) for a general niche definition and risk assessment, site index models to describe yield and carbon sequestration potential and provenance trials to give hints on alternative provenances with a higher vitality under expected warming. Our approaches are applied to 30 tree species which consist of all important main and secondary tree species as well as the most relevant non-native tree species. Due to increasing data requirements from simple presence/absence data over age, height and DBH (stem diameter at breast height) measurements to detailed data of provenance trials, each method is applicable to a certain range of species. SDMs are available for the complete tree species list, site index models could be established for 25 species and provenance models are available for nine species. The project outcome provides a data-based foundation for optimally managing the forests of the future and strengthening their resilience against climate change. The final models and digital maps can then be integrated into existing decision support systems and additionally the results are to be published on a website via an interactive dashboard.

Macroecology (ME)

Macroecology: investigating large-scale biodiversity patterns under global change

Short title: Macroecology

Chairs: Alke Voskamp, Eva Katharina Engelhardt, Susanne Fritz

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This session aims to bring together research on the responses of biodiversity to global change in the past, present and future. Halting biodiversity loss is one of the major global challenges faced by humanity in the 21st century and human wellbeing, economies and livelihoods all depend on biodiversity. Changes in land and sea use are a key driver of global biodiversity loss, which is characterized by the responses of individual species, species communities and ecosystems to ongoing environmental change. In line with the conference theme 'The future of sustainable land use across ecosystems, landscapes and biomes', we call for contributions focusing on the impacts of anthropogenic drivers on biodiversity loss, especially land-use change, but also other key drivers including climate change, pollution, and invasions. Understanding the mechanisms behind the changes caused by these and other drivers of biodiversity loss, is vital to develop solutions for a more sustainable future. We welcome submissions from all macroecological fields that investigate past, present, or future responses of biodiversity to environmental change, whether empirical, conceptual or methodological, as well as studies working at the intersections of macroecology with earth-system science, geosciences, paleobiology, geography, conservation, and social ecology. Studies should focus on a large spatial, temporal or taxonomic scale and investigate changes to biodiversity patterns including spatial patterns of species richness, community composition, and functional aspects.

ME1
01

Modelling the impact of forest loss and fragmentation on bird species richness at large spatial and temporal scales

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Habitat loss is a key driver of biodiversity change in forest ecosystems, while the consequences of habitat fragmentation (per se) have been intensively debated. The vast majority of habitat loss and fragmentation studies use snapshot data from a single time point and focus on comparably small scales. In contrast, our study aims at large spatial and temporal scales. Specifically, we investigate the impact of forest cover change and forest fragmentation on bird species richness in the US and Canada over the past three decades, focusing exclusively on forest specialist species. We employ a spatial regression model to analyse the association between biodiversity change and corresponding changes in forest cover and fragmentation, using time-series data from the North American Breeding Bird Survey (BBS). To derive levels of forest cover and fragmentation, we use an integrated remote-sensing product of global tree-canopy cover data spanning three decades. We assess the sensitivity of our results to the use of several measures of habitat fragmentation, including measures derived from binary (forest vs. no forest) as well as from continuous forest cover maps. The findings of this study provide valuable insights into the relationship between habitat loss, habitat fragmentation, and biodiversity, highlighting the importance of addressing fragmentation in conservation planning and management strategies. This research contributes to a better understanding of the ecological consequences of land use change and the potential implications for biodiversity conservation in forested ecosystems.

ME1
02

Exploring the drivers of ecological specialization in the geography

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Ecological specialization occurs when species adapt to a narrow range of habitats and environments, resulting in a reduction of their niche breadth. Despite this reduction, specialized species often exhibit higher performance and fitness within their specific conditions. Specialization is influenced by various evolutionary and ecological processes such as adaptation time, climatic stability, and competition. However, the extent of these factors' influence on the geographic distribution of ecological specialization remains unclear. In this study, I aim to make use of the Emberizoidea (Aves: Passeriformes) radiation—a clade known for its remarkable ecological diversity, high niche partitioning, and widespread distribution—to analyse the macroecological patterns of specialization. Specifically, I plan to assess emberizoid assemblages globally and examine the relationship between different aspects of specialization (diet, foraging behaviour, and habitat preference) and factors such as adaptation time, climatic stability, and competition to help advance our understanding on how ecological specialization is driven within biological communities.

Rethinking functional equivalence in island bird communities

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The equilibrium theory of island biogeography (ETIB) predicts species richness results from the interplay of immigration and extinction, influenced by island isolation and area. However, recent trait-based approaches challenge this assumption of functional equivalence underlying ETIB. For example, trophic and dispersal traits likely influence the probability of colonization regardless of how immigration rates vary with island isolation and area. We tested this hypothesis by examining the dispersal and trophic trait spaces of 3278 terrestrial bird taxa inhabiting 2539 of the world's islands. Our findings reveal that non-endemic bird faunas on highly isolated oceanic islands exhibit better dispersal abilities than those on less isolated oceanic islands. Additionally, larger equatorial islands harbour avian communities with more diverse feeding traits than smaller islands at higher latitudes. Our results suggest that (i) the assumption of functional equivalence is overly simplistic and ignores significant functional differences affecting colonization, and (ii) island area influences not only species richness per se but also the trophic diversity of that richness.

ME1
04

Species traits and community structure can drive scale-dependent propagation of effects in ecosystems

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Species can directly and indirectly affect others across communities and habitats, yet the spatial scale over which such effects spread remains unclear. This uncertainty arises in part because the species traits and landscape structures allowing indirect effects to propagate may differ across scales. Here, we use a topological network metric, communicability, to explore how indirect effects propagate across space in simulated metacommunities and in a large-scale plant-frugivore network across the territory of Aotearoa New Zealand. We show that generalist birds and plants spread indirect effects efficiently at the local scale, whereas a widespread distribution further allowed species to propagate effects across the landscape. Habitat composition, rather than arrangement, was the most important landscape factor in our study, generating several hotspots of effect propagation around forested areas. Overall, our results indicate that generalist and widespread species, two characteristics associated with species invasions, are the most likely to propagate large-scale ecological impacts.

ME1
05

The importance of biotic interactions among Fynbos Proteaceae for ecological niches, geographical ranges and species' vulnerability to global change

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A major contribution of Hutchinson's niche concept is the distinction between fundamental and realized niches (the sets of environments where intrinsic population growth rate r0 > 0 in the absence and presence of interacting species, respectively). Differences between fundamental and realized niches reflect the impact of biotic interactions on population dynamics and geographic ranges of species, thereby playing an important role in ecological and biogeographical theory. However, disentangling abiotic and biotic factors and quantifying fundamental vs. realized niches is hardly possible based on species occurrence data alone. In our study we thus combine measurements of fundamental demographic rates in 5085 populations across the geographic ranges of 29 Proteaceae species in the South African Fynbos with data on environmental variation and abundance of co-occurring species to parameterize demographic niche models that integrate abiotic and biotic effects on population growth rates. Analysing the thereby quantified niches reveals distinct variation across our study species, where the effects of biotic interactions and thus the differences between fundamental and realized niches are largest for species with wide fundamental niches (environmental generalists) and smallest for species with narrow fundamental niches (environmental specialists). We furthermore find that larger differences in the geographic projections of fundamental vs. realized niches (i.e. the area, where species' geographic distributions are limited by biotic interactions) can often be attributed to biotic effects on specific demographic rates and along specific abiotic gradients. Investigating these underlying processes as well as the consequences of differences between fundamental and realized niches is not only the key to understand present patterns of biodiversity, but also crucial for predicting the vulnerability of plant species and communities to ongoing environmental change.

ME1
06

Land-use effects on freshwater biodiversity: synthesis based on a new global database

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Freshwater ecosystems have been heavily impacted by land-use changes, but syntheses on the impacts on freshwater ecosystems are still limited. First, we compiled a global database encompassing 242 studies and 4,653 sites with species abundance data (from multiple taxon groups and geographic locations) across sites with different land-use categories. This database is now the largest database to incorporate the abundance data of freshwater biota across different land-use categories. Then, we analysed this database to investigate the effects of land-use change on freshwater biodiversity by comparing less impacted sites with more impacted sites across different spatial scales (e.g. α, β, γ), employing multiple biodiversity metrics (e.g. richness, evenness, abundance). Our analysis showed the freshwater ecosystems in urbanization had the strongest declines in species richness, rarefied richness and evenness, while not in abundance. This study will facilitate a better understanding of how land use alters freshwater assemblages on a global scale.

ME1
07

On the role of microclimatic heterogeneity on biodiversity in mountain landscapes: Impacts on organisms of different strata

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Climate is one of the mayor drivers of assembly processes and, therefore, of distribution and diversity patterns. As the availability of suitable microclimatic conditions forms the basis for the presence of most organisms, the number of species which potentially inhabit a certain environment is expected to be determined by the nature of the microclimatic landscape. In mountain regions, spatial and temporal microclimatic heterogeneity is enhanced by both, the tessellated spatial configuration of habitat types and the complex topography, and thus it is suggested to play a crucial role in conserving populations in the course of climate change. Here, we combined in-field microclimatic temperature measurements close to the ground and spatial microclimate modelling (1-m resolution) to investigate how the richness of multiple taxonomic groups of organisms recorded in various strata and by different methods is affected by the characteristics of the surrounding microclimatic context. Therefore, we compiled biodiversity data from four research projects (235 sites, 2019–2021) collected along elevational macroclimatic gradients in a topographically rich temperate mountain region (Berchtesgaden National Park, Germany). Spatial microclimatic heterogeneity at the study sites was an important additional driver of diversity after accounting for the effects of micro- and macroclimate per se. Observed effects were, however, more pronounced for ground-dwelling organisms such as arthropods caught with pitfall traps, herb-layer-plants, or insect herbivores than for flying insects and birds. Our results underscore the pivotal importance of microclimatic heterogeneity for maintaining the rich biodiversity of mountains where species with diverging niches can persist in proximity, creating refugia in times of global change. Including microclimate is necessary to accurately predict changes and shifts in biodiversity patterns with ongoing climate warming.

ME1
O8

Interactive effects of macro- and microclimate on species diversity

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Within one macroclimatic regime, species can experience a range of microclimatic conditions shaped by local topographic and structural features; particularly microclimatic buffering or amplification of macroclimatic temperatures can modify species communities and responses to macroclimatic warming. Yet, it remains poorly understood how microclimate affects species diversity in different macroclimatic contexts. We here test whether and how micro- and macroclimate interactively affect α- and β-diversity across trophic levels (including bacteria, fungi, plants, arthropods, and vertebrates) in a temperate mountain ecosystem. We collected biodiversity and in-situ microclimatic data from 213 plots spanning a macroclimatic and a microclimatic buffering gradient associated with elevation and vegetation, respectively. We then used GAMs to address how microclimatic buffering affects species richness and pairwise beta diversity in interaction with macroclimatic conditions. During summer, macroclimatic mean temperatures and microclimatic buffering had independent linear and non-linear effects on several taxonomic groups, particularly arthropods. Arthropod species richness tended to increase with temperature at the macroclimate scale and was higher in less strongly buffered habitats. However, interactions between macroclimate and microclimatic buffering indicated that under cool macroclimatic conditions, microclimatic buffering reduced species richness, whereas the effect of microclimatic buffering became hump-shaped or positive under warm macroclimatic conditions. Our results suggest that macro-microclimate interactions play an important role for communities, particularly in ectotherms. In-situ microclimate data are increasingly available, generating new opportunities to incorporate microclimatic conditions when predicting macroclimatic effects on species diversity. Yet, future studies should aim at disentangling confounding factors that change along microclimatic gradients.

ME1
09

How rising temperatures might elevate rates of evolution

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Accelerated evolutionary rates could enhance adaptive capacity and increase the likelihood of successful adaptation to global change, but evolutionary rates are difficult to quantify. In ectothermic animals, environmental temperature determines the regulation of body heat and shapes metabolic rate, body size, and generation time. The frequency of successive generations or the development rate are therefore important temperature-dependent drivers of the rates of mutation and recombination. To infer potential evolutionary rates under climate change, an understanding of the relationship between temperature and development rate is crucial, but this relationship has not been investigated systematically across taxa. We developed a species-specific and spatially explicit method to predict the number of generations per year for ectothermic animals under given climate conditions. We utilized empirical data to model temperature-dependent development across 52 species of terrestrial invertebrates (mostly insects), and combined the predicted relationships with species distribution models and a stage-structured population model. We then projected temperature-dependent modelled population structures across the globe for each species for four time periods: before the onset of anthropogenic climate change (CE 1860), for the present (1981–2010), and for two future scenarios (2071–2100; a mild climate-change scenario, SSP1-2.6, and an extreme one, SSP5-8.5). Our results show that the ongoing increase in global surface temperature has already substantially shortened ectothermic generation times across a diverse range of species and across different regions of the globe, increasing the number of generations per year by ca. 30% on average. Even more extreme results are obtained for the future, indicating that development might be more than twice as fast by the end of century as it is today. We demonstrate how much anthropogenic climate change likely elevated ectothermic rates of evolution already, and show that this trend is expected to accelerate in the future, with significant socio-ecological consequences.

Projected impacts of climate and land-use change on terrestrial mammal diversity

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Changes in climate and land-use are two of the main drivers of global biodiversity loss. Whilst land-use change often results in fragmentation or loss of species' natural habitats, main responses of species to climate change have been changes in range extent and distribution. These responses to climate change have been observed to be heterogenous across species, potentially leading to a global reshuffling of the geographic distribution of species. The implication of this reshuffling would be that, additionally to a loss of suitable climate and habitat, species face further threats through potential changes in ecological processes. The latter are result of changes to the structure of species assemblages which can be assessed by looking at the phylogenetic diversity (PD), i.e. the diversity of phylogenetic lineages present in the assemblage. Here we investigate the combined effect of land-use and climate change on terrestrial mammal assemblages globally. We model the distribution of around 4000 terrestrial mammals and project their distribution under two different future scenarios, a 'sustainability' (SSP1-RCP2.6) and a 'inequality' (SSP4-RCP6.0) scenario. We assess changes to local species assemblages by comparing projected changes in species richness (SR) within an area to the projected changes in PD. We show that SR patterns are projected to change markedly by the mid-century but that these changes are not always reflected by the projected changes in PD. Our results corroborate the importance of using variety of indicators when assessing biodiversity loss.

ME1
011

Stop stubbornness: needs, opportunities and obstacles for integrative research in climate change ecology

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The accelerating biodiversity crisis, for which climate change has become an important driver, urges the scientific community to answer the question whether and how species are capable of responding successfully to rapidly changing climatic conditions. For a better understanding and more realistic predictions of species' and biodiversity responses, the integrative consideration of different factors and processes is crucial. Here, I argue, supported by a quantitative literature review, that the scientific community was not very successful yet in doing so. After pointing out some of the potential reasons for this unfortunate lack of integration, some of which may relate to key deficits e.g. in the reward and incentive systems of academia, I suggest a few ideas that might help overcoming some of the barriers between separated research communities. Furthermore, I present several examples for promising research along the integration frontier, after which I outline some research questions that could become relevant if one is to push the boundary of integration among disciplines, of data and methods, and across scales even further – for a better understanding and more reliable predictions of species and biodiversity in a world of global change.

ME1
O12

Burrowing facilitated the distributional success of mammals and imposes contrasting responses to climatic stability

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Species' ability to cope with climatic instability varies greatly, influenced by factors like dispersal, physiological adaptations, and phylogenetic conservatism. Here, we investigate how burrowing behaviour – a key component of species' endurance strategies and ecosystem functioning – shaped the distributional expansion and diversification of mammalian lineages. Analysing 4,407 terrestrial mammal species and novel trait data on 3,096 species, we reveal distinct responses to climatic factors between burrowing and non-burrowing species. Burrowing lineages are disproportionately species-rich at lower temperatures and productivity levels. Both range size and species richness steeply increase with climate seasonality in burrowing species, as opposed to non-burrowing species. Constituting 47% of all terrestrial vertebrates, the proportion of burrowing species increases latitudinally, and particularly regions with greater Pleistocene temperature changes are almost exclusively composed of burrowing species. Trait conservatism, higher diversification rates, and Eocene peak diversification provide the evolutionary context to these contemporary gradients, underscoring the role of burrowing for mammalian radiations into cold-temperate climates. Our study highlights the potential of readily available behavioural information in improving forecasts of species' responses to climatic changes and showcases divergences of broad importance for targeted conservation efforts.

ME1
O13

Phylogenetic diversity patterns and drivers of trees in mountains across the globe

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Mountains exhibit exceptionally high levels of biodiversity, fostering diverse ecosystems in short geographical distances. Mountain biodiversity faces significant threats from global change drivers. However, a global understanding of how clades have established and evolved across mountain regions remains unclear. Using a comprehensive tree plot-level dataset from mountain regions worldwide, we quantify taxonomic and phylogenetic diversity at both alpha and gamma scales. We derived phylogenetic relatedness across elevations from regional and global species lists and found tree communities in higher elevations are overall evolutionarily younger and have lower species richness than lower elevation ones. But communities' relatedness did not change as a result of variations in elevation. We found water availability to be the most relevant variable influencing tree phylogenetic and taxonomic diversity in mountain regions worldwide. With less related and evolutionarily younger communities in drier and colder biomes, and more related, older, and species richer communities in wetter and warmer biomes. Our results highlight the threats of climate change to the evolutionary history of mountain communities worldwide, and the relevance of protecting their different environmental regions.

Tracing the impact of global change on populations of marine gastropods: A phylogeographic perspective from the Macaronesian islands

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Background: The unique marine biogeography of the Azores offers a living laboratory for studying evolutionary dynamics and ecological patterns in oceanic islands. Known as the 'Azorean Biogeographical Paradox', the unusual dispersal patterns and colonization routes of marine taxa challenge traditional biogeographical models, particularly for gastropods with varying larval development strategies. Methods: This study employs a population genetics and phylogeographic approach focusing on several gastropod species: *Tectarius striatus*, as well as several species of the genus *Bittium*. Utilizing mitochondrial sequencing and microsatellite markers, we aim to assess genetic diversity, population structure, and the impact of historical and current oceanographic processes on species distribution. Results: Preliminary findings suggest differences in genetic structure correlated with larval development modes and geographic distribution, highlighting the role of ocean currents and historical climatic changes in shaping the genetic makeup of these species. The presence of cryptic speciation and unrecognized diversity within these taxa also suggests a complex evolutionary history influenced by the islands' geological dynamics. Conclusion: The results of this study will enhance our understanding of marine biodiversity in the Macaronesian Islands and contribute to broader ecological and evolutionary theories. By addressing the complexities of marine life evolution in isolated systems, this research supports conservation efforts and provides insights into the resilience of marine populations to environmental changes. Significance: Reflecting on macroecological scales, this research emphasizes the integration of phylogeographic and population genetic data as a vital approach for addressing global biodiversity crises. The findings not only enrich our understanding of marine biodiversity dynamics but also inform conservation strategies and sustainable management practices necessary for mitigating biodiversity loss due to human activities.

Distributions, drivers, and trends of submerged macrophytes: Insights from lakes and rivers in Bavaria

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Aquatic ecosystems face many anthropogenic changes, including eutrophication, invasive species, and climate change. These changes affect the distribution of submerged macrophytes, which are essential in water bodies for oxygen production, sediment stabilisation, and as food and habitat for other species. Understanding how submerged macrophytes respond to multiple, interacting anthropogenic changes, especially in different freshwater system types and at larger geographical scales, remains essential, also for biodiversity conservation strategies. Therefore, we addressed the following questions: (i) What are the current spatial distribution patterns of submerged macrophytes in Bavarian rivers and lakes? (ii) What are the underlying drivers of these patterns? (iii) Have the patterns and drivers changed over the past two decades? – To answer these questions, we used open monitoring data from the Bavarian State Office for the Environment (LfU). We examined the distribution of submerged macrophytes in 41 large, deep lakes and 340 river monitoring sites across Bavaria. We used geographical, physico-chemical, and environmental data from the Bavarian State Office of the Environment as explanatory variables. We used Generalized Additive Mixed-Effect Models to identify the primary drivers of species diversity and Nonmetric Multidimensional Scaling to describe species communities. We found 41 submerged macrophyte species in lakes and 127 in rivers. Lake size and phosphorus content were the main drivers of submerged species diversity in deep lakes. We also observed waterbody type specific trends in species richness, including invasive *Elodea* species, Charophytes in lakes, and *Najas marina ssp. intermedia* in lakes. These findings highlight the diversity of submerged macrophytes in Bavaria's varied landscape and provide a broad overview. Moreover, the differential responses to environmental changes underline the importance of considering water body types in management strategies.

Macroecology of host-parasite interactions: patterns and drivers of the variation of parasitism across latitudinal gradients

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Climate change is one of the major causes of biodiversity loss. One-way in which climate change can cause or contribute to extinction is by facilitating the spread of diseases and modifying host-pathogen interactions in a way that is detrimental to hosts. Therefore, understanding how climate impacts host-pathogen interactions across latitudinal gradient is crucial. Here, we studied latitudinal variation of parasitism in damselflies to determine how climatic factors impacts host-parasites interactions. We studied seasonal variation of parasite prevalence (i.e. the proportion of damselflies parasitised), and parasite intensity (i.e. the number of parasites per infected damselfly) from 32 sites across a 3000 km latitudinal cline in the eastern coast of Australia and from 61 sites across a 4100 km latitudinal range using *Coenagrionidae* damselflies and water mites as host-parasite study system. We showed that in Australia parasite prevalence and intensity are lower at higher latitudes and higher at lower latitudes and positively correlate with temperature and parasitism. In Europe, the relationship is, however, complex and varies across species where species in their range edge have more parasites than range core. Our study provides evidence that host-parasitism varies across latitudes as temperature and rainfall are most likely drivers of the observed variation. Temperature and rainfall possibly cause variation of parasitism by impacting damselflies immune system and modifying concentration of parasites in the habitat. Our study suggests that parasitism is most likely to increase due to global warming, which would decrease insects' fitness, limit range expansion and thereby contributing to global insect decline.

ME1

017

Species distribution modelling of freshwater invertebrates in the Guineo-Congolian region: A Predictive conservation approach

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The Guineo-Congolian region is an important biodiversity hotspot in Africa, with many rare and threatened species. It has numerous outstanding freshwater systems, which are grossly underreported. Our research hinges on the concept that the loss of some threatened freshwater invertebrates and pristine freshwater ecosystems may be inevitable in this hotspot unless their actual and potential distributions are discovered. We prepared an extensive database of all available freshwater macroinvertebrate species occurrence records from 14 countries. We also employed open-source software such as GRASS-GIS and R to estimate the potential geographical distribution of species across a newly developed, high-resolution hydrographic network to assess biogeographic patterns of freshwater biodiversity in this unique hotspot. We further used future climate predictions to obtain an estimate of how species distributions might be impacted by global change. We present the final output of 7,809 occurrences consisting of 4 phyla, seven classes, 31 orders, and 965 species across the time frame of 1984–2023. There are four main outputs (species presence, the species model, the prediction table, and a raster file displaying the actual and possible distributions) for each scenario (present or future) and for each modelled species. Current and future scenarios of the selected modelled species indicate that the Lower Guinea Forest of West Africa and the Congo Basin are potentially higher biodiversity hotspots than the Upper Guinea Forest. The findings of this research have a very high potential to depict the present and probable future status of freshwater biodiversity in the region and to guide conservation efforts.

ME1
P1

A spatial inventory of freshwater macroinvertebrates in the Guineo-Congolian biodiversity hotspot

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The Guineo-Congolian region, extending from Guinea in West Africa to the central part of Africa, is considered an important biodiversity hotspot in the Afrotropics. Aside from the underreport and underestimation of freshwater ecosystems, incorrect coordinates and taxonomical inaccuracies pose another major hurdle that may hinder freshwater conservation efforts in the hotspot. Hence, it is crucial for species distribution modelling and conservation initiatives to use datasets that are, to the largest possible extent, free of spatial and taxonomic errors. To give a more precise account of freshwater invertebrates in this region, we collated species occurrence records of freshwater invertebrates from the following sources: published articles through PubMed and Google Scholar, personal field surveys, and also through the Global Biodiversity Information Facility (GBIF) database. We combined and processed these data for taxonomic cleansing using the R package 'taxize'. We then performed a coordinate cleaning to remove occurrences that have duplicate records and those that fall within 1 km from country centroids and capital centroids, as well as biodiversity institutions (e.g. zoos and herbaria). We present the final output of 8,807 occurrences consisting of four phyla, eight classes, 32 orders, and 1,104 species. The macroinvertebrate occurrence records also consist of a total of 2,890 catchments. These records are considered valid and can be used for modelling the distribution of freshwater macroinvertebrates in this important freshwater biodiversity hotspot.

ME1
P2

Potential implications of climate change on the interplay between cocoa landscapes and biodiversity in Ghana and Côte d'Ivoire

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Climatically suitable areas for species and agricultural production are expected to shift in the coming years due to climate change. Climate-change induced shifts in crop production areas may exacerbate pressures on local biodiversity. Here, we focus on 155 species which are potentially threatened by cocoa plantations and model the impact of climate change under a high-emission scenario on their distributions in Ghana and Côte d'Ivoire. We use climate data from two General Circulation Models (GCMs), representing drier conditions (5–10% less precipitation) compared to historical values, as well as warmer (+1.2 °C) and hotter conditions (+1.7 °C), respectively. We then overlay the changes in range shifts of species to the projections of a mechanistic model addressing shifts in climatic suitability for cocoa cultivation in Ghana and Côte d'Ivoire. On average, among the assessed species, birds, mammals and insects are projected to lose range under both GCMs. Due to the projected loss of cocoa-growing areas under hotter conditions, there is an overall decrease in the probability that cocoa is grown in species' climatically suitable areas. In contrast, under warmer conditions, the suitability of cocoa-growing areas, as well as the projected overlap of species with cocoa plantations, are projected to remain similar to historical values. However, in all cases, values vary greatly among species. These findings indicate that climate change causes a shift of cocoa and species' climatically suitable areas, whereby changes in the climatic suitability for cocoa have the potential to amplify or ameliorate the threat to local biodiversity.

ME1
P3

Assessing topoclimatic drivers of vine-diversity in global wine regions under climate change

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Halting biodiversity loss in the face of ongoing environmental change is a critical global challenge. Climate change significantly impacts biodiversity patterns in agroecosystems, by inducing shifts in suitability and cultivation practices. Viticultural regions serve as valuable agroecosystems to explore the interplay between human activity, climate, and biodiversity, due to their high potential for varietal diversity and strong dependence on specific climatic conditions. The goal of this study is to elucidate the influence of topoclimatic conditions on varietal diversity and its potential response to climate change in viticultural agroecosystems. Utilizing comprehensive datasets on grape varieties and their cultivation area, we analysed varietal diversity of multiple global wine regions and coupled this information with high-resolution topoclimatic data. We found significant associations between topographic features, climatic variables, and varietal diversity within wine regions. Furthermore, our results suggest significant alterations in varietal composition and distribution under climate projections, highlighting the vulnerability of viticultural ecosystems to climate change. These results underscore the importance of considering topoclimatic factors in biodiversity conservation strategies for agroecosystems, especially in the context of changing climatic conditions. By elucidating the intricate relationships between topoclimatic conditions and varietal diversity, our study provides critical insights into the mechanisms driving biodiversity patterns in agroecological landscapes and offers valuable insights into the dynamics of biodiversity under human influence. Thereby, this research contributes to the overarching goal of understanding the responses of agrobiodiversity to anthropogenic drivers, particularly climate change.

ME1
P4

BirdWatch - an online platform for the improvement of habitat suitability of farmland birds in the EU

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Over the past decades research has revealed the decline of our global bird diversity. Especially farmland birds suffered strong declines. Major drivers are the decrease in habitat availability and suitability. To optimize farmland management that benefits the farmers as well as biodiversity, we are designing the BirdWatch tool that integrates Earth Observation (EO), species distribution models (SDMs) and decision support tools and will provide an online platform for stakeholders and politicians. This tools will be tested in four study regions across Europe: Flanders, Belgium; Lithuania; South Tyrol, Italy; and Germany. Here we present the SDM workflow. First, we collect and collate EO-based environmental data (e.g. land-cover, soil moisture, mowing intensity, and topographic data) and species occurrence data at the regional/country level scale and climate data at the European scale. To quantify the state of habitat suitability across the four regions we use a nested SDM approach to incorporate the fact that different environmental drivers act at different spatial scales. Specifically, we estimate macroecological climate associations for entire Europe and fine-scale preference for different habitat and land management practices at the regional level. SDM transferability will be tested through cross-regional predictions. Finally, an optimization algorithm will test different trade-offs between the desired habitat suitability for different farmland birds and supported management actions. BirdWatch will provide an online platform that stakeholders can use to make informed decisions for farmland practices with the protection of biodiversity in mind. For example, politicians can decide which actions are most deserving of subsidies and farmers can use the information provided to plan their fields in consideration of the environment. BirdWatch will provide several suggestions per species on the best agricultural feasible actions. These suggestions also take into account what effects they will have on other species as well.

ME1
P5

How do the dispersal and landscape configuration affect processes of speciation and extinction?

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With global changes accelerating at an unprecedented rate, it is crucial to understand the complex mechanisms that shape biodiversity patterns, as this knowledge is key for predicting and interpreting species' responses. One significant factor influencing these patterns is fragmented habitats and the spatial distribution of suitable habitats within a landscape. While the negative impacts of anthropogenic fragmentation on biodiversity are well-established, its role in promoting biodiversity through speciation and understanding extinction processes is equally critical. This study introduces a model that integrates spatial configuration with the dispersal abilities of individuals to examine how landscape structure affects the evolutionary trajectories of species. Our microevolutionary model characterizes individuals by their dispersal capacity and genetic composition, allowing for population evolution and diversification. The landscape is represented by a mosaic of suitable and unsuitable sites, reflecting varying degrees of habitat fragmentation. Our findings indicate that intermediate dispersal abilities are beneficial for diversification. However, in highly fragmented landscapes, the total population size and the proportion of occupied habitats decrease, particularly for species with limited dispersal abilities. Moreover, we observe that moderate levels of fragmentation can increase species richness, whereas higher fragmentation levels correlate with more frequent speciation and extinction events. Our results highlight a complex relationship between species richness and dispersal ability, affirming that moderate dispersal enhances diversification. This study emphasizes the intricate interplay between landscape configuration and species dispersal abilities in driving speciation, extinction, and diversification, underscoring the challenges fragmentation poses to biodiversity in a rapidly changing world.

Collection-based research in plant ecology

Chairs: Robert Rauschkolb, Negin Katal, Paul Kühn

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Plant collections provide an ecologically valuable resource and range from living collections in botanical gardens, to stored collections in seed banks and herbaria. More recently, global databases like GBIF also collected data from observations, which combine plant images with location data and timestamps. For many decades, collections have been used to support taxonomic and systematic research. However, interest in using biological collections to capture, analyse, and understand plant or ecosystem responses to changes in land-use and climate during the last two centuries continues to grow. In addition, new methods have been developed and applied to extract information on morphological and chemical traits using non-destructive and cost-effective methods. In order to provide an overview on the state-of-the art in collection-based research and to further explore and discuss the potential of plant collections for ecological research, this session brings together scientists with different backgrounds. We specifically invite contributions that integrate plant collections in their research to (i) understand the responses of plant species or plant communities to environmental changes, (ii) to investigate ecosystem processes like plant-pollinator or plant-herbivore interactions and (iii) to develop methods to extract ecological information from data collections. In addition, the advantages and difficulties that arise when working with biological collections will be presented and discussed.

Plant photographs: an important resource for biodiversity research

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Plant collections refer to organized plant specimens that are typically gathered and maintained for scientific research, conservation and education. Plant collection range from living collections in botanical gardens, stored collections in seed banks and herbaria to digital plant collections stored in biodiversity databases like GBIF which often include photographs of plant recordings. Photographs of plants play a crucial role in conservation and research by aiding in species identification in the field. They are fundamental to the creation of field guides, identification keys, and public engagement in plant science. These images capture essential information about plants, such as growth habit, leaf orientation, flower color, and habitat details, which may not be discernible from pressed specimens alone later. Furthermore field photographs of plants, particularly those from citizen science datasets, are increasingly used in large-scale trait-based research. They help assess the potential impacts of climate change on phenology, describe unusual flowering events, and map global trait patterns. In my talk, I will provide a brief overview of the significance of plant photography in biodiversity research and want to highlight how photographs serve as an important complement to physical vouchers, especially when the two are combined for the same specimen.

ME2
02

What can we learn from individually based phenology data in a botanical garden?

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Botanical gardens provide a unique opportunity to observe and study growth strategies of large sets of plant species within one season. They enable us to measure growth of single individuals from the beginning of spring until their senescence and thus to determine a number of species-specific phenological traits in an accurate fashion. This permits to address a number of questions on how phenological traits of growth, flowering and senescence respond to species morphological traits and how they are related to species niches in the field. We used this opportunity to measure size trajectories in 231 species in a botanical garden from the beginning of their growth in the spring until their senescence. We extracted species-specific parameters of growth, flowering and senescence from these data, taking into account intraspecific variation among measured individuals. We linked these species-specific phenological traits to bud and whole-plant traits, and to parameters of species niches. To connect processes at the beginning and end of the season, we also calculated season length and investigated how niche parameters and species traits combine in their effect on such species-specific season length. We showed that the timing of flowering and growth of perennial herbs was mainly determined by bud traits such as flower and leaf preformation and primordia volume. It is strongly linked to light conditions of their habitats. Flowering was largely correlated with growth phenology, but occurred later (relative to growth) in late species. While spring growth was highly synchronized across species, interspecific variation in senescence was high and largely determined the species-specific season length. All these data show that temperate species have evolved a number of strategies how to exploit the limited temporal window of the favourable growth season; these strategies are largely driven by the length of this window and potential competition for light by neighbouring species.

ME2
03

Seasonal patterns in flowering intensity in herbaceous species are strongly influenced by temperature and flowering duration

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Phenological research often focus on single events in time such as first flowering day, and assume that species-specific differences remain consistent over the season. However, species-specific differences in first flowering day do not provide enough information when it comes to the evaluation of the role of these phenological patterns for biotic interactions. The consideration of the availability of flowers, becomes particularly relevant when studying plant-pollinator interactions. However, most large-scale phenological observation networks do not take the temporal course of the availability of open flowers into account and therefore data on this is scarce. In the PhenObs network scientists record the flowering intensity during weekly monitoring of populations in botanical gardens, providing unique data to analyse species-specific differences in seasonal flowering patterns in response to abiotic and biotic cues. In this study we analysed flowering intensity curves of more than 300 perennial herbaceous species across a spatial gradient to detect associations with climatic conditions and species' functional traits. We considered data collected in 14 botanical gardens in 2019–2023. Using linear-mixed effect models we explained the skewness of the flowering intensity curves per year, garden and species with variations in climatic variables of the different sites and years, and species' functional traits. We found that the flowering curves were more right-skewed at warmer temperatures indicating that the populations reached peak flowering with a steeper slope before the flowering intensity slowly decreased. Furthermore, species with a longer flowering duration were also more right-skewed. Our findings contribute significantly to a more detailed understanding of the seasonal variation flowering intensity in herbaceous species, which will be of crucial importance for future phenological research, especially on plant-pollinator interactions.

Exploring historical plant archives – their potential to reveal long-term changes in arthropod-plant interactions and biodiversity

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Community changes and interactions play an important role in biodiversity research. Long-term sampling is particularly important for detecting changes in arthropod communities. For example, studying the temporal plant-arthropod interactions can provide insights for understanding the consequences of global change in relation to their role in the establishment of terrestrial food webs. Due to a lack of standardized temporal monitoring data the specificity and longevity of interactions and changes in arthropod communities are poorly understood. Here we attempt to provide new insights into both questions using two different archived plant collections. One of these collections are herbaria. Due to the mass of historical plant records from all over the world, these are not only valuable for studying the population genetics of the plants themselves but can also provide insights into understanding the structure of plant-associated communities. We used DNA metabarcoding to analyse the arthropod communities from archived herbarium specimens of different ages and origins. The herbarium specimens yield arthropod DNA across various ecological guilds and trophic levels over multiple decades. Furthermore, specialists could be detected on their known host plants. In an experiment, we demonstrate that the typical dry storage of plants does not alter the recovered arthropod diversity and community composition. By analysing a time series of leaf samples from a forest monitoring project, we have characterized changes in arthropod biodiversity over nearly two decades. Despite major fluctuations, our results show that arthropod richness remains stable over time in the studied forest sites. Our study demonstrates the untapped potential of herbaria and plant archives to gain better insights into plant-arthropod interactions and further possibilities of monitoring spatiotemporal changes in arthropod communities.

Revealing global macroecological gradients from open-access biodiversity data

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The exponential growth of open-access biodiversity data collections presents novel possibilities for investigating current biogeographical patterns and respective environmental determinants. These patterns and drivers, when explored jointly, can explain better the processes that shape biodiversity under ongoing environmental change. However, whether this unsystematic data can help to decipher essential macroecological signals across the global continuum remains unexplored. Here we employ Isometric feature mapping as a nonlinear ordination method to derive leading macroecological patterns from the data set of more than 110 million seed plant GBIF-mediated observations on almost 230,000 species. The leading four dimensions (representing over 90% of the data variance) reveal clear spatial gradients that can be related to climate, geographic isolation and human impact. Differences between gradients derived from the subsets with and without non-native occurrences confirm the fading importance of geographic isolation in the era of human-mediated species distribution. Our results show that with the future growth in quantity and quality, the open-access biodiversity data can expand the knowledge on biogeographic arrangements and their reorganisation in response to human influence and climate change.

Temperature thresholds for spring growth of perennial herbaceous plants

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Perennial plants in seasonal climates need to optimize the timing of their spring growth to avoid risks of late spring frost while not losing competitiveness through late growth. It is widely assumed that the threshold temperature for plant growth is around 5.7 °C, but some evidence suggests plants grow below this temperature limit. As climate change progresses, these limits are reached earlier in the season, extending the growing seasons worldwide. Therefore, understanding the sensitivity of plant growth to the temperature is crucial for understanding the shifts in spring growth phenology. We evaluated the pattern of spring growth of 252 perennial herbaceous species. We calculated growing degree days for sixteen different temperature thresholds. For each temperature threshold, we modelled plant growth in two different ways: (i) as a logistic where early plant growth is exponential up to a point in time after which growth decelerates until the plant reaches its final size, and (ii) as a hyperbolic where almost linear growth is assumed if time is inhomogeneous due to sums of effective temperatures. We compared the goodness of fits of logistic and hyperbolic models for each temperature threshold to identify the point under which the temperature does not play a substantial role in plant growth. For most of our species, we found that decrease in the temperature threshold led to the better fit of logistic models while increase in the temperature threshold lead to the better fit of hyperbolic models. For these species, we were able to identify the point at which temperature starts to play a crucial role in plant growth. We demonstrated the huge variability in temperature thresholds for plant spring growth, and we have shown that a temperature limit substantially below or above 5 °C is not unusual.

Insights from globally coordinated and distributed experiments and surveys

Short title: Globally coordinated experiments

Chairs: Yujie Niu, Tyson Terry, Viviana F. Bondaruk

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Globally coordinated experiments and surveys in ecology research are crucial to address the intricate challenges that span our planet's ecosystems and advance our understanding of global ecological patterns. To gain a comprehensive understanding on global change issues in ecosystems such as biodiversity loss, invasion and species redistribution, climate change and extremes, eutrophication, and land use changes, numerous coordinated initiatives (e.g. BugNet, DarkDIVNet, Dew, NutNet, DragNet, DroughtNet, GLORIA, HerbDivNet, MIREN, TraitDivNet) have been developed. Coordinated experiments not only enable scientists to explore diverse ecosystems and species to provide a holistic perspective on ecological dynamics, but they also foster collaboration by creating standardized methodologies that facilitate data integration for more robust statistical analyses. This collaboration broadens ecological research and fosters a globally mechanistic understanding of ecosystem functioning, aiding evidence-based conservation and sustainable resource management. Through the synthesis of ecological knowledge on a regional or global scale, this session seeks to provide a platform to exchange experiences, methodologies, and findings.

ME3
01

General independent negative effect of drought and positive effect of nutrients on grassland biomass production

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Anthropogenic increases in nutrients enhance grassland plant biomass, while droughts reduce it. These changes could have significant implications for nature's contributions to people. Biotic factors (e.g. plant composition, diversity) and abiotic factors (e.g. aridity) in grasslands can influence responses to nutrient enrichment and drought, as well as their interactions. However, the role of these factors and how variations in grassland responses to nutrient enrichment and drought, and their interactions, differ across environmental gradients, remain unclear. Using a globally distributed experiment simulating once-in-a-century droughts and adding nutrients with standardized sampling across 26 sites in eight countries worldwide, we found no significant interaction between drought and nutrient addition. Specifically, independently, nutrient addition increased biomass by 23%, while drought reduced it by 17%. Together these treatments cancelled each other out, resulting in no overall significant impact on biomass, although cross analysed gradients the effects of nutrients and drought on biomass declined with increasing interannual precipitation variability. Nutrient addition exhibited significantly stronger positive effects in arid and semi-arid grasslands, diminishing towards more humid sites. Moreover, the positive impact of nutrients was more pronounced with increasing richness. Despite variability in climatic and biotic conditions, we did not observe a strong interaction between nutrients and drought. Our results contribute to a clearer understanding of responses to environmental changes, essential for advancing knowledge of key ecosystems that support various functions and biodiversity in the context of global change.

Decade-long active restoration of extremely degraded alpine meadows improved turnover and stability of soil carbon

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Soil carbon sequestration and stability are pivotal metrics for assessing the rehabilitation of degraded grasslands. Nevertheless, the outcomes of protracted active restoration efforts in severely degraded grasslands remain unpredictable, particularly in the face of climatic warming. This study set out to ascertain the dynamics of soil carbon decomposition and its sensitivity to climatic shifts following long-term vegetation restoration in alpine meadow ecosystems. We selected three study sites, each approximately 100–120 km apart, across the Tibetan Plateau. The rate of soil organic carbon (SOC) mineralization was found to decline with increasing grassland degradation but showed a marked increase following prolonged (>10 years) restoration initiatives. The most influential predictor of CO_2 production (CO_2-Q_{10}) varied among meadow conditions: microbial biomass for intact meadows, basal microbial respiration rate for degraded meadows, and soil bulk density for restored alpine meadows. The Q_{10} value for organic carbon mineralization decreased with restoration planting due to the increased soil bulk density, which emerged as the predominant negative predictor. Additionally, the Q_{10} for SOC mineralization in the topsoil was 14% greater than in the subsoil, a difference likely attributable to higher microbial abundances and exoenzyme activities. A decade of active restoration in the extremely degraded alpine meadows has enhanced the turnover and stability of soil carbon. To deepen our global understanding of soil carbon dynamics, future research should be directed toward designing coordinated and standardized soil incubation protocol and experiments that span broad geographical gradients.

LegacyNet – An international voluntary network investigating multi-species grassland leys to support sustainable agriculture

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The benefits of grass-legume mixtures for grasslands regarding biomass and nitrogen yield, as well as weed suppression, and forage quality are well-known. Still poorly quantified are, however, the performances of multi-species mixtures including herbs for forage production and as a weed-suppressing, nitrogen-delivering preceding crop in agricultural rotation. LegacyNet is a voluntary network of sites performing a common field experiement investigating yield benefits of multi-species grassland leys and their carry-over effect from the grassland (e.g. supply of symbiotically fixed nitrogen, soil health and fertility) to a follow-on crop in a rotation. LegacyNet uses an innovative experimental design with 40 systematically varying combinations of six forage species to test a range of multi-species mixtures (1–6 species) with complementary traits (two grasses, two legumes and two herbs), and to design species combinations (and proportions) that optimize forage production, forage quality and legacy effects. This experimental design was established across thirty sites with grassland mixtures being maintained for at least 18 months, and a follow-on crop (cereal or grass monoculture as model species) was used to investigate the legacy effect of the grassland composition. Here, we report on success factors learned from the establishment and running of the network. Among these are a stringent common experimental design, harmonized sampling protocols, and a solid statistical framework supported by a team of statisticians. We show first results across all sites from the grassland phase, and showcase how the established experimental sites have been used as a platform for add-on investigations.

ME3
04

Controlled environment experiments: key findings from the Montpellier European Ecotron

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In this presentation, I will use several experimental studies from the Montpellier European Ecotron (CNRS, France, www.ecotron.cnrs.fr), an advanced controlled environment facility for ecosystem research, to highlight key emerging findings related to experimental approaches in controlled settings. Specifically, I will discuss: (i) the risks associated with extreme simplification of model systems, (ii) the necessity for accurate and realistic environmental control, (iii) the advantages of continuous measurements of response variables, and (iv) the potential benefits of employing more complex and realistic model systems to enhance the reproducibility and external validity of findings.

ME3
05

15-year seasonal warming effects on plant community dynamics

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Climate warming is expected to be spatially and seasonally different. The magnitude of winter warming, particularly in mid-latitudes, already experienced more than double the global average in the last decade. However, a deep understanding of the relevant winter warming processes and their ecological influences on plant communities is still lacking, because manipulation experiments commonly apply uniform warming only during the growing season or entire year. Seasonal warming might be significant for shifts in community composition, likely leading to strong consequences for ecosystem functioning. From 2008 to 2023, we have altered seasonal temperature (ambient, winter warming, summer warming) at a level of 1.5 °C in temperate semi-natural grassland in Bayreuth, Germany. Aboveground biomass (AGB) production of different functional groups and plant-community composition based on species-specific cover data under different experimental treatments were collected in 15 consecutive years. Results from the early years of the experiment showed that winter warming was ecologically more relevant for soil-related processes and the onset of species flowering than summer warming. However, long-term winter warming did not lead to increased AGB, decreased species richness, or changed species turnover at the community level. Changes in species ID and functional group, as well as species reordering (changes in abundance), explained plant community compositional dynamics under seasonal warming.

Nature Conservation (NC)

Perspectives on biodiversity monitoring are diverse

Short title: Diverse perspectives on biodiversity monitoring

Chairs: Johannes Rüdisser, Ulrike Tappeiner, Davnah Urbach

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Amateurs love butterflies; politicians call them pollinators; ecologists claim they are suitable biodiversity indicators. There are as many different perspectives on why biodiversity matters as there are on biodiversity monitoring: from successfully integrating citizen scientists in data collection, to the scientific analysis of drivers of biodiversity changes, to the application of 'pollinator indicators' to evaluate the success of the envisaged EU nature restoration law. Biodiversity monitoring is a key tool for documenting ecological changes, identifying trends in these changes and their causes, and identifying evidence-based measures to protect both, species and their habitats. Well-designed biodiversity monitoring is an indispensable prerequisite for evidence-based decision-making towards sustainable land use in a fast-changing world. This session deals with differing stakeholder perspectives on biodiversity monitoring, with a focus on method development and quality criteria for implementing comprehensive biodiversity monitoring. Our goal is to bring together an interdisciplinary group of scientists to achieve an overview of existing approaches in biodiversity monitoring and discuss what novel monitoring approaches are needed to deliver scientific and quantitative information about the state and trends of various biodiversity aspects in social-ecological systems and best inform environmental policies.

NC1
01

Results from the first five years of Biodiversity Monitoring South Tyrol (Province of Bolzano/Bozen, Italy)

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In 2019, the Biodiversity Monitoring South Tyrol program was launched. Using standardized protocols, it aims to survey species groups considered sensitive to climate and land-use changes, i.e. vascular plants and bryophytes, orthopterans, butterflies, birds, bats, soil fauna and freshwater macroinvertebrates. They are investigated in 320 terrestrial and 120 aquatic sites over repeated time periods of five years. Sites were selected using a stratified sampling design to cover the most representative habitat types from near-natural to strongly anthropogenically altered ones. In addition, data on abiotic factors, landscape structure, and land-use management are collected. Moreover, a strong focus is placed on stakeholder engagement and communication. In the presentation, we present results of the first monitoring round (2019–2023). They clearly show the different quality of the surveyed habitat types for the investigated taxonomical groups, e.g. the dependence of butterflies and grasshoppers on extensively managed grasslands and of bird and bat diversity on landscape diversity. For the second monitoring period, which has just started we are adding new methodological approaches: The ornithological survey is supported by automated sound detectors, image-based insect camera traps will be tested for the recognition of nocturnal insects and additional eDNA approaches are tested within the soil monitoring part. The first five years of the program have shown that our approach is well suited for evidence-based decision making. The stakeholder involvement from the beginning has been crucialto the success of the program – especially when it comes to solving applied research questions. Finally, the strategy to foster collaborations both in international scientific consortia (e.g. GLORIA, Biodiversa+) and with local citizens and amateur naturalist associations allowed us to enlarge the impact and the outreach of the program significantly.

NC1
02

Benefits of an advanced sampling design for national vegetation monitoring of protected biotopes

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National vegetation monitoring usually aims at providing reliable estimates of predefined indicators for the whole area under study as well as for different geographical and ecological stratifications within the area. In order to achieve broad sample coverage, high estimation accuracy and/or low survey costs, sampling methods such as grid, stratified and cluster sampling are generally used. In Switzerland, the programme 'Monitoring the Effectiveness of Habitat Conservation in Switzerland' (WBS) for was launched in 2011. The aim of the programme is to assess the development of important conservation values through repeated vegetation surveys on permanent plots in biotopes of national importance. The vegetation surveys are carried out in dry meadows and pastures, floodplains, fens and bogs. For the selection of sites and plots within sites, we used two-stage unequal probability sampling and prior information on vegetation types to increase the coverage of small regions (e.g. Southern Alps, Jura) and rare vegetation types (e.g. Stipo-Poion) in our sample. Sampling efficiency, i.e. the accuracy of the estimates, was ensured by an additional balanced distribution of samples (sites and plots) across geographical and ecological space. We will demonstrate the principles and benefits of the advanced sampling design and present exemplary results of state and change estimates for three types of indicators (number of species, plant indicator values, area of target vegetation types).

NC1
03

Human–computer interaction – reflections on the impact of design and development of a smartphone-app for citizen science and nature experience

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In the last two decades, citizen science has received a major boost through the use of technology and numerous smartphone apps have been created. Particularly in the field of plant and animal observation and identification, there are numerous mobile apps in use worldwide that initially appear very similar. However, a closer analysis of the human-computer interaction based on the design and functions reveals several approaches. These differences ultimately lead to different potentials and challenges in terms of citizen science observations and user experience of nature. In our talk, we will use the Naturblick smartphone app, which we have been developing in an interdisciplinary team since 2015, as an example to show how design and functions influence interaction with users. The smartphone app Naturblick supports nature experience in urban environments with a variety of functions to identify animals and plants and save observations. Observations are based on the users' spontaneous interests which are sparked by their nature interactions. We will discuss our approach in comparison to other widely used apps such as iNaturalist. Using users' observations we will show patterns in urban nature experience, as well as compare geographical coverage. Furthermore, we will critically reflect the influence the user-interaction has on the usability of opportunistic citizen observations for citizen science.

NC1
04

Measuring aquatic environments: upscaling the resolution of a biotic index

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Aquatic macroinvertebrates are a diverse and ecologically relevant organismal group, yet strongly affected by anthropogenic activities. As many of these taxa are highly sensitive to environmental change, they are a particularly good early warning systems of human-induced change, thus leading to their intense monitoring. In aquatic ecosystems there are a plethora of biotic monitoring approaches which are used to calculate ecological indices describing the state of aquatic systems. Many of the methods and indices used are not only hard to compare but are difficult to scale in time and space. Novel DNA-based approaches to measure the state and change of aquatic environments now offer unprecedented opportunities, also for possible integration towards commonly applicable indices. Here, we move beyond traditional point based biotic indices with a proof of concept for spatially upscaling ecological indices based on environmental DNA, demonstrating how integration of these novel molecular approaches with hydrological models allows an accurate evaluation at the catchment scale.

NC1
05

Rapid Biodiversity Assessment survey for efficient forest biodiversity evaluation in central European forests

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We propose a forest biodiversity monitoring method using a 'Rapid Biodiversity Assessment' protocol, developed for central European forest ecosystems, within the framework of the Trittsteinbiotope projects (https://trittsteinbiotope.at/). It encompasses forest structural elements and different species groups, incorporates insights from established monitoring systems, and prioritises species for monitoring under changing climate conditions. This modular survey approach combines standard assessments and intensive surveys. Standard assessments are carried out on 300 m^2 circular plots, providing fundamental information on forest structure, including elements such as forest stand site conditions, detailed tree information, deadwood and tree-related microhabitats (TreMs). Intensive surveys focus on specific taxonomic groups – namely vascular plants, fungi, birds, bats, saproxylic beetles and soil organisms – using a combination of expert knowledge from trained taxonomists, machine learning and bioinformatics. A critical component of our methodology is the connection between the soil intensive survey and the rapid biodiversity assessment. The intensive forest soil biodiversity study specifically looks at the relationship between the below- and above-ground biodiversity. The forest soil intensive study assesses abundance and diversity of three taxonomic groups, namely bacteria, fungi and arthropods, and aims to identify the environmental and forest specific drivers of soil community composition. The intensive surveys will help achieve our goal of identify indicator species linked to forest structural elements, allowing for rapid and comprehensive evaluations of forest biodiversity. Such optimised monitoring activities are crucial in assisting informed decision-making for conservation strategies to forest owners and policy-makers alike.

NC1
06

Systematic changes in diversity and composition of tree-related microhabitats across climate and human impact gradients on a tropical mountain

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Tree-related microhabitats (TReMs) have been proposed as important indicators of biodiversity to guide forest management. However, their application has been limited mostly to temperate ecosystems, and it is largely unknown how the diversity of TReMs varies along environmental gradients. In this study, we assessed the diversity of TReMs on 180 individual trees and 46 plots alongside a large environmental gradient on Kilimanjaro, Tanzania. We used a typology adjusted to tropical forests and a tree-climbing protocol to obtain quantitative information on TreMs on large trees and dense canopies. We computed the diversity of TReMs for each individual tree and plot and tested how TReM diversity was associated with properties of individual trees and environmental conditions in terms of climate and human impact. We further used non-metric multidimensional scaling (NMDS) to investigate the composition of TReM assemblages alongside the environmental gradients. We found that diameter at breast height (DBH) and height of the first branch were the most important determinants of TReM diversity on individual trees, with higher DBH and lower first branch height promoting TReM diversity. At the plot level, we found that TReM diversity increased with mean annual temperature and decreased with human impact. The composition of TReMs showed high turnover across ecosystem types, with a stark difference between forest and non-forest ecosystems. Climate and the intensity of human impact were closely associated with TReM composition. Our study is a first test of how TReM diversity and composition vary along environmental gradients in tropical ecosystems. The importance of tree size and architecture in fostering microhabitat diversity underlines the importance of large veteran trees. Because diversity and composition of TReMs are sensitive to climate and land-use effects, our study suggests that TReMs can be used to efficiently monitor consequences of global change on tropical forest biodiversity.

NC1
07

High throughput digital processing of bulk insect samples for biodiversity monitoring

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Monitoring of insect biodiversity is limited by the workload required for detailed sorting and manual identification from bulk samples that normally result from traps. The effort is generally too high to allow a complete analysis of such large samples, which can consist of several thousand individuals. Therefore, frequently general variables like biomass are used. Hereby, small taxonomic groups remain understudied even when coupled with a species list from metabarcoding. This makes it difficult to determine processes that are part of biodiversity loss, such as species turnover, relative abundance, and changes in functional diversity. A more complete characterization of the bulk samples is therefore desirable. We present a procedure that allows the automated detection of individuals in a bulk sample. Specimen are automatically sorted into size classes, digitized as bulk and organized as single objects into a database using object recognition. The procedure can be linked to machine learning approaches to further sort specimen in groups. Currently, 435 different taxonomic categories defined by size and taxonomic group at the family and genus level can be identified. We show that monitoring relevant changes in insect biodiversity can be more accurately determined by abundances of taxonomic groups than by total biomass or individual numbers. When comparing sites with different vegetation structure, small insects in particular show a response. It is likely that taxonomic groups containing parasitoids are particularly sensitive to drivers of biodiversity loss. To investigate this further, a resolution of the method to the species level is sought by complementing the investigations with metabarcoding and massive parallel barcode sequencing of digitized specimens. The barcode data will be used to inform the training database for the ML algorithm. Data are presented showing the potential of the approach to determine species inventories from bulk insect samples.

NC1
08

Wild bee monitoring in agricultural landscapes – A conceptual approach incorporating DNA analyses in biodiversity monitoring

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Wild bees are vital pollinators essential for functioning agro-ecosystems. Yet, they have faced strong population declines caused mainly by land-use change and climate change. The increased awareness for the importance of wild bees among policymakers and the general public, together with a lack of robust data on wild bee populations has led to the development and partial implementation of a nation-wide wild bee monitoring in agricultural landscapes in Germany. This monitoring scheme is, amongst others, based on non-lethal species detection via citizen science. This approach is combined with DNA analyses in order to obtain more comprehensive data on wild bee communities in agricultural landscapes. For example, *COI* (meta-)barcoding is used to achieve species-level identification for cavity-nesting wild bees and bumblebees. Additionally, pollen metabarcoding allows reconstructing plant-pollinator interactions in the surrounding agricultural landscapes. Last but not least, (phylo-) genetic diversity is assessed using different molecular biological methods and indicators. Our approach incorporates DNA-based analyses into the overall monitoring scheme and thereby achieves an ecosystem-wide understanding of wild bee communities that reaches far beyond species inventories. Therefore, our aim is to inspire researchers and policy-makers to integrate genetic methods into other long-term monitoring programmes.

NC1

09

Butterfly monitoring – survey methods and their applications

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In times of increasing pressure on biodiversity, monitoring programs are highly important to inform policy makers and the public, and support decision making towards a more sustainable future. Biodiversity loss is not a local or regional but a global phenomenon and hence collaboration between different monitoring programs is needed. The application of different monitoring methods often hinders the integration of data. The analysis of monitoring methods regarding their compatibility is therefore an important pre-requisite for a meaningful integration of data from different programs. We compared two methods used to monitor butterflies – an important biodiversity indicator group with a long history of monitoring both on national and international levels. We present results from 576 surveys at 144 sites in a study region in Western Austria comparing the widely applied transect counts (or 'Pollard walks') with more extensive area-time counts. We found strong linear relationships between the observations from the two methods regarding local and regional indicators. Our results support the integration of data from both methods for the calculation of international butterfly abundance trends such as the European butterfly indicators. The compatibility of the methods in many aspects allows the use of the monitoring method that is most suitable in the context of an individual monitoring program without losing possibilities for international cooperations. Transect counts are especially suitable in citizen science monitoring programs as they reduce the disturbance by an observer. Area-time counts are more focused on a given location. The surveyed habitat is therefore more homogeneous compared to transect walks of the same intensity which facilitates the analysis of drivers of butterfly habitat quality.

O10

Evaluation of non-destructive lysis for insect DNA metabarcoding

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In the current biodiversity crisis, the fast generation of biodiversity data is more crucial than ever. This holds especially true for so far poorly monitored groups such as insects. DNA metabarcoding of bulk samples from Malaise traps is a novel approach to obtain monitoring data of insects. DNA metabarcoding can provide large datasets on community composition with high taxonomic resolution in a very short time. To date, the most reliable metabarcoding method is based on DNA extracted from homogenized bulk samples. A proposed non-destructive alternative is DNA extraction via mild lysis. Here samples are soaked in lysis buffer from which DNA for the metabarcoding is then extracted. This approach remains the exoskeletal integrity of specimens but is more costly and time-consuming. A systematic comparison of the performance of both methods based on identical samples is lacking so far. Therefore, we here compared the performance of non-destructive lysis and homogenization of the same insect bulk samples processed with an up-scalable protocol including identical post-lysis processing of non-destructive lysate and homogenate. Our data indicate that sample homogenization delivers more reliable and comprehensive taxa lists than non-destructive lysis in most of the investigated samples, while both yield a high overlap of detected taxa. Even though both treatments recover comparable communities, we conclude that non-destructive lysis is not ideal for standard monitoring applications due to its high costs and high handling time. Still, it is a valuable tool for specific purposes that require specimen integrity.

CRISPR-Dx assays detect more elusive and endangered amphibians in environmental DNA samples compared to traditional monitoring

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Innovative biodiversity monitoring methods are required to inform conservation measures addressing the ongoing biodiversity crisis. Environmental DNA (eDNA) has been shown to be a promising method for biodiversity monitoring, for (semi-)aquatic organisms, such as amphibians. However, the large-scale application of eDNA is often limited due to the time and labor required for the analysis (metabarcoding) or for the assay development (qPCR). Instead of metabarcoding or qPCR assays, CRISPR-based diagnostic systems (Dx) may offer a more efficient alternative to analyse eDNA samples. Previous studies applying CRISPR-Dx to detect target species in eDNA used species-specific primer for amplification, which restricts their versatility for multi-species assessments. We developed a methodology termed 'ampliscanning' which combines metabarcoding primer for the amplification and CRISPR-Dx to detect several target species of interest. We created CRISPR-Dx assays for nine amphibians native to Switzerland, of which three are classified as regionally endangered, to demonstrate the potential of ampliscanning. We compared traditional monitoring data to the species detected through ampliscanning and showed that the assays can detect more species per site compared to traditional monitoring. CRISPR-Dx assays and eDNA samples specifically found more newt species per site than traditional monitoring, highlighting the potential of eDNA and CRISPR-Dx assays to monitor elusive species. Ampliscanning could therefore be suitable for large-scale assessments of elusive or endangered species to improve conservation measures and inform environmental policies.

NC1
O12

Metatranscriptomics of soil eRNA: a test study analysing soil animal communties along two elevation gradients in the Alps

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Soil communities include an infamous diversity of organisms, ranging from microorganisms and fungi to animals. These organisms coexist in the same patch, or interact by feeding on each other, or by competing for resources. Notably, organisms of soil communities differ in their body-sizes by several orders of magnitude, ranging from a micrometer to several centimeter. This diversity of organisms usually requires different extraction techniques to separate them from the soil matrix in order to assess and count species diversity. This, however, excludes the assessment of the complete community from the same patch of soil. Molecular-based, high-throughput sequencing supported methods provide a toolbox that is supposed to accelerate processing of samples and aid taxonomic assignment. Here, I will present soil community data based on RNA sequences (metatranscriptomics) that were directly generated from soil (eRNA). In contrast to metabarcoding and metagenomics, this method is expected to describe only active, i.e. living organisms, which reduces the representation of artefacts that come from shed body-particles and other molecular traces organisms leave behind. Data were collected from two different habitat types along two identical elevational gradients in the Swiss Alps. Results focus on community composition of soil invertebrates and show that metatranscriptomic data are in particular useful to assess microarthropod diversity across samples. Further, community data suffices to detect ecological differentiation across habitat types, indicating that metatranscriptomics is an interesting and informative tool for soil animal monitoring. Advantages, disadvantages and further steps required for standardisation of this type of soil monitoring will be discussed.

NC1
P1

Concept for a biodiversity monitoring in small standing waterbodies of the agricultural landscape in Germany

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Small standing waterbodies (SWBs) harbor the highest species diversity and the highest proportion of endangered species at landscape level compared to other water ecosystems. Agricultural land use can lead to plant protection product (PPP), nutrient pollution and habitat degradation, and can have profound effects on biodiversity in those waterbodies. Due to their variable hydro morphological characteristics, high heterogeneity and variety, it is especially challenging to monitor those pressures and biodiversity changes in small SWBs like kettle holes. Within the framework of the National Monitoring of Biodiversity in Agricultural Landscapes (MonViA) of the Federal Ministry of Food and Agriculture, a concept for biodiversity monitoring in small SWBs in Germany's agricultural landscape was developed. The concept focusses on benthic macroinvertebrates (BM), as they have been proven excellent bioindicators for agricultural and other anthropogenic stressors on ecosystems. Furthermore, it includes indicators concerning the state of BM diversity (taxa count, Shannon diversity and number of EPT taxa), the impact of habitat diversity on BM diversity, as well as corresponding PPP load, nutrient load, risk of PPP pollution and riparian vegetation structure. The indicators are adapted to the usage of taxonomically adjusted data and a uniform spectrum of PPP substances. A first usage of the indicators was carried out monitoring 81 kettle holes of the northeast German lowlands in regions of intensive agriculture, where the applicability of the proposed indicators has been proven successful. Additional indicators for the monitoring of the impact of PPPs on biodiversity and of aquatic vegetation are still under development. In the future, the proposed concept is intended to be applied every five years for a long-term monitoring, not only onto kettle holes but also on other small waterbody types like heath ponds, bog ponds, as well as oxbow lakes and floodplain waters.

DivMoSt – Monitoring of meadow orchards: Methods for an automated localization of meadow orchards and biodiversity evaluation of indicator organisms to supplement established biodiversity monitoring in Austria

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In recent decades, the intensification of agriculture has rapidly increased, leading to a dramatic loss of extensively managed landscapes such as meadow orchards. Meadow orchards are characterized by extensively managed grasslands on which high-stem fruit trees of different species and ages grow. These, multi-structured, semi-open habitats provide essential nesting and feeding grounds for many animal species, thus supporting biodiversity in cultural landscapes. Now no comprehensive dataset about the spatial distribution over Austria exists. For this a method has to be developed. Different characteristic meadow orchard tree categories across the Austrian eco-regions will be defined by field work in 46 meadow orchards. The field work is the basement for finally deriving a method to extract meadow orchard trees based on geospatial analysis. This will be done by combining spectral data with different spectral, temporal, and spatial resolution. As well as canopy height models derived from aerial imagery and airborne laser scanning. The aim is to identify single trees and detect the flowering stage for species differentiation. Further, established biodiversity monitoring schemes considering meadow orchards lacked in Austria so far. The project aims to address this monitoring gap by surveying specific indicator animal groups (wild pollinators, birds, and bats). To survey pollinators, i.e. wild bees and butterflies, we conduct standardized transect walks (80 m; 20 min) at each study site. Bats are recorded with automated ultrasonic recorders and captured using mist nets. Bird vocalizations are recorded with audio devices and compared to observations made at the study sites. All specimens found are identified to species level. These findings will contribute to the Austrian biodiversity report, enabling conservationists to detect potential threats sooner and implement targeted protective measures accordingly.

NC1
P3

Bumblebee monitoring in agricultural landscapes in Germany: the informative value of structured and unstructured data

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Bumblebees are important pollinators of wild plants and crops, yet their populations are declining worldwide. Among the main pressures are the intensification of agricultural land use and climate change. To better understand bumblebee population trends and the role of impact factors such as land use, large scale acquisition of bumblebee population data is needed. To obtain such large biodiversity data sets, citizen science (CS) approaches have become increasingly popular. Their ability to provide robust data on species distributions and population trends have, however, yet to be evaluated. We compare data on bumblebee populations in Germany sourced from two different CS programs: first a standardized transect-based monitoring scheme in agricultural landscapes and second unstructured data from app-mediated occasional observations. In both cases, observations were validated by experts solely on the basis of voucher photos. As could be expected, we found differences in terms of spatial and temporal coverage between the two CS programs. The unstructured scheme delivered far more observations in total, but a representative coverage of agricultural areas could be better achieved by a structured scheme. We also compared the number and share of species, as well as the proportion of observed individuals that cannot be determined to species level with certainty. We found that both CS-schemes can deliver data for different purposes such as distribution maps, bumblebee phenology and resource utilization. For a comprehensive understanding of large-scale bumblebee population trends, we suggest an integrated analysis of both structured and unstructured data in the future.

MarginUp! — How to assess the impact of new industrial feedstocks on biodiversity of marginal lands?

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Soils lost or depleted due to degradation processes such as erosion or pollution caused by agricultural intensification or abandonment can require hundreds or thousands of years to be regenerated. These, and other lands with low profitability are referred to as 'marginal lands'. To this effect, identifying practices that secure land use and return profitability to marginal land is crucial and an important contribution to European policies such as the 'European Green Deal, Circular Economy action plan, Bioeconomy and Biodiversity strategies'. In the EU-28 region, 29% of the agricultural land is classified as marginal land. The MarginUp! project is developing sustainable and circular value chains to produce bioproducts from natural raw materials grown on marginal lands and is building on learnings from seven use cases (UC): Spain, Greece, Sweden, Germany, Hungary, Argentina and South Africa. Each UC considers the current use and properties of its area and proposes crops/strategies to increase soil productivity according to local requirements. Additionally, new cropping systems provide a chance to introduce land use options that allow for integration of biodiversity promotion effects. This requires finding a balance between productivity and ecosystem services (ESS), and to consider biodiversity and social sustainability goals in the design of the systems. A central content of the MarginUp! project is the development of a Regionally Adapted Biodiversity Indicator System (RABIS), in order to be able to carefully analyse the impact of biodiversity. The scientific innovations of RABIS include the integration of the following six elements: (i) targets/indicators for multiple spatial scales, (ii) objectives of nature conservation and sustainable agriculture, (iii) influences from the diverging landscape context, (iv) multi-indicator system for two dimensions: Inside single taxa and across taxa (different trophic levels), (v) triple reference system (i.e. adjacent semi-natural habitats, previous kind of land use, and typical surrounding agriculture), and (vi) implementation of co-design activities with stakeholders/regional experts.

GolfBiodivers: The combination of traditional and novel approaches in a biodiversity monitoring scheme on golf courses

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There are few other sports where the effect on the environment is discussed as much as in golf, mainly due to the use of water, fertilizer and produced greenhouse gas emissions. Another often-discussed aspect is the space required for building golf courses, but the fact that only around 40% is covered by intensively mowed turfs is less known. The BfN-funded project 'GolfBiodivers' takes the approach of investigating the potential positive impact the remaining areas on golf courses can have on biodiversity and, in a second step, implementing different grassland restoration measures, such as sowing perennial wildflower strips and improving the mowing regime. To understand the effects of these measures, the applied biodiversity monitoring scheme starts before their implementation and will be continued until four years after. The project is carried out by four universities across Germany. A closely coordinated monitoring protocol was developed. The aspects of biodiversity monitored are vegetation, butterflies, wild bees, grasshoppers, birds and bats. While vegetation, butterflies and wild bees are monitored by established methods such as transect walks (butterflies, wild bees) and a modified Brau-Blanquet approach (vegetation), we chose the rather novel method of passive acoustic monitoring for bird, bat and grasshopper monitoring. Additionally, trap nests for solitary wild bees were installed. The combination of these methods should ensure the feasibility of such an extensive monitoring without diminishing the quality of data generated. Another aspect of the project is communicating results with other stakeholders such as golf course managers and involving the club members in citizen science projects to ensure the continuation of the measure implementation and the monitoring of their effects.

Genetic monitoring of populations by amplicon based high-throughput genotyping

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Genetic monitoring, the observation of changes of population genetic parameters during time, can help to investigate processes of biodiversity loss. Important drivers of biodiversity loss act at the population level and research plays a major role in conservation genetics and other biological foundations of nature conservation. However, genetic monitoring is not yet an established. While genetic data collections are occasionally carried out using DNA-based methods, there is a lack of a systematic and long-term approach to continuously track changes in the genetic characteristics of populations. This is mainly due to methodological limitations in terms of available marker systems, technical demand and potential of standardization. The use of high-throughput amplicon sequencing had been suggested by several authors to be used for genotyping. We further developed this approach as SSR-GBAS (short sequence repeat-genotyping by amplicon sequencing). It represents a fast and effective approach for the genetic analysis of a species and its populations. It enables the detection of a large number of markers (routinely around 100) and the cost-effective, parallel measurement of several thousand samples. The core of our method is the automated allele call based on the whole sequence information, which allows to reach a high reproducibility of the data collection and standardization, and to reduce homoplasies when only length polymorphisms are measured. It therefore allows the inclusion of SNP based markers like analysis of candidate genes. Most importantly, the information content of the markers are increased by the ability to identify a higher number of alleles. We present here the latest status of software development, conceptual advances. One of the examples of application is the cross species application of our method that forms the base of a long term monitoring approach in wild bees.

NC1

P7

Assessment of species diversity of Enchytraeidae (Annelida: Clitellata) along two abiotic gradients using metabarcoding

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Enchytraeidae are an important functional group in soils of temperate regions, in particular in soils with low pH. However, this group is little investigated, mainly because morphological determination is challenging. This is only possible if animals are alive, and the number of taxonomic experts is limited. Metabarcoding is a tool that may replace morphological determination by assigning species names to molecular data. These data are obtained from samples in which multiple individuals are pooled, thereby accelerating processing times considerably. However, this method has rarely been applied to soil-living enchytraeid communities. Therefore, we tested if metabarcoding is a suitable tool to assess species richness and community composition of Enchytraeidae in soil and litter layers. Samples were taken along a temperature and phosphate gradient within the framework of the ForestFloor project. In total, 23 species of 13 genera were assigned based on metabarcoding. Species richness did not differ among plots, but community composition was significantly affected by temperature and phosphorus concentration. This demonstrates that enchytraeid communities are sensitive to varying environments, and that metabarcoding data is efficient to reveal ecological trends. However, parameter of bioinformatic analyses strongly affected species assignment. We show that standardization of the workflow is necessary to generate comparative datasets and to exclude incorrectly assigned species (false positives). We conclude that metabarcoding is a promising tool to include Enchytraeidae into a wide range of ecological studies. Close cooperation with taxonomic experts is recommended to establish reliable reference databases and comprehensive assignment of metabarcoding data to species until workflows are standardized.

Trends in grassland conservation and restoration

Short title: Grassland conservation and restoration

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For many years, grasslands have been in the spotlight of conservation and restoration. Grasslands host a high biodiversity on relatively small areas and they support numerous ecosystem services, among them pollination, erosion control and carbon sequestration. Unfortunately, the abundance and quality of grasslands are declining in many regions, mostly due to intensification or abandonment of agricultural management. This sparks interest in grasslands as part of green infrastructure, in reseeding of grass-dominated swards, plant–insect interactions, ecosystem engineering of site conditions, and the socioecological framework for successful initiatives. Moreover, delayed responses of grassland communities to changed site conditions are expected in terms of 'extinction debt' and 'restoration credit'. Thus, this session aims at compiling the latest knowledge on synergies and trade-offs between grassland conservation and restoration.

NC2
01

Is trait-based restoration able to achieve European habitat types?

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Ecological restoration assists ecosystems to develop towards a desired state such as certain European habitats. Such habitat types are well defined by plant sociology through the expert system (ESy), and by general descriptions of geographical distribution and qualitative site conditions. However, for predictive restoration, it is important to start with quantified site conditions and the functional trait space (mean, diversity) of the target plant communities. Thus, we wanted to know how much the trait space of negative and positive reference sites differs from that of restored grasslands. Furthermore, we searched for the main drivers of differences in trait space. For this study, we analysed data from reference and restored grasslands in Germany. In total, we studied 128 negative and 132 positive references as well as 484 restored plots, distributed over 187 sites. We used the ESy to assign certain habitat types to the vegetation records, ranging from relatively dry (Mesobromion) over mesic (Arrhenatherion) to wet grasslands (Molinion, Calthion). We collected data of soil conditions, restoration and management measures, and landscape characteristics. The functional traits of the leaf-height-seed scheme were used, i.e. specific leaf area, canopy height and seed mass. We expected clear trait differences between the dry and wet habitat types compared to the negative references, because the latter were intensively used homogeneous and species-poor mesic grasslands. We hypothesized few differences in mean trait values between mesic grasslands and references. However, we hypothesized a lower trait diversity (higher convergence) of negative references compared to restored plots and positive references. We predicted that a combination of local site conditions, management and landscape factors determine the trait space. Our results provide a representative assessment of the practicality of trait-based restoration with the goal of achieving certain protected European habitat types. The presentation is part of the Grassworks project with the University of Applied Science Anhalt: Anita Kirmer, Annika Schmidt, Line Sturm; and the University of Lüneburg: Christin Laschke, Vicky Temperton, Alina Twerski

NC2
02

Spatial patterns of taxonomic, phylogenetic, and functional diversity in plant communities across grassland habitat types

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Benchmarking biodiversity in grasslands is crucial to prioritise areas for conservation or restoration. However, monitoring plots in grasslands have different plot sizes which poses challenges for benchmarking and comparing biodiversity across sites. Additionally, most biodiversity benchmarks are currently based on species richness. But, to maximize the diversity of ecosystem functions and services, it is recommended to also consider phylogenetic and functional diversity. However, our understanding of how phylogenetic and functional diversity patterns align with species richness patterns in grassland communities, and if this varies with spatial scales and habitat types, is limited. In our study, we compared the plant species, phylogenetic, and functional trait diversity of grassland communities sampled in seven plot sizes (0.0001–100 m^2) across different grassland types in Ukraine. We determined whether patterns are scale-dependent, whether they align across the three tested biodiversity facets, and whether they differ across habitat types. By considering both species presence/absence and relative cover in the community, we evaluated the influence of locally common and rare species. Our results indicate that the richest habitats vary with scale, but also depend on the biodiversity facet being considered. This was particularly evident for functional diversity, where communities were poor at small but rich at larger scales in meso-xeric grasslands, and vice versa in pody grasslands. The ranking of grasslands in terms of their biodiversity varied depending on whether rare and common species were given equal weight. This highlights the influence of rare species on the scale-dependent patterns of biodiversity. Based on our findings, we emphasize the importance of incorporating spatially resolved data on phylogenetic and functional diversity into the benchmarking of biodiversity to maximize the alignment with management, conservation and restoration goals.

NC2
03

Estimating grassland restoration success across environmental conditions using beta diversity and metanetworks

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Seed limitation in degraded grasslands is a major restoration challenge. A common countermeasure in restoration projects is the transfer of seed-containing plant material from species-rich donor sites. So far, however, results are mixed due to high context specificity. Here, we present an attempt to quantify restoration success across a highly variable set of plant species and site conditions. We investigated 41 restored grassland sites and their 37 respective donor sites in Germany and Luxembourg. In 2021, vegetation of donor and restoration sites was sampled in two to four 25 m² plots each. Altogether, 430 plant species were recorded, each of which occurred on average in 10% of the sites. We defined the plant community of a donor site connected to a restoration site as ecological target. Restoration sites differed in previous land use, post-restoration management, type and design of seed/plant material transfer and year of restoration activity. Mean beta diversity between pairs (or groups) was low, but related to several site factors (previous land use, later management and plant species richness). Next, we constructed metanetworks by linking successfully transferred plant species to restoration sites, allowing for comparisons among species across environmental conditions. We identified overlapping sets of 'over-achiever' plant species based on indices related to similarity, contrast and site relevance compared to other species. The same analyses were conducted for a metanetwork linking plant species in donor sites to restoration sites were transfer was unsuccessful, revealing analogous plant species sets of 'under-achievers'. In conclusion, in the highly diverse dataset, the analyses allowed to identify rare and common plant species that are successfully transferred under variable environmental conditions versus rare and common plant species that need more attention for facilitation of widespread restoration success.

NC2
04

Evaluating the impact of grassland management on wild bee communities along an elevational gradient

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The ecological significance of grasslands and their role in supporting wild bee populations is widely acknowledged. However, these ecosystems face threats from both land-use practices and climate change. Elevational gradients pose an interesting opportunity to test the potential cumulative or synergistic impacts of land-use intensity and the varying abiotic conditions encountered along elevational gradients. Understanding these effects is imperative for developing effective conservation strategies, particularly in the context of climate change adaptation. In this study, we explore the influence of these factors on wild bee communities and their functional and taxonomic diversity. Wild bee communities were assessed in 30 grassland sites, which are characterized by varying degrees of elevation (700–2100 m a.s.l.) and land-use intensity. Surveys were carried out during two seasons from May to August using time-area standardized transect walks and yellow, white, and blue colored pan traps. In the first of two survey years a total of 1216 individuals and over 130 wild bee species were recorded. Preliminary analyses were conducted using flower richness as a proxy for land-use intensity, indicating that the effect of increasing elevation on wild bee abundance is more pronounced when flower richness decreased. Wild bee species richness in turn decreased with decreasing flower richness, indicating a potential positive effect of grassland extensification on wild bees along elevational gradients. Analysis on functional diversity and community composition, along with specific land-use variables, will provide further insights into wild bee community responses and adaptations to land-use intensity and their interactions with the changing climate.

05

Does the protection of Swiss dry grasslands of national importance work?

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To protect precious habitats and to counteract the ongoing decline of area and biodiversity, Switzerland designated about 7000 legally protected sites of national importance, representing a crucial element of the network of protected sites. In 2011, the program 'Monitoring the effectiveness of habitat conservation in Switzerland' was launched to observe developments and changes in the sites of national importance. Using remote sensing as well as floristic and faunistic field surveys, we evaluate whether these sites are developing in line with their conservation targets and whether the area and quality of habitats are maintained. The first survey period was finished in 2017, the second in 2023. Of these 7000 sites, 3951 are so called dry meadows and pastures of national importance, covering 0.7% of the country. These sites represent various vegetation types of mostly semi-natural grasslands and cover wide ecological and elevational gradients. They are extensively managed by farmers, receiving direct payments. Based on repeated vegetation surveys of about 3000 10-m^2 plots in about 450 grassland sites, we will analyse temporal changes of mean ecological indicator values and species richness and whether changes varied along ecological gradients (e.g. elevation) and are affected by several abiotic factors (e.g. slope, soil, climate). First analyses suggest positive developments such as decreasing mean nutrient values. Additionally, we compared new with six-year-old aerial pictures to quantify trends in the encroachment of woody species, and we report these trends to the cantons by means of an online early-recognition system. So far, already 523 grassland sites have been evaluated by the cantons and in several sites, measures were taken to counteract negative developments. In conclusion, we highlight the scientific and applied importance of biodiversity monitoring programs and of protected sites for habitat conservation.

NC2
06

Nitrogen limitation promotes the competitive strength of invasive plants in temperate grasslands

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Understanding the mechanisms underlying the competitive interactions between native and invasive plant species is crucial for effective ecosystem management, especially under the many challenging scenarios posed by global changes. In temperate grasslands, where these dynamics play a pivotal role in biodiversity conservation, the role of nutrient ratios vs nutrient amounts in shaping competitive outcomes remains a key question. Through a series of pot experiments, this study investigates the impact of N:P ratios as well as of different N:P amounts on the competition between common native and invasive plants in temperate grasslands. By manipulating levels of nitrogen limitation (different N:P ratios) under high and low nutrient amounts, we assessed the relative importance of N:P ratios in influencing species interactions. In one experiment, species grew in monocultures or in invasive-native pairs with *Solidago gigantea* and *Erigeron canadensis* as invasive, and *Plantago lanceolata* and *Centaurea jacea* as native species. In another experiment, the invasives *Eragrostis curvula* and Portulaca oleracea grew in monocultures or in mixtures where one invasive plant competed with four common native species (n = 5 plants per pot). We examined nutrient effects on plant growth, above- and belowground biomass, root-to-shoot ratio and functional traits associated to resource-use strategies. Our findings show that nutrient ratios exert a stronger influence on competitive outcomes than nutrient amounts. Specifically, native plants compete more strongly with invasive species under conditions of balanced N:P ratios. In turn, imbalanced ratios that exacerbate nitrogen limitation, favour invasive species over natives. Our results highlight the importance of considering nutrient stoichiometry in predicting and managing plant invasions in temperate grasslands. These insights can inform the development of conservation strategies aiming at mitigating the impacts of invasive species and protecting native biodiversity in grassland ecosystems.

NC2
07

Alien plant invasions in a temperate grassland biome: a case study from northern Kazakhstan

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The spread of alien invasive species has severe environmental and socioeconomic impacts, and necessitates expensive management actions. Theory predicts that plant community invasibility is an important determinant of invasions. While many empirical studies have shown contrasting levels of invasion across habitat types, there are relatively few studies from temperate Asia. This study is one of the first baseline studies on the levels of invasion in the Central Asian steppe biome, where marked land-use changes and expanding traffic have taken place. The goal of the research is (i) to compare the levels of alien plant invasion across five habitat types (steppe grasslands, brackish grasslands, shrublands, riparian forests and ruderal vegetation) in the region, and (ii) to identify the drivers of invasion, hypothesizing that levels of invasion are related to land-use type, degree of disturbance, vegetation type and soil structure. Field data were gathered from surveys of 177 plots in the steppe region of north-eastern Kazakhstan, south-western Siberia. Shrublands and ruderal sites were the most invaded habitats, riparian forests were moderately invaded, while dry steppe and brackish grasslands were least invaded. Considering land-use type, agricultural (both former and current), industrial and residential use favoured the establishment of alien plants. In contrast, free-roaming livestock on pastures did not promote invasions. In ruderal and shrubland habitats, high levels of disturbance increased alien species abundance. In all habitat types, the percentage cover of ground vegetation was negatively correlated with invasion level. We conclude that high levels of anthropogenic disturbance are increasing habitat invasibility, while abiotic stress, low rates of introductions and invasion lags likely constrain invasions in dry steppe and brackish grasslands in the study region.

NC2
O8

Grazing effects on insect communities and insect-plant networks in mountain pastures

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Grazing management has to be adapted to an earlier start of the growing season induced by climate change to maintain pastures productive and prevent shrub encroachment. To date, we lack information on how plant and insect communities respond to these changes in site conditions and management. We investigated how different livestock turnout dates affected (i) the composition and diversity of vegetation as well as plant biomass, (ii) the diversity of pollinators and phytophagous insects, and (iii) insect-plant networks. To do so, we studied the effect of different livestock turnout dates in eight alpine pastures in the Berchtesgaden biosphere region (Bavaria, Germany), six of them located in the National Park (Northern Limestone Alps). Over the grazing seasons 2021 and 2022, we surveyed wild bees, butterflies, planthopper, vegetation and insect-plant interactions in early and mid/late summer. In total, 323 vascular plant species were identified with an average of 45 ± 14 plant species per 9-m^2 plot. We collected 27, 56 and 95 species of wild bees, butterflies and planthoppers. We found that the diversity of wild bees and plant hoppers (but not that of butterflies) was affected by early turnout dates mediated by vegetation. Moreover, the phylogenetic diversity of wild bees, butterflies and monophagous plant hoppers was significantly higher in late livestock turnout treatments than in early ones.

NC2

09

Productivity, moisture, competition — Habitat conditions affecting population viability of the wet grassland orchid *Dactylorhiza majalis* under conservation-oriented management

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Semi-natural wet grasslands are targeted for conservation due to their high biodiversity. Despite conservation efforts, they often face ongoing declines in typical species. To enhance the viability of typical grassland species, a nuanced understanding of the site-specific conditions affecting their fitness and recruitment is needed. We studied 95 extensively used wet grasslands in NE-Germany to identify habitat conditions jeopardizing long-term population growth, abundance, recruitment and fecundity of *Dactylorhiza majali*s, a characteristic orchid of Central European semi-natural wet grasslands. Despite conservation-oriented management (e.g. annual biomass removal), increased site productivity emerged as primary threat to *D. majalis* viability. Moist, but not excessively wet conditions and high base-saturation proved particularly beneficial for *D. majalis*. High abundance and recruitment of *D. majalis* coincided with positive long-term population growth and the occurrence of further rare specialist species. Interestingly, larger plant sizes in *D. majalis* were related to low population viability, deteriorating site conditions and rather generalist species. Our results suggest that the occurrence of few but larger *D. majalis* individuals may indicate deteriorating site conditions, requiring intensified management. In rather productive sites, more frequent or earlier biomass removal would be beneficial for viability of *D. majalis* and other habitat specialists. While stabilizing catchment hydrology is crucial for wet grassland conservation in general, moist areas without excessive or permanent saturation must be ensured to conserve particularly species-rich types of semi-natural wet grasslands.

NC2

O10

Sowing functional grasslands: Effects of forb- and legume-rich seed mixtures on biomass yield and fodder quality – a mesocosm experiment

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The scientific debate on agriculture vs biodiversity is driven by the increasing amount of global livestock and the corresponding need for intensive grassland use. The main challenge is that high intensity grasslands produce high dry matter yields but maintain low species diversity. Increasing the fodder quality produced in more diverse grasslands might be an alternative option combining agricultural needs with contributions to biodiversity. Reseeding species-poor stands with legumes and other forbs has become possible with the increasing commercial availability of native seeds. Thus, functional mixtures should be developed and tested, since there is little knowledge on establishment of such species and their effects on fodder quality. Therefore, we designed four forb- and legume-rich seed mixtures and studied them in a four-year mesocosm experiment that imitated agricultural management through cutting and fertilising. Species establishment, dry matter yield, net energy lactation as a measure of fodder quality, and plant functional indices, i.e. species richness, divergence and evenness, were measured every year. Dry matter yield increased with time, and a high proportion of forbs and legumes improved fodder quality while not compromising yield. The functional indices differed among mixtures but had no further effects, whereas annual variation in yield and fodder quality was considerable. While not all species persisted, we identified some legumes and forbs with potential to be reseeded at larger scales. This application would benefit biodiversity without jeopardising yield or fodder quality of agricultural grasslands.

NC2

O11

Bringing back bumblebees: Modest diversification in intensively used grasslands promotes pollinators

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The intensification of grasslands over the past century led to homogenous meadows and pastures of very low plant diversity. The strong dependency of the dairy production system on few highly-productive species poses a risk under global change. The vulnerability of the key species perennial ryegrass to droughts, reoccurring calamities, and infestation with robust weeds increasingly reduces the efficiency of these systems. Diversified grasslands with legumes, herbs, and several grass species can increase the resilience of the ecosystems and secure productivity under the pressure of climate extremes by harnessing biodiversity effects. By including legumes and herbs, the floral resource availability of the landscape increases strongly and, therefore, provides food for insect pollinators. In a field trial, five grassland mixtures were tested under real-life agricultural conditions. They were monitored for their vegetation composition, fodder value, and attractiveness for wild bees and hoverflies. Generalist wild bees, mainly bumblebees, showed strong increases in abundance. Hoverfly abundance benefited from presence of ribwort plantain. The diversified fodder fulfilled the high demands of dairy cows. The good performance was consistent over three different soil types and a range of demanding weather conditions over a three-year period. A modest diversification proved to be easily applicable with fast results for both farmers as well as pollinators.

NC2

P1

Biodiversity dynamics in response to land use intensification in Swiss grasslands

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In Switzerland, traditionally managed grasslands are part of the Alps' cultural landscape. Lowland grassland management has intensified since the 1950s and replaced traditional management, decreasing biodiversity and homogenising community assemblages. Recent studies indicate that land-use intensification is also increasing in mountainous regions. However, this process received only little attention and parallels what has happened in the lowlands in the past. We assess the increase in land-use intensification, and its effect on biodiversity, using data from Swiss national diversity monitoring programs collected over the past two decades. We quantify land-use intensification using shifts in vegetation and link them to diversity changes along elevation, climatic, and other environmental gradients. The first results indicate that land-use intensification is linked with a decrease in vascular plant richness, and that this effect depends on elevation. The results of this project will help orientate conservation policies in the Swiss Alps.

P2

Interactions between parasitic plants and invasive hosts: the experimental evidence

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Plant invasions are a component of global change that threatens biodiversity and impacts ecosystems worldwide. The main concerns of traditional invasion biology were exclusively alien invaders, but expansions of native species (native invaders) have recently been shown to have comparable effects on biota. Preventing further invasion, reducing invasive species, and restoring the original diversity represent a major global challenge. Biological control represents a significant component of plant invasion management. Parasitic plants may be used within the Biotic Resistance Hypothesis framework, which relies on antagonistic ecological interactions between the invader and its generalist native enemy. Therefore the recent experience suggests mainly root hemiparasites and parasitic vines (*Cuscuta, Cassytha*) with relatively wide host ranges as potential biocontrol agents. Our recent project focuses on gathering systematic empirical evidence on the interactions between alien and native invasive plants and root-hemiparasites in the Czech Republic. We have conducted an extensive pot experiment testing parasite-invader combination. Pilot field trials were consequently established for the promising associations. Among all the candidate invader-hemiparasite pairs, we identified *Melampyrum arvense* and *Odontites vernus* as hemiparasites, which may suppress alien invaders *Solidago gigantea*, and *Symphyotrichum lanceolatum*. For these, we established detailed field experiments. Just after one year, *Melampyrum* proved to be highly successful against *Solidago* and moderately against *Symphyotrichum*. With *Odontites*, we encountered issues with its establishment, which we hope to overcome next year. Additional hemiparasite-host combinations still wait to be tested.

NC2

P3

Gene flow in three common grassland species – Isolation by distance or isolation by resistance?

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European grasslands, while known for their biodiversity, suffer from change due to intensification of management and abandonment of traditional land use. This has led to a decrease in total grassland area and increased fragmentation of remaining habitats. Fragmentation of habitats and the resulting isolation of populations can have many negative effects on populations. Ecological networks are one way to counteract fragmentation and the resulting negative effects on populations. The Günztal in Bavaria, Germany is characterized by intensive agriculture, however, about 40% of the area are covered by grassland. To counteract fragmentation and preserve remaining habitats, an ecological network has been established. To evaluate the functionality of the ecological network and offer insights into possible improvements we studied gene flow of three common grassland species. We collected leaf samples of *Ranunculus acris, Galium album* and *Anthriscus sylvestris* in the whole 700-km² study area and used the MIG-seq method to discover de novo SNPs. We used pairwise genetic distances between individuals to optimize resistance surfaces. These surfaces consisted of raster files of different landscape features that are hypothesized to influence gene flow (e.g. land cover, number of mowing events). In an optimization process, resistance values were attributed to different landscape elements that represent how permeable the element is to gene flow. Isolation by resistance was also compared to a simple isolation by distance model based on geographic distances. The results of this study indicate that isolation by distance alone does not sufficiently explain the genetic pattern of the studied species, and that the landscape influences gene flow. The results of this study will help to evaluate and improve the ecological network by giving insights into drivers and inhibitors of gene flow.

NC2
P4

Woody encroachment effects on biodiversity and carbon storage of mountain grassland ecosystems

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In the last 150 years, the decline of mountain agriculture has resulted in a noteworthy abandonment and ecological succession of many mountain pastures. The consequences are a loss of centuries-old cultural landscapes, associated unique biodiversity and ecosystem services important to society. Currently, in more productive and accessible pastures close to the mountain huts, land-use is intensified while remote pastures are prone to woody encroachment and abandonment. These changes are caused by issues of profitability, a lack of staff and changed management incentives. In this project we explore how woody encroachment affects the biodiversity and carbon soil storage. To do so, we selected mountain pastures along an elevational gradient in the Berchtesgaden biosphere region (Bavaria, Germany), within Berchtesgaden National Park (Northern Limestone Alps). Within each pasture, we established a gradient with three levels of woody encroachment (low intermediate, high) based on the cover of encroaching trees, such as sycamore, spruce and larch (*Acer pseudoplatanus, Picea abies, Larix decidua*). Five 9-m^2 transects were randomly placed within each woody encroachment level. Within these transects, we sampled grassland insects using sweep-netting in early and mid/late summer, and additionally grasshopers were recorded using isolations quadrats of 1 m^2 in late summer. Plant species composition and shares of plant functional groups were surveyed in subplots of 1 m^2. For invading trees, we recorded the cover, abundance, annual shoot length and browsing damage. In addition, we collected soil samples (topsoil 0–10 cm and subsoil 10–30 cm) to analyse soil biogeochemistry (including carbon, N and P stocks), and to inspect key flows associated with nutrient cycling and trace gases. Our results will provide insights into how woody encroachment affects the interplay between below and aboveground ecological processes and biocenoses.

NC2
P5

Vegetation diversity of alpine pastures in the Berchtesgaden Biosphere Region

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The Berchtesgaden biosphere region contains large areas of mountain pastures. Many years of extensive use resulted in the establishment of characteristic grassland ecosystems. As part of a field experiment comparing the effect of different livestock turnout dates on agronomic parameters and the diversity of plants and insects, vegetation data were collected on eight mountain pastures and compared to existing vegetation data of this region. The following research questions were addressed: (i) Which typical plant communities can be found on the examined mountain pastures? (ii) How relevant are the plant species compositions of the mountain pastures for biodiversity and nature conservation? (iii) Which local site conditions influence the establishment of these plant communities? Eight mountain pastures were selected in the Berchtesgaden biosphere region. A total of 13 vegetation relevés were recorded per mountain pasture. The classification of vegetation relevés and the exploration of the correlation between plant species composition and site factors were conducted using two reference datasets. We used lists of biotope indicators to evaluate relevance for nature conservation. To evaluate the effect of local site conditions, we used Ellenberg indicator values. Agglomerative clustering of experimental plots revealed (i) eight clusters belonging to Nardion (two clusters), Poion alpinae (two clusters) and Cynosurion (two clusters), Caricion ferrugineae as well as Seslerion. (ii) Being characterized by high numbers of biotope indicator species, Nardion, Caricion ferrugineae and Seslerion grasslands fall under the protection by §30 of national conservation law. (iii) Correlations with mean Ellenberg indicator values with NMDS-axes suggested vegetation composition was chiefly driven by a combination of soil pH and moisture on the one and macronutrient supply on the other hand. Meso-eutrophic pastures were additionally differentiated by elevation.

NC2
P6

Mitigating the effects of land management on farmland birds: a nesting ecology perspective

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Halting the continuous declines of farmland bird populations remains a challenge even in areas with targeted conservation management. This may be due to lacking or incomplete information on the degree to which farming practices compromise nest survival and thus local productivity. Taking a nesting ecology perspective for two conservation target species, Corn Bunting (*Emberiza calandra*) and Skylark (*Alauda arvensis*), we illustrate how data on local breeding performance inform conservation efforts. For the Corn Bunting, we characterize variation in nesting ecology between habitats, years and agricultural landscapes in relicts of its critically endangered SW German population and link nesting phenology to site-specific agricultural schedules. We suggest adapted management of fallow fields, meadows, pasture, and clover-grass leys to improve local reproductive output and stabilize populations. For the Skylark, we focus on alfalfa and clover-grass leys, a central element of crop rotation in organic farming that serves weed control, nitrogen fixation, bioenergy and fodder production. This crop provides highly attractive nesting sites for several ground nesting birds but is an ecological trap due to short harvest intervals. We report first insights on how unmown strips and elevated bar mowing may support Skylark nesting success.

NC2

P7

Quantity, not placement, of agri-environmental schemes influence the population and distribution of the grey partridge *Perdix perdix* in simulated landscape scenarios

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Habitat loss and fragmentation has caused the decline and extinction of many species globally. The grey partridge, *Perdix perdix*, is one of those species, which has declined enormously across Europe. Using real-world data on its population and distribution in Schleswig Holstein (SH), Germany, we calibrated a series of Rangeshifter models to estimate how different land cover types – including agri-environmental schemes (AES) – affect the species. Rangeshifter individual based models were tuned to match the existing population and distribution trend over a five-year period (2016–2021). New landscape scenarios for the quantity and placement of AES were then generated across Schleswig Holstein using the LandscapeR package. Three quantity categories were used: baseline (2400 AES areas, the same as currently used in SH), 25% natural (enough AES generated so that 25% of Schleswig Holstein is covered in semi-natural habitat) and 30% natural. We also tested different placement strategies by biasing or limiting the creating of new AES schemes in the simulations, including: purely random placement (AES could be generated in any agricultural area), biased (more areas were generated in areas with low permanent habitat), clumpy (new AES were clustered close together) and combination biased/clumpy. Using the tuned Rangeshifter models, we then ran them on the new landscapes and forecasted the population of *P. perdix* to 15 years into the future. Altering the placement strategy did not change the estimated abundance of *P. perdix* after 15 years for the baseline quantity scenarios (populations were predicted to remain at approximately 2800 pairs). Landscapes with increased quantities of AES had significantly higher populations of *P. perdix* after 15 years, increasing to approximately 5400 pairs on average for the 25% scenarios and 10,000 pairs under the 30% scenarios. However, there were no significant differences in simulated final populations between placement strategies.

New perspectives on biodiversity conservation and restoration success through biotic interactions

Short title: Conserving and restoring biotic interactions

Chairs: Elena Velado-Alonso, Felipe Librán-Embid

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Ecosystem restoration schemes mostly focus on re-establishing vegetation and evaluate restoration success through the abundance of indicator species or richness indexes. Conservation measures have often concentrated on flagship species or iconic habitats, neglecting broader ecosystem dynamics such as gene flows, plant-animal interactions or trophic relationships. However, fundamental ecosystem processes, such as energy flows, nutrient cycling, pollination or seed dispersal depend on the maintenance or rehabilitation of biotic interactions. Thus, assessing biotic interactions could help to evaluate biodiversity conservation and restoration success from a functional perspective. Species interactions also serve as crucial indicators to monitor systemic properties such as ecosystem stability and sensitivity to environmental changes. In this session, we propose to address biotic interactions in restoration and conservation approaches across different trophic levels, geographical scales and ecosystem types to promote ecosystem multifunctionality and guide future environmental conservation and restoration policies. We also welcome socio-ecological approaches that help to better understand the success of conservation and restoration initiatives through species interactions. Considering the 2021–2030 Decade on Ecosystem Restoration, the European Nature Restoration law and European Biodiversity Strategy this session covers a topic of high importance to tackle current societal challenges. Effective and scalable approaches are required to maintain and restore ecosystem multifunctionality. Ecological interactions can provide a new perspective to promote biodiversity and ecosystem resilience for a sustainable future.

NC3
01

Restoration success through socio-ecological interactions

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International and European policies such as the UN 2021–2030 Decade of Ecosystem Restoration, the Kunming-Montreal Global Biodiversity Framework, the EU Biodiversity Strategy 2030 and the European Nature Restoration Law are driving the implementation of restoration projects in Europe and worldwide. To facilitate large-scale restoration efforts, it is necessary to develop effective approaches to restore ecosystem multifunctionality and to provide actionable knowledge to key stakeholders. A key element for the success of restoration initiatives is the recovery of fundamental ecosystem processes, such as ecological functions, which depend on the restoration of species interactions. It is therefore essential that the implementation and evaluation of biodiversity conservation and ecosystem restoration move forward to integrate biotic interactions into their objectives and standards. The InterRest project addresses this issue by studying restored and unrestored calcareous grasslands in a transnational approach, investigating interaction networks at different trophic levels. Calcareous grasslands are one of the most biodiverse habitat types in continental Europe, but they are threatened by the current abandonment of traditional agricultural practices. InterRest explores how local restoration actions interact with agricultural management at the landscape scale to promote more complex and stable interactions, using new methodologies such as spatial meta-network approaches. It also analyses the social contexts of restoration programs and promotes knowledge dissemination through participation in the recently established BiodivRestore Knowledge Hub. By strengthening the knowledge base on restoration targets and needs through the collaboration of a European scientific network, the knowledge hub will support the implementation of the Nature Restoration Law and Habitats Directive. This presentation will provide a framework for new perspectives on biodiversity conservation and restoration success through biotic interactions, based on the InterRest experience.

NC3

02

Recovery dynamics of the functional diversity of plant-frugivore interactions after deforestation

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Interactions between plants and their animal seed dispersers are disrupted by deforestation, and it is still unclear how quickly seed-dispersal interactions can recover. We conducted an empirical study along a chronosequence of forest regeneration to investigate the time needed for the functional diversity of plants, animal frugivores and their interactions to recover. We recorded plant-frugivore interactions across 62 plots along a recovery gradient including active pastures and cocoa plantations, regenerating forests (1–38 years of forest regeneration) and old-growth forests in the Ecuadorian Chocó. For each of the recorded plant and animal species, we measured key functional traits such as fruit and gape size. Based on these data, we built trait spaces for plants, animals and plant-animal interactions. We used these trait spaces to quantify the originality of species and interactions. By computing the mean originality in each plot, we quantified the functional diversity of plants, animals and plant-animal interactions. We modelled recovery times of plant, animal and plant-animal functional diversity with an exponential function using the old-growth forests as reference plots. We observed 69 plant and 72 animal species forming a total of 290 links in the interaction network. We found that recovery times differed among the functional diversity of plants, animals and plant-animal interactions. The functional diversity of plant-animal interactions required more than 30 years of forest regeneration to recover. Plant functional diversity recovered more quickly, and animal functional diversity required more time to reach levels of functional diversity comparable to that in old-growth forests. We conclude that old-growth forests harbor functionally unique interactions and that the functional diversity of plant-frugivore interactions requires a long time to recover. Our findings suggest a bottom-up control of the recovery of plant-frugivore interactions, as the functional diversity of plants recovers more rapidly than that of animals.

NC3
03

Disrupted connections: Rainforest fragmentation affects the robustness of interaction networks between frugivorous birds and fruit-bearing trees

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Tropical rainforests are biodiversity hotspots providing a multitude of ecosystem functions and services. Seed dispersal through frugivorous birds, a vital process for tropical rainforest regeneration, is increasingly under threat from widespread deforestation, primarily due to human activities such as expanding agricultural land. This results in forest fragments of different sizes and degrees of isolation. Here, we examined the effects of forest fragmentation on the robustness of trophic interaction networks between frugivorous birds and fruit-bearing trees in the tropical lowland forests of northern Costa Rica. Our findings reveal that bird richness increased with increasing forest fragment size and landscape connectivity as well as with greater fruit availability. Additionally, modularity and robustness of plant-frugivore interaction networks was greater in larger and better connected fragments. By calculating the among-module connectivity and the within-module degree, key bird species could be identified that are crucial for network functioning. Our study demonstrates that deforestation and disturbances along forest edges result in vegetation simplification, especially reducing food sources for birds, and thereby decrease bird diversity and the robustness of plant-frugivore interaction networks in smaller and more isolated forest fragments. Consequently, the conservation of large (>220 ha), contiguous forest fragments is essential, however, we recommend to also protect the remaining small fragments (<40 ha) as they improve landscape connectivity and still harbour a considerable diversity of birds. Furthermore, conservation measures should not only focus on the threatened specialist species, but more on the key species that enhance network structure and consequently increase the resilience and robustness of species interaction networks.

NC3
04

Forest composition shapes seed-rodent interactions in a gradient of broadleaves and conifers

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Non-native tree species and mixed forests have been increasingly employed in forestry practice as a safeguard against climate change effects, and as a tool to foster biodiversity while providing economic benefits. Though these changes in forest composition may affect animal communities and ecosystem processes, they are seldom studied through a plant-animal interaction perspective. Here we investigated how forests with varying proportions of a native broadleaf (*Fagus sylvatica*) and two conifers (introduced *Pseudotsuga menziesii* and native *Picea abies*) affect rodents and their interactions with seeds. We surveyed terrestrial small mammal communities, estimated species' densities, assessed seed preference by rodents, collected data on environmental variables (understory density and tree basal area), measured *Fagus sylvatica* seed production, and tracked 1200 seeds of *Fagus sylvatica* in 20 different forest plots in northern Germany in a mast and non-mast year for *Fagus sylvatica*. Forest composition influenced the interactions between rodents and seeds. In forests with a lower proportion of broadleaves, beech seeds were harvested faster and in greater quantities, had diminished survival, and were less often cached. These results agree with three other findings: (i) seed fate responded to the proportion of broadleaves and conifers irrespective of conifer tree identity; (ii) rodents preferred nutritious beech seeds over small conifer seeds; and (iii) higher proportions of seeds were harvested during the period when beech seeds were scarce (non-mast year). Syntheses and application: This work provides evidence of how forest composition can affect plant-animal interactions without necessarily altering animal communities or population densities. Specifically, we found no differences between forests with native and non-native conifer trees regarding small mammal community, seed-rodent interactions, or seed fate. Furthermore, rodents may provide a service in mixed forests by primarily preying upon seeds of *Fagus sylvatica*, a superior-competitive species, and thus mitigate beech dominance over conifer species.

NC3

05

Restoration models based on diversity and facilitation that benefit nature and people

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Biotic interactions between plant species and between plants and their seed dispersers can define the future success of restored areas. It is well known that diversity can have a positive influence on ecosystem functioning due to the complementary use of resources by plant species. Facilitation, on the other hand, can enhance ecosystem functioning because nurse plants improve environmental conditions, leading to greater establishment and growth of neighbouring species. Therefore, the role of biodiversity and facilitation in promoting ecosystem functioning during restoration must be deeply understood. In 2016, we implemented a restoration experiment based on Biodiversity and Ecosystem Function (BEF) in a semi-arid tropical region where plant-plant facilitation interactions and tree species diversity were experimentally manipulated. In this experiment, we implemented 46 models of restored plant communities that were replicated at least three times. In these model communities, plant diversity levels ranged from 1, 2, 4, 8 and 16 species. Facilitation was included in the experimental design by assembling communities in which plant species ranged from low to high facilitation capacity, which was previously defined experimentally. The positive interaction effects between plants (facilitation) in restored communities increased leaf biomass production and the number of flowering plants over the years. In addition, plant species diversity in restored communities increased the frequency and distance of seed dispersal by ants, as well as the average number of flowers produced by *Piptadenia stipulacea* (Fabaceae), an important honey tree species planted in the experiment. These results supported the selection of nature-orientated restoration models, focusing on plant growth, reproduction and dispersal success, as well as bioeconomy-orientated restoration models, focusing on the extraction of pharmaceutical products from the leaves and honey production. Future perspectives on how biodiversity can provide economic engagement for human populations during restoration practices are discussed.

NC3

06

Seasonally changing interactions of species traits of termites and trees promote complementarity in coarse wood decomposition

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Complementary resource use by functionally different species may accelerate ecosystem processes. However, how co-variation in plant traits and animal traits promotes complementarity through temporal plant-animal interactions is poorly understood, even less so in detrital systems, thereby hampering our fundamental understanding of decomposition and carbon turnover. We hypothesized that, in seasonal subtropical forests where termites are major deadwood decomposers, trait complementarity of both termite species and tree species should promote overall deadwood decomposition through different seasons and years. Findings from a four-year coarse wood decomposition experiment involving 27 tree and 5 termite species support this hypothesis. Phenological and mandibular traits of the two most abundant termite species controlled wood decomposition of tree species differing in wood traits, through the seasons over four years, thereby promoting overall deadwood decomposition rates. Our findings indicate that complementarity in functional trait co-variation in plants and animals plays an important role in carbon cycling.

NC3
07

Impact of increased honeybee densities and landscape conservation measures on flower-visitor networks

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The structure and dynamics of plant-pollinator interactions are important for determining network vulnerability to perturbations and consequently ecosystem functioning. In agricultural landscapes, disturbances may arise from two primary sources: First, intensive agricultural practices lead to a decline in flowering plants and the depletion of semi-natural habitats, thus reducing pollen and nectar supplies as well as bee habitats. Second, proliferation of honeybee populations, commonly used to pollinate flowering crops, which often spill over into adjacent semi-natural habitats after crops have ceased flowering, may potentially reshape bee-flower networks. However, different landscape conservation measures such as organic farming, semi-natural habitats and flower fields may be able to counteract these adverse effects of land use intensification and competition between honeybees and wild bee species. To investigate the interactive effects of different landscape conservation measures and high honeybee densities on plant-visitor (wild bee) networks, we selected 32 landscapes with three orthogonal landscape gradients (organic crop cover, annual flower field cover, and semi-natural habitat cover) and conducted a honeybee density augmentation experiment in 2022. We undertook transect walks in the years before, during and after honeybee density augmentation from May until August to record bee-flower interactions in seven locations per landscape. Our study aims to assess whether increases in honeybee density (i) lead to the rewiring of plant-visitor interactions by changing the links between plant species and bees, and (ii) whether landscape conservation measures influence these outcomes. Our results will be crucial for identifying the importance of different landscape conservation measures for promoting robust flower-visitor networks and mitigate detrimental effects of high honeybee densities.

NC3
08

Effects of local and landscape restoration on plant-pollinator networks in calcareous grasslands across Europe

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Calcareous grasslands are important semi-natural ecosystems in Europe which provide habitat for species-rich communities. Yet, most of these grasslands are threatened by abandonment and fragmentation. To preserve these valuable habitats, restoration measures are widely implemented across Europe. At the local scale, the reintroduction of traditional grazing is commonly applied and measures at landscape scale might enhance the success of local restoration activities. Such landscape-wide measures can comprise, for instance, the implementation of agri-environment schemes or the conservation of semi-natural habitats. To evaluate the success of restoration measures, it is important to investigate the effects on various system properties. Besides species abundance and richness, species interaction networks can provide crucial insights into the functional recovery of ecosystems and thus, should be included in the assessment of restoration success. Yet, it is not well known how restoration measures at different spatial scales affect networks. To address this question, we analysed the interactive effects of local and landscape restoration measures on the structure of plant-pollinator networks. During 2022 and 2023, we conducted transect walks on 96 calcareous grasslands in three countries across Europe: Estonia, Germany and Spain. First results show that increasing plant diversity reduces the nestedness of plant-pollinator networks. In addition, there is evidence that agri-environment schemes in the surrounding landscape might lead to less nested networks in Germany, while grazing intensity might increase nestedness in Spain. The preliminary results demonstrate the importance of local and landscape restoration measures on the structure of plant-pollinator networks, but the effects are highly region specific. We discuss the implications of our results for the planning of restoration measures on a regional scale to advise European restoration policy.

NC3
09

Comparison of plant and insect diversity on different flowering field mixtures and densities

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Land-use intensification is one of the main drivers of the loss of biodiversity in insects and plants. Many different arrangements have been developed to counteract this massive decline. As such, flowering fields are a popular instrument often used in agricultural land, villages and cities. In practice, the large variety of flowering fields makes it difficult to monitor their effectiveness, thus, calling for systematic experiments. This study reports on a 5-year experiment within a comprehensive research project to evaluate the effects of flower strips on plant and insect diversity. In spring 2020, we set up a field experiment with five seed mixtures differing in diversity, provenance and composition as well as three seed densities. Results show that effects of seed density are negligible in comparison with the impacts of seed mixture on plant establishment, diversity and flowering. A moderately diverse regional mixture showed the highest plant diversity and attracted many pollinators. However, the highest diversity mixture was more resistant against encroachment by spontaneous plants ('weeds'). Among the commercially available (and thus cheaper) mixtures, the ones with more species performed better. These results should be translated into updated practical advice for improved flower strips in agricultural landscapes.

NC3
O10

Small scale spatial repartition of plant and pollinator communities shape the structure of plant-pollinator networks in semi-natural grasslands

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Plant-pollinator networks associated with particular habitats are often simplified, with small-scale heterogeneity in the spatial distribution of plant and pollinator species being rarely taken into account when assessing network structure. In this study, we investigate the influence of small-scale habitat heterogeneity on plant-pollinator network structure using erosion hills within a semi-natural grassland matrix in Transylvania (Romania) as models. We aim to understand whether interactions between plants and pollinators on different slopes or on different hills create distinct subnetworks within a larger metanetwork, and how this structure contributes to the overall structure of plant-pollinator networks in these semi-natural grasslands. Our results concur with previous research highlighting a distinct succession of plant communities between the northern and southern facing slopes of individual erosion hills. Xerothermic grasslands with east-continental characteristics thereby define the southern slopes, whereas mesophile vegetation more characteristic to the central European deciduous region define the northern slopes. These differences in vegetation composition impact the associated pollinator communities, at least in part, leading to the partitioning of plant-pollinator networks into distinct subnetworks. Moreover, variations in hill size and height further influence network structure, emphasizing the role of small-scale heterogeneity in shaping local plant-pollinator networks. Given the trend of land-use intensification leading to the homogenization of agricultural landscapes, we emphasize the importance of preserving small-scale heterogeneity to maintain stable and resilient plant-pollinator networks and, consequently, ensure effective pollination function.

NC3
011

Balancing biodiversity and yield: Innovative agricultural practices in the Swiss lowlands

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Identifying and prioritizing both local and regional challenges of biodiversity-agricultural production trade-offs are prerequisites to formulating potential solutions to improve biodiversity conditions in agricultural landscapes and support ecosystem services such as pest regulation. In the Swiss lowlands of Solothurn, 38 agricultural fields are engaged in a co-innovative trial with farmers, testing interventions reported to benefit biodiversity in agricultural systems, including undersowing techniques and flower strips. The experimental set-up involves a pairwise design that allows evaluation of the interventions compared to traditional management in comparable environmental settings. These fields are part of a six-year crop rotation, out of which three crops, i.e. wheat, barley and oilseed rape, were monitored in 2022 and 2023. The study assesses the effects of these interventions on vascular plants, as a prerequisite for arthropod diversity, along with the abundances of natural enemies (spiders, carabids, and staphylinids) and infestation pressure of major pests (cereal leaf beetle and cabbage stem flea beetle). Additionally, yield and other agronomic and economic parameters, such as pesticide use, were collated. We found that vascular plant abundance is higher when management intensity is reduced, a result supported by increased environmental heterogeneity. Landscape-level processes are clearly shaped by the directly adjacent vegetation structure: forests and species-rich field margins drive vegetation diversity within fields and provide the resources, i.e. shelter, habitat and food, required to host abundant and diverse arthropod communities. We further confirm that reduced management helps to increase predator abundances. However, the moderating effect of predator abundances on pest populations might be minor compared to the effects of chemical pesticides and environmental factors, such as forests acting as reservoirs for pest populations. Ultimately, productivity in innovative fields was approximately 11% lower. This study lays the foundation for further research to untangle the feedback mechanisms governing pest control by natural enemies and trade-offs around ecosystem service delivery, productivity and conservation.

NC3
012

Flower-bee vs pollen-bee metanetworks in fragmented landscapes

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Understanding the organization of mutualistic networks at multiple spatial scales is key to ensure biological conservation and functionality in human-modified ecosystems. Yet, how changing habitat and landscape features affect pollen-bee interaction networks is still poorly understood. Here we analysed how bee-flower visitation and bee-pollen transport interactions respond to habitat fragmentation at the local network and regional metanetwork scale, combining data from 29 fragments of calcareous grasslands, an endangered biodiversity hotspot in central Europe. We found that only 37% of the total unique pairwise species interactions occurred in both pollen transport and flower visitation networks, whereas 28% and 35% were exclusive to pollen transport and flower visitation networks, respectively. At local level, network specialization was higher in pollen transport networks, and was negatively related to the diversity of land cover types in both network types. At metanetwork level, pollen transport data revealed that the proportion of single-fragment interactions increased with landscape diversity. Our results show that the specialization of calcareous grasslands' plant-pollinator networks decreases with landscape diversity, but network specialization is underestimated when only based on flower visitation information. Pollen transport data, more than flower visitation, and multi-scale analyses of metanetworks are fundamental for understanding plant-pollinator interactions in human dominated landscapes.

NC3

013

Fitness of four parasitoid Hymenoptera species is related to nest quality and the size of their 15 bee and wasp host species, but not to the wider environment

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Body size determines insect mobility and fitness in various ways. Yet, especially in parasitoid species, drivers of body size are poorly understood as they can be influenced by complex interactions of the environment and their hosts, as well as nest diameter. Here, we studied relationships between the size of 393 individuals of four parasitoid Hymenoptera species and nest and host quality, for fifteen species of bee and wasp hosts, along four environmental gradients (canopy cover, structural complexity, herb cover and deadwood diameter) in the Southern Black Forest, Germany. Host identity, nest diameter, and to a lesser extent, size differences within host species, were primary drivers of parasitoid body size, albeit parasitoid species differed in their responses. For instance, when the host *Trypoxylon figulus* doubled in size, *Nematopodius debilis* (parasitizing the host directly) increased by 37% in size, while *Trichrysis cyanea* (parasitizing food resources) increased by only 8%. Across host-parasitoid species combinations, there was only a weak positive relationship between the size of parasitoids and their hosts. In addition, we did not observe size variations in hosts and parasitoids across environmental gradients. This study underscores that parasitoid size strongly depends on the parasitism strategy, host identity and nest quality. In addition, host-parasitoid size relationships are largely independent of the wider environment, suggesting that parasitoids can maintain their size even in low-quality habitats.

014

Community dynamics modifies pollutant-driven species extinction risk: Simulation study with dynamic food web models

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During the ongoing biodiversity crisis it is crucial to understand the different drivers of biodiversity loss. Among these, the fastest growing driver, chemical pollution is being recognised as key. Effects of pollutants have been traditionally studied using ecotoxicological laboratory methods at a single species level ignoring biotic interactions. While these techniques are able to quantify species sensitivities to toxins in lab conditions, they perform poorly when extrapolated to the community level. Natural communities are complex networks of species with diverse traits and links. This leads to the presence of indirect effects which can modify the effect of environmental perturbations making ecotoxicological predictions at the community level difficult. The limitations of studying these network effects using experimental methods can be remedied through the use of modelling and simulation methods. In particular, food web networks can act as a great modelling tool to quantify ecological interactions of a community. Here we generate 200 synthetic food webs with energy dynamics based on Allometric Trophic Network (ATN) theory in the ATNr package. We expose them to 140 toxin levels and then simulate their population dynamics to measure species extinction rates. We show that model predictions of the extinction risk of species improve from ~20% when using intrinsic toxin sensitivity as the sole predictor to ca. 80% after adding food web traits, i.e. trophic position, eigen centrality, and generality to the model. We find that trophic position is the key predictor of relative species extinction risk followed by toxin sensitivity and eigen centrality. Generality has an insignificant effect on extinction risk. These findings have important implications in wildlife conservation and management practices, where risk assessment is an important aspect of determining species in need of most protection as well as those that can be harvested with minimal ecological impact.

NC3
015

From the FFH directive to practical implementations

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The Habitats Directive (Council Directive 92/43/EEC) is one of the main pillars to protect wildlife and nature of the European Union. The national governments were requested to specify areas for the conservation of wild fauna and flora species and their habitats, respectively. The natura 2000 network in Thuringia was established to realize this directive. It was funded by the Thuringian Ministry for Agriculture, Nature Conservation and Environment and includes twelve stations and the competence centre throughout the Free state. The stations act in the interplay of various stakeholders such as governmental and voluntary nature conservationists, forester, farmers, or diverse landowners. According to management guidelines e.g. listed within the management plans of the nature protection areas, nature conservation and restoration is initiated and conducted acquiring various public fundings. The implementation of measures includes the restoration or maintenance of different habitats mainly formed by historical use such as semi-natural grassland formations, meadow orchards or small water bodies characterized. Furthermore, species of the FFH directive like the yellow-bellied toad need increased attention to protect and develop the population. Here some examples and challenges are shown. The implementations are conducted on different local scales have single measures on very local scales or establishing connecting corridors, e.g. to enable the migration of wild cats and associated forest species between fragmented forests. Thus, intensive communication with different participating actors is essential for the success of the restoration projects. Due to their regional presence, their continuous work, and the close cooperation with stakeholders these stations are locally well connected and act as reliable partners which increase the success and acceptance of nature conservation measures within the region.

NC3

016

Towards climate-smart rewilding

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The European Union has set ambitious targets to tackle climate change: reducing net carbon emissions by 55% by 2030 and achieving net-zero emissions by 2050. To achieve these targets, it is essential that the EU focuses on increasing carbon storage in our soils and forests. This approach can also bring other benefits, such as preserving biodiversity, adapting to climate change and protecting our cultural heritage. Many experts, including the IPCC and IPBES, emphasise that ecosystem restoration and the implementation of nature-based solutions (NbS) are crucial to tackling the climate crisis. Rewilding is a type of NbS that aims to allow nature to regenerate through minimal human intervention. WildE, an innovative Horizon Europe-funded project, is introducing a new rewilding strategy called 'Climate-Smart Rewilding', which aims to generate climate-related benefits while achieving other important goals, including ecosystem restoration, biodiversity conservation and the well-being of local communities. Climate-smart rewilding could bring numerous economic benefits, particularly through the acquisition of new carbon credits. At low cost, this strategy could help meet other environmental and societal needs. Our research explores how different rewilding interventions can help mitigate and adapt to the negative impacts of climate change on both ecosystems and human well-being. We develop a conceptual framework that incorporates key components such as land use, biodiversity, climate change mitigation and adaptation, and socio-economic aspects in an integrated re-wilding analysis. This framework can enable policymakers, conservation managers, communities and the private sector to jointly develop climate-smart strategies as effective NbS across the European continent to achieve EU climate and biodiversity targets. The flexibility of the approach and the potential for economic benefits make it a compelling solution to the challenges of the coming century.

NC3
017

Rewilding indicators across Europe

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Unsustainable use of ecosystems has led to the degradation of biodiversity and ecosystem services including reduced carbon sequestration, reduced pollination, and an increase in natural disasters. Widespread restoration of these ecosystems is crucial to address the biodiversity and climate crisis. Rewilding is a form of restoration aiming at improving the condition of ecosystems by recovering natural ecological processes. It intends to restore functional and self-sustaining ecosystems that provide multiple ecosystem services and require little to no human management in the long term. In this context, we seek to develop a set of spatially explicit indicators for monitoring rewilding trends and outcomes. Mapping wildness across Europe is essential to identify priority areas for rewilding and to support the implementation of restoration targets at national and European levels. We consider that the wildness of an ecosystem depends on its ecological integrity and the extent of human pressure. The former relies on three main components: trophic complexity, connectivity, and stochastic disturbance regimes. The more natural these components are, the higher the ecological integrity. We relate trophic complexity to the extent of defaunation: the presence of large-sized fauna – based on Europe wide database and species distribution modelling – in relation to its potential. In terms of connectivity, we consider terrestrial landscapes fragmented by urban fabric, linear infrastructure, and intensive agriculture, and aquatic landscapes fragmented by dams. Natural stochastic disturbances (e.g. floods and fires) are considered through the forestry, agricultural, and grazing impacts on primary productivity. Human pressure is captured through human presence and artificial interventions. Mapping such wildness indicators provides insight into the potential areas for resilient and self-sustaining ecosystems and identifies areas where restoration efforts should be focused.

NC3
P1

Layer nests a standardized method to study multitrophic interactions of cavity nesting Hymenoptera

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Trap nests for cavity nesting Hymenoptera attract bees, serving as pollinators, and predatory wasps, controlling insect populations and pest species. Additionally, the Hymenoptera nests attract natural enemies such as parasitoids. Therefore, trap nests are a widely used method to study the effect of the environment or of experimental conditions, on the abundance and species richness of Hymenoptera and their host-parasitoid interactions. Commonly, trap nests are composed of a bundle of thin, dry, and hollow plant sticks, such as reed internodes. The use of this natural material may introduce unwanted variation in the colonizing communities, hindering standardisation of the method, and express additional drawbacks such as prohibiting insight into the nest cavity without destruction. To overcome these limitations, we developed a new trap type in which cavity diameters are standardized, visual access to the nest is given through a transparent foil, and in-time extraction of fresh nest material is facilitated without destruction of the complete nest. We compared common reed nests to the new design in terms of the Hymenoptera community composition, parasitism rates, and the economic benefits and drawbacks between both methods. In exemplary studies we highlighted how tri- to quad-partite interaction networks can be reconstructed from the new layer nest method. With this, layer nests give in depth insight into responses of trophic interactions between parasitoids, Hymenoptera hosts and their food resources, to show ecological dependencies and inform nature conservation.

From office to field and back to the lab: A journey in European mink conservation

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The European mink, a flagship species crucial for the health of freshwater ecosystems, is on the brink of extinction, necessitating urgent conservation efforts. Our project 'Restoring the European Mink in the Romanian Carpathians' is a critical initiative aimed at reviving this species and its habitat. By integrating data modelling with in-situ conservation strategies, we bridge the gap between theoretical assessments and practical conservation outcomes. Our initial phase involved creating a comprehensive model to objectively assess habitat suitability across potential restoration areas in the Romanian Carpathians. By incorporating expert opinions and analysing extensive datasets, we identified two promising restoration sites. Understanding that success depends on real-world conditions, we moved out of the office and into the field. We evaluated on-site habitat suitability, finding minimal to moderate anthropogenic impacts that could be easily mitigated. We then conducted extensive surveys using camera traps and live traps to assess species presence. Despite exhaustive efforts, no mink, either European or American, were captured. We also collected fecal and water samples for DNA and eDNA analysis, complementing traditional survey methods. This shift 'back in the lab' represents a critical juncture, enhancing our understanding of species dynamics and informing future conservation strategies. This project serves as a preparatory step towards securing long-term funding once we have substantial results from our fieldwork. The primary objective is to confirm or refute the presence of European mink in the Romanian Carpathians. Based on these results, future projects will focus on either reintroducing the species or managing the habitat to support the population. In summary, our project highlights the importance of integrating fieldwork with laboratory analysis to enhance biodiversity conservation and restoration efforts. By adopting a holistic approach that combines theoretical modelling with practical application, we aim to ensure the long-term survival of the European mink and the ecosystems it inhabits.

Are wolves re-establishing a landscape of fear in the Bohemian Forest Ecosystem?

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The Bohemian Forest is the largest strictly protected continuous forested area in Central Europe, and is of great importance for the protection of wildlife species especially animals with large home ranges. After over 170 years of absence, the first wolf pack was confirmed in the protected area in 2017. The return of this large carnivore has the potential to restore biotic interactions and the associated resulting trophic cascades, and thereby also resulting in consumptive and non-consumptive effects on wild ungulates. Red deer are the main prey species for wolves in the area, and it is possible that they have adjusted their behaviour in response to predation pressure from wolf recolonisation. This study examines red deer behaviour before and after wolf recolonisation using movement data from the Bavarian Forest National Park available since 2002. By employing integrated step selection analysis and Hidden Markov models we analyse habitat selection and behavioural states at diel and seasonal scales, whilst we investigate changes in movement speed using continuous time-movement modelling. Additionally, we also include human disturbance variables (hunting and recreation) to account for anthropogenic influence. Anticipated responses of red deer to wolf recolonisation include increased selection for closed habitats and denser vegetation cover (as wolves generally use a cursorial hunting strategy), heightened movement speeds, and altered diel activity patterns. This research offers insights into how wolves influence ungulate behaviour, providing valuable data for conservation management and implications for trophic cascades in the European context where wolves are recolonising historic ranges now under increased anthropogenic effects.

Emerging challenges in wildlife ecology and management in the Anthropocene

Short title: Wildlife in the Anthropocene

Chairs: Wibke Peters, Hendrik Edelhoff

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This session focuses on the pressing topic of how land use and other human induced changes affect wildlife species in multi-use landscapes. We will address the challenges faced by wildlife in adapting to the changes brought about by human activities, including climate change. Yet, while some species will be negatively affected, others could benefit. In this session speakers should illustrate diverse ways in which species, from large mammals to birds, have been influenced. Key topics range from habitat alteration, such as agricultural expansion, reforestation efforts, fragmentation or urbanization, as well as recreation and hunting. Research presented may cover various methodological approaches drawn from e. g. movement ecology, species distribution modelling, nutritional ecology, etc. Thus, also advances in technologies like GPS tracking, satellite imagery, camera traps or genetic studies and how they can inform our understanding of wildlife and human interactions may be addressed. Finally, traditional approaches to wildlife management could no longer suffice in the face of these changes. Speakers may discuss how wildlife management practices need to adapt to ensure a sustainable balance between the needs of wildlife and the demands of human society. By bringing together different perspectives and the latest research, we hope to encourage discussions on effective wildlife management strategies in the Anthropocene era.

NC4
01

Feed on fire: Forage quality dynamics after wildfire in semi-natural grassland grazed by red deer

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In large-scale rangelands, pyric herbivory, i.e. the interactions and feedback between large herbivores and fire, is known as an important process shaping ecosystems. But our understanding of the implications of fires for habitat use and foraging behaviour of wild ungulates in Central Europe is still limited, although wildfire risk is increasing with climate change. In the present study, we took advantage of a wildfire burning ca. 170 ha on a military training area in Germany in August 2022. Red deer (*Cervus elaphus*) are highly abundant and the main grazer species in this area. The burnt site was mainly covered by a small-scale mosaic of semi-natural grassland communities. We measured vegetation height, forage productivity, quality, and forage removal by red deer on 37 locations in October 2022 as well as in May, July, and October 2023. Comparison data on forage quality and vegetation height were available from six corresponding sampling dates in previous years (2016–2018). After the fire in October 2022, the crude protein concentration in the freshly regrowing forage was approximately twice as high and vegetation height was half as high compared to previous years. This boost in forage quality caused by the fire was noticeable for almost one year – differences between burnt and unburnt conditions vanished by July 2023. Movable exclusion cages provided evidence for substantial forage removal during the study period. Telemetry data of collared red deer in the area will show whether the animals responded to the fire and subsequent alteration in forage characteristics by changes in movement and habitat selection. The results of our study provide insights into the implications of climate change on habitats and wildlife in temperate Europe and encourage to explore the potential of integrating the concept of pyric herbivory into future wildlife and conservation management.

NC4
02

Estimating human and wildlife activities in a Bavarian multi-use forest ecosystem

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Large forested areas are attractive for human recreational activities, leading to increasing visitor numbers and potential ecological conflicts. To adapt strategies for visitor management, modelling and predicting human activities and its effects on wildlife is necessary. Here, we applied automated image recognition algorithms for classification, facilitating the efficient handling of a large data set from camera traps in the Veldensteiner Forest, which is representative for Bavaria in terms of interest groups (forestry, tourism, nature conservation, hunting) and wildlife species (ungulates, top-predators, meso-carnivores, neozoa). We designed a model capable of predicting visitor numbers for the study area, including temporal (e.g. day, season), spatial (e.g. infrastructure, parking lots, gastronomy, land cover and land use information) and weather-related factors as explanatory variables. Additionally, we modelled wildlife activities and abundances, applying novel methods such as AI-enhanced Distance Sampling. This work lays the foundation for a detailed investigation of interactions between recreationists and wildlife, such as spatial or temporal avoidance strategies.

NC4
03

Mountain ungulates and humans – Experimental behavioural analyses of the reaction of male chamois (*Rupricapra rupricapra*) to hiker

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Landscape utilisation by humans in the form of recreational tourism has changed and intensified in recent decades. However, the associated consequences for wildlife are still often unknown. Specifically for the Alpine chamois (*Rupricapra rupricapra*), the German Red List identifies increasing Alpine tourism as one of the potentially detrimental factors for this species. In this paper, we analyse the response of male Alpine chamois to hikers in a study area in the Bavarian part of the Eastern Alps. To measure individual spatial and temporal responses, we fitted male chamois (n = 10) with GPS collars. In an experimental approach, two different treatments, (i) hikers staying on the trail (n = 45) versus (ii) hikers leaving the trail (n = 34), were conducted between June and October. The route of the hikers were continuously recorded with a GPS device and the positions of the chamois were determined every 5 min using the GPS collars. To first identify reactions of the chamois to the hikers and to first classify the movement patterns (reaction vs. no reaction), we used an experiment-specific upper-control limit (UCL). In the next step, we used generalised linear mixed models (GLMMs) to test how the variation in escape distance and flight distance depended on the two treatments, path density and distance to retreat areas. The chamois ID was included as a random effect to account for repeated measurements. Our initial results indicate that male chamois show little response when hikers do not leave official trails. In contrast, clear reactions could be measured when hikers moved off the trails. The results regarding the individual movement parameters and possible consequences for tourism management in the Bavarian Alps are discussed.

NC4
04

Seasonal habitat selection by Alpine chamois (*Rupicapra rupicapra*) in the Bavarian Alps

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The Alpine chamois (*Rupicapra rupicapra*) reaches its northernmost distribution in the Bavarian Alps, where detailed knowledge of its spatio-temporal habitat use across different time scales remains limited. To address this gap, the Bavarian State Institute of Forestry initiated a research project in 2018 to investigate the habitat selection patterns of chamois. Herein, we present preliminary results based on high-resolution GPS data of 34 adult male (n = 14) and female (n = 20) chamois captured in the Karwendel study area. We investigated the seasonal home ranges, their habitat composition and habitat selection. Telemetry data was divided into summer (June–October) and winter (January–April) based on previous analyses of seasonal migration patterns. Habitat selection was then analysed using resource selection functions (RSFs) at the landscape and home range scale as a function of landcover (forest, alpine meadows, rocks and scree), tree cover density, distance to paths and topography. Models were fitted using generalized linear mixed models (GLMMs). Chamois showed distinct sex-specific habitat selection patterns. On landscape scale for example, females preferred great distances to forest roads and hiking paths during the winter season, while males did not. In general males used forested areas more frequently than females. Yet on the home range scale, females positively selected dense forest cover during summer. The distinct patterns in the spatio-temporal behaviour can be explained by different strategies of males and females to maximize their own reproductive success and stress avoidance.

NC4
05

Modelling seasonal space-use of multiple ungulate species in mountain forest ecosystems using camera traps

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Based on a camera trap study, the seasonal distribution of several sympatric ungulate species was recorded in two study areas (Karwendel and Chiemgau) in the Bavarian Alps. To illustrate the distribution patterns of roe deer, chamois, and red deer, wildlife cameras were installed at 73 randomly selected locations in both areas over a period of more than two years. First, we tested for changes in presence of wildlife species at camera trap locations with a time series analysis to objectively determine the largest alterations in space use within the study areas. Concurrently, three seasons were identified across species: winter (January–April), summer (May–August), and fall (September–December). Within these periods, the relative abundance index (RAI) for each wildlife species was calculated, considering the effective camera operating times, and extrapolated to the study areas using a Kriging method. A comparison with the results of a faecal pellet collection in fall was used to validate the estimated models. The results highlighted seasonal changes in wildlife distribution, which differed between the two areas. In the area with the lower altitude amplitude (Chiemgau), we observed shifts in the space use of roe deer and red deer between summer and winter. In the Karwendel, with a higher proportion of high mountain areas, roe deer remained predominantly in the lower elevations throughout the year. Chamois generally preferred higher and steeper regions in both areas, with changes over the course of the year being more pronounced in the Karwendel than in the Chiemgau area. The high degree of congruence with the results from the faecal collection supports the potential application of camera traps for determining seasonal differences in wildlife distribution in their habitat.

NC4
O6

Red deer habitat selection in the face of forest and human disturbances

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Red deer are widespread in Europe with increasing population numbers in many forested regions. Several factors can influence their distribution and habitat selection, such as forest dynamics and varying levels of human disturbance. In the future we will experience an increase in forest disturbances due to climate change, as well as an increase in human-wildlife-encounters due to the ongoing trend of recreational outdoor activities. However, it is yet unclear, how red deer select forest disturbances compared to closed forests and open foraging grounds and how this selection may be affected by different levels of human disturbance. We investigated red deer habitat selection in a mountainous area with forest disturbances in Berchtesgaden National Park, Germany. The two management zones of the national park (i.e. core and intervention zone) were used to analyse selection in areas with varying levels of human disturbance. Working with GPS data of 30 female red deer, we were able to assess habitat selection for one population which experienced different levels of hunting pressure and tourist activities within its home range, which guaranteed novel insights into this topic. Multi-level resource selection functions revealed that the selection of forest disturbances differed spatially and temporally depending on the level of human disturbance. Furthermore, forest disturbances were neither comparable to forests nor open areas, as they showed a unique constant circadian selection. The spatial multi-level analysis also highlighted the specificity of forest disturbances, as they were identified as the most strongly selected habitat. This strong preference for forest disturbances may lead to considerable changes in habitat selection of red deer in the future, which could also necessitate a change in management strategies for forest and wildlife management.

NC4
07

Maternal and neonatal behavioural components of roe deer bed-site selection in grassland habitats: implications for mowing activities

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In multi-use landscapes wildlife and human habitat use often overlap in space and time. Therefore, conflicts may arise, especially if vulnerable times for wildlife, like parturition and rearing, overlap with human land use. For wildlife that inhabits grasslands during spring, e.g. fawns of roe deer (*Capreolus capreolus* L.), a hider species, agricultural mowing practices pose a potentially severe threat. During their first weeks of life, mowing is one of the main causes of mortality among roe deer fawns in cultural landscapes. In this study, we aimed to understand the driving factors of bed-site selection of roe deer fawns and the influence of their mothers simultaneously, by addressing two different scales of selection. A coarser maternal scale, which reflects the selection between different meadows, and a finer fawn scale, which represents the bed-site selection within a meadow. We used a comprehensive dataset of more than 600 locations of fawns detected across a wide environmental gradient in Bavaria, Germany. At the coarser scale, we applied a GAMLSS model to test for the effect of environmental characteristics for both fawn presence and abundance in meadows. At the finer scale, we analysed fawn bed-site selection by comparing bed-sites with random sites using a clogit. Some selected environmental factors were the same for the coarser and the finer scale, while others differed, allowing us to separate the influence of females and fawns on bed-site selection. The bed-site selection at the coarser scale was mainly driven by factors describing habitat diversity, suggestive for forage availability, and cover simultaneously. Factors that characterized avoidance of predation risk dominated selection at the finer scale. Interestingly, the influence of human disturbances differed between the scales. Our findings can help wildlife managers and volunteers to prioritize areas potentially preferred by roe deer fawns and to intensify targeted searches prior to mowing.

NC4

08

An experimental assessment of acceleration, energy expenditure and behaviour-specific metabolic rates in European brown hares

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European hares (*Lepus europaeus*) are significant agents of ecological connectivity, especially in anthropogenically altered landscapes. Understanding the energetic costs associated with mammalian movement is fundamental for explaining activity patterns, movement paths and therefore the species' contribution to landscape connectivity. However, quantifying their energy expenditure in free-living conditions, especially during various activities, presents challenges necessitating innovative experimental approaches. This study aims to quantify activity costs and behaviour-specific energy expenditure of European hares and establishes a calibration for Overall Dynamic Body Acceleration (ODBA) as a proxy for energy expenditure. ODBA is easily derived from the signal of triaxial acceleration sensors by summing up the three orthogonal vectors and is therefore often used as a proxy for energy expenditure. However, it needs calibration to be applied reliably. Combining ODBA with daily energy expenditure values measured via the Doubly Labeled Water (DLW) technique, we conducted a comprehensive investigation on 26 captive hares. We incorporated differently sized semi-natural enclosures, to ensure a range of daily activity intensities. The DLW technique provided data on total daily energy expenditure, ODBA served as a proxy for activity-specific costs, while continuous camera observation allowed for a gapless behaviour classification of four non-locomotive and four locomotive behaviours. Our findings unveil the energetic demands of hare activity across various behaviours and also provide a calibration for translating the proxy of ODBA to the exact energy expenditure of European hares. Since ODBA is easily calculated in studies utilizing GPS- and acceleration collars, this study provides the basis for energy-focused research in wild European hares without impeding their natural movement.

Hot topics in butterfly research: filling gaps in our knowledge of the vulnerability of butterflies to climate change

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Climate change is a growing threat to species worldwide, yet our current knowledge of the vulnerabilities of species to climate change is biased and contains critical gaps, even in well-studied taxa. The result of this is that we are at risk of making ill-informed decisions to protect biodiversity before it is lost. Butterflies represent a particularly well-studied taxon, however the majority of our knowledge of this group comes from adults from temperate regions. Here I present data on two under-studied groups, tropical species and the larval life stage, focusing on their capacity to thermoregulate, and compare this data with temperate adults to highlight potential vulnerabilities to climate change. We found that the thermoregulation ability of adult butterflies from both temperate and tropical regions show consistent patterns relating to morphology and taxonomy, with similar traits influencing their capacity to thermoregulate across regions. We found substantial differences between life stages, with adults being able to thermoregulate more efficiently that larvae, highlighting the importance of research across the life cycle of holometabolous insects, and how the timing of extreme weather events may play a critical role in determining how species cope with climate change.

NC4
O10

Thirty years of Smooth-coated Otter presence in Singapore: Emerging challenges and future research perspectives on the return of charismatic freshwater fauna into an urban environment

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Freshwater otters as semi-aquatic carnivores are particularly sensitive to urbanization as key requirements essential for species survival are destroyed, and the risk of being persecuted is increased. The Asian smooth-coated otter *Lutrogale perspicillata* has undergone severe population declines throughout its distributional range, listed locally as `Critically Endangered` and as `Vulnerable` in the IUCN list of threatened species. In contrast, following the transformation of the island city state of Singapore from a highly urbanized industrial megacity into a `City in Nature` with restored, species-rich clean freshwater environments, since 1994 smooth-coated otters have increasingly appeared all over the island after not having been detected for almost 50 years. The otter species is currently widely distributed across all freshwater environments in Singapore, reaching high population densities that are to date not known from elsewhere throughout its distributional range. Having lost all shyness from humans, otters are even found in the city center holding dens and rearing pups on or besides pedestrian walkways. Being featured also as one of the urban-success story animal species in the BBC series `Mammals`, the otters of Singapore became famous as a major tourist attraction. Research published to date about smooth-coated otters in Singapore majorly covers behavioural and field ecology using non-intrusive methods, followed by review articles e.g. about mortality reasons and potential reasons for establishment success in Singapore. Nevertheless, a large proportion of grey and non-scientific literature that is sometimes difficult to access was detected. Future important research perspectives and challenges not addressed so far comprise elucidating the population demographic history, population trends, and especially the connectivity to the other otter populations of mainland Malay Peninsula. Emerging urgent issues include resolving the hybrid-species complex as which the otter population in Singapore is considered by some authors, as well as addressing and managing the emerging and increasing challenges posed by human-animal and animal-animal conflicts.

NC4
011

Crop diversity but not smaller field size benefits bats in landscapes dominated by agriculture

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Farmland biodiversity continues to decline due to the expansion and intensification of agriculture. Historically, efforts to conserve farmland biodiversity have focused on conserving habitats outside agricultural production areas. More recently, attention has turned to the conservation potential of the cropland matrix, where reducing field size and increasing crop diversity to promote crop heterogeneity can significantly benefit farmland biodiversity. Bats are one group of farmland species that have experienced dramatic declines over recent decades. Here we investigated the effects of crop heterogeneity (crop diversity, field size) and landscape structural elements on the activity of bat functional groups. Increasing crop diversity led to greater bat activity. However, contrary to expectations, bat activity was not affected by heterogeneity in crop configuration, i.e. field size. Furthermore, structural landscape elements, including hedgerows and distance to forest, were important predictors of bat activity, especially for species that hunt in highly cluttered spaces. While crop diversity clearly benefited bat activity, the lack of effect of crop compositional heterogeneity on bat foraging activity may suggest heterogeneity-area trade-offs and negative effects from intensive pesticide use in small-scale vegetable production. Therefore, in addition to maintaining high levels of crop diversity, promoting hedgerows and tree lines between farmland and woodland may facilitate bat activity across the agricultural landscape matrix. We conclude that the combination of high crop heterogeneity and structural elements provides favourable hunting grounds for bats and may promote their conservation in agricultural landscapes.

NC4
O12

The spatial configuration of maize fields and its impact on bird diversity in summer and autumn

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In Germany, the cultivation of maize has increased from <0.5 million ha to 2.5 million ha in the past 50 years. The benefit of maize fields for bird diversity is generally considered to be low. However, standardized data collection is scarce, especially outside the breeding season. The aim of the project is therefore to investigate if spatial configuration of maize fields (e.g. landscape context, distance to the field boundary, weed infestation) lead to better or worse suitability of maize fields as resting and feeding habitat for songbirds in summer and autumn. Based on these results, we want to develop criteria for more bird-friendly maize cultivation. Species diversity and abundance were recorded by mist-netting in maize fields (2016–2024) and the spatial use of individual birds was recorded using automated radio telemetry (2022–2023). Since 2016, almost 9500 birds of a total of 74 species have been ringed in over 100 maize fields in eleven federal states and about 900 recaptures of 29 species have been recorded. Blue Tit, Chiffchaff, and Great Tit were the most common species in maize, accounting for almost 50% of first captures. Initial results suggest that the density of individuals decreases with increasing distance from the field boundaries of maize fields, indicating that smaller fields are used more frequently. In contrast and depending on the species, the proportion of maize, woodland and shrubs in the surrounding area has either a positive, negative or no influence on the density of birds.

013

The raptor lockdown menu – Shifts in prey composition suggest urban peregrine diets are linked to human activities

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Raptors can thrive in cities where food supplies are abundant and seasonally stable. The availability of such resources may be linked to spatiotemporally predictable human activities generating reliable food subsidies for both raptors and their prey, capable of sustaining large populations. However, raptors may become affected by shifts in human behaviour. Here, we explore how urban peregrine falcon *Falco peregrinus* diets respond to changes in human activity levels amidst COVID-19 pandemic social restrictions. We used online nest cameras to study peregrine diets and reproduction across 31 sites in 27 UK cities over three breeding seasons, including one during lockdown. Prey composition changed significantly between years, and these differences varied by region. During lockdown, London peregrines took a lower proportion of pigeons (-14.5%), offset by a greater proportion of starlings *Sturnus vulgaris*(+6.9%) and ring-necked parakeets *Psittacula krameri* (+3.2%). In other cities, lockdown diets showed no change for pigeons (+0.3%), starlings comprised a lower prey proportion (-4.3%), while non-dominant corvid prey (+2.3%) and waterbirds (+2%) had greater importance. Racing pigeon prey also decreased during lockdown, significantly outside London. However, breeding parameters (number of eggs, hatchlings, fledglings) were not significantly different, suggesting urban peregrines may not have experienced food shortages amidst restrictions. Thus, our study demonstrates that human activity can influence urban peregrine predation opportunities but is unlikely to be more important than other factors like habitat availability. It also highlights how impacts can vary regionally, which may have been driven by social and geographical differences between the capital and other cities.

NC4
O14

Birdie, albatross, eagle? Avian diversity on golf courses

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Golf courses have a fairly negative image regarding their impact on the environment. Topics like water consumption, greenhouse gas emissions or fertilizer use underlie this perception. In the BfN-funded project GolfBiodivers, in contrast, we focus on their potential positive impact on biodiversity. Golf courses cover an area of 70 ha on average. Yet, only 40% of these are intensively mowed turfs, while the remaining area consists of semi-natural elements such as ponds, grasslands, hedges or woodland. Predominantly undisturbed, these areas could provide more breeding and feeding grounds for wild species than other land-use types in their surroundings such as agricultural or urban landscapes. Here, we hypothesize that variation in composition and configuration of golf courses and their embedding in the landscape lead to differences in the species numbers and identity of birds they harbour. We conducted line transects according to the DDA standard and passive acoustic monitoring on eleven golf courses in landscape contexts consisting of forests, conservation areas, peri-urban or intensive agricultural areas. There were on average 30 species on each transect walk that utilized these areas. Avian diversity are related to landscape data gathered from CORINE land cover classification and another one based on digital orthophotos. In addition, the two monitoring methods are compared in their efficacy. Thereby, we are not only aiming at understanding the role of golf courses in biodiversity conservation, but also at supporting golf course managers in applying multi-use strategies for improving and promoting conservational aspects on their grounds without diminishing the recreational function in a human-dominated landscape.

A death trap in the nest. Anthropogenic nest material entanglement causes significant nestling mortality in a terrestrial bird

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Studies of the impact of anthropogenic nesting material (ANM) have shown that entanglement of seabird nestlings is a common and serious threat. As human waste is also ubiquitous in terrestrial environments, the same may be true for terrestrial birds, but this is less well studied. This study focuses on assessing entanglement mortality of nestlings and the abundance of anthropogenic nest material. We used the White Stork (*Ciconia ciconia*) as a case study of a large terrestrial bird species. Over a period of four years, we photographed over 100 nests/year and assessed the ANM content of the nests. From these images, and through systematic weekly surveys, we investigated nestling entanglement mortality rates and entanglement materials. We also assessed the habitat surrounding the nests to infer the origin of the materials. The results showed that 91% of the nests had ANMs, with White Stork nestling entanglements occurring in almost a third of the nests. 12% of the nestlings were entangled (causing e.g. necrosis, blood poisoning and limb loss), with most entanglements occurring at an early age (~2 weeks). Rope was identified as the main material causing entanglement (almost two thirds of all entanglements) and the number of ropes in a nest was associated with a higher probability of entanglement. Most of the ropes were baler twine, a polypropylene rope commonly used in the surrounding agricultural areas. This study reveals a high level of mortality caused by ANMs and especially baler twine during the early life of nestlings. Entanglement mortality would go undetected or put down to natural mortality, in the absence of frequent surveys. This shows an urgent need for policies to stop the use of polypropylene baler twine and a call for its removal from the environment, as it clearly is detrimental to the survival and welfare of terrestrial bird nestlings.

NC4
O16

Interactive effects of forest quality and weather on nestling conditions of a cooperative breeding Afro-tropical bird

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In the Anthropocene, global forest biodiversity faces threats from changes in forest quality and fluctuating weather conditions. A comprehensive understanding of how forest organisms cope with the interaction between these changes is still lacking, as such studies require long-term observations. In this study, we utilized a dataset collected over 13 breeding seasons (2007–2021) in eight forest fragments of varying sizes and degrees of degradation within the Taita Hills, Kenya, to investigate the effects of forest quality and weather (temperature and precipitation) on nestling body condition in *Phyllastrephus placidus*, a tropical forest specialist. We used fragment sizes and canopy cover structure, collected through remotely sensed (LiDAR) techniques, as proxies for forest quality. Our findings revealed that nestlings were in better body condition (estimated as scaled mass index (SMI)) in larger, less degraded fragments. In addition, nestlings in small fragments were affected by weather conditions as they had lower SMI when temperatures were higher than the mean and higher SMI when temperatures were lower than the mean, while the opposite was true for wing length. In contrast, weather conditions had only little effect on nestlings' condition in large fragments. The contrasting results regarding the influence of forest quality and weather on SMI and wing length suggest that during early development, organisms may cope with adverse environmental conditions by allocating resources to critical body features, such as wings in the case of birds, which may increase their independence and enhance their chances of survival. Furthermore, the results indicate that large fragments with intact canopy cover can mitigate extreme weather effects while forest degradation enhances the negative effects of climate change on tropical forest birds. Thus, maintaining intact forest structures is paramount to facilitate species persistence in the face of climate change.

Living in a polluted environment – Detection of microplastics in Eurasian otter (*Lutra lutra*) feces along the River Inn

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Microplastics (MP) are omnipresent in a multitude of environments, constituting a potential threat for both aquatic and terrestrial wildlife species. Several features of MP drive their bioavailability in an ecosystem context, including their size, density, abundance and color. The pathways and consequences of MP intake are diverse and context-dependent and they include a wide range of possible effects from physical injuries to physiological responses or pathological reactions. In view of potential bioaccumulation of MP, (apex) predators are of particular interest for environmental MP studies and might be used as sentinel species. The Eurasian otter (*Lutra lutra*) is an apex predator in (semi-)aquatic habitats feeding primarily on fish, but also on amphibians, crustaceans, small mammals, reptiles, mollusks and waterfowl. The species is classified as 'near threatened' on the IUCN Red List. Thus, the Eurasian otter is of conservation concern and it might serve as a bioindicator for MP pollution in freshwater systems. First reports of MP in otter spraints appeared within the last few years, yielding evidence for MP intake of the Eurasian otter in northern Italy and Ireland and of the marine otter (*Lontra felina*) in Peru. However, data on the MP contamination of Eurasian otters in the Alps were still missing and monitoring of MP bioavailability within alpine river systems by means of bioindicators is urgently needed. As specific, validated protocols targeting at an efficient and standardized extraction of MP from otter sprainst are missing, experimental results reported from different groups are challenging to compare. Therefore, we present steps towards a standardized protocol for the extraction of MP from otter feces and apply them to field samples from five study sites along the River Inn (n = 50). We detected MP of different size and shape (ranging from microfibers to road abrasion and tire wear) in all otter tested spraint samples.

The future of biodiversity in interdisciplinary research

Short title: Interdisciplinary biodiversity research

Chairs: Margarita Hartlieb, Johanna Berger

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The loss of biodiversity, such as the decline of insects, is an anthropogenic issue, and research for its protection concerns more than just biologists. It poses a significant risk to the environment and humanity, with drivers such as changes in land use, direct exploitation, climate change, pollution, and invasive alien species. In ecology, despite its broad scope, interdisciplinarity is often understood to mean collaboration with other areas of the natural sciences. However, the future and transformation of sustainable land-use across ecosystems, landscapes, and biomes requires interdisciplinary work between natural sciences with humanities and social sciences. Interdisciplinary collaboration is essential for addressing the complex challenges of the modern world and driving innovation and progress across various fields, but also because biodiversity and human health cannot be thought of separately. Despite the additional effort involved in collaborative projects, these enhanced connections can lead to a social gain and a more effective way to reduce the loss of biodiversity and ecosystem functions. In an interdisciplinary context, researchers can learn from each other and find ways to think about social and environmental issues together to find holistic solutions. The aim of this proposed session is to bring scientists together, who are working in biodiversity research in an interdisciplinary way and would like to present interdisciplinary research projects between natural sciences with humanities or social sciences. Discussions in this session should be an inspiration to more interdisciplinary research and future solutions for biodiversity.

NC5
01

Novel natures: New technologies in nature conservation require interdisciplinary debates

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Natural environments are undergoing significant changes due to human influences. At the same time, new technologies emerge with the promise to provide solutions to environmental crises. For example, genomic analyses have revealed human-induced processes in nature that previously went unnoticed, such as the ongoing hybridization of wild and domesticated cats, potentially leading to a 'silent disappearance' of wild cats in their previous form. In addition, technological advances open up new possibilities for intervening in nature. One example is de-extinction, that is, the 'resurrection' of species using cloning techniques; another is the hotly debated application of gene drive technology in nature conservation. These new areas of research and possibilities for biotechnological intervention in turn raise significant questions about the aims and strategies of nature conservation. With this contribution, we want to point to the need of broad, interdisciplinary debates about the impact various forms and ideas of novelty in technology and in nature have on nature conservation and restoration. We will summarize discussions at a symposium that brought together an interdisciplinary group of researchers from the social and natural sciences and the humanities, as well as stakeholders from NGOs and administration, and culminated in a Focus Section titled 'Novel natures –New technologies and conflicts in nature conservation' in the journal *Gaia*. A focus of this presentation will be the suggestion of 'novel natures' as an umbrella term for considering the interconnections between novel phenomena, such as historically unprecedented combinations of species and abiotic conditions, and cultural and philosophical ideas that determine how such novelty is perceived and valued. Our aim is to open the floor for cross-disciplinary debate, thus preparing the ground for conscientious, well-informed and equitable decision-making in nature conservation and restoration.

NC5
02

What can environmental ethics do? A critique of the use of 'relational values' in nature conservation

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Nature conservation is genuinely confronted with normative questions. Ecology attempts to describe the state of ecosystems and their internal processes. However, nature conservation follows at least the normative premise that nature is worth of protection. Thus, it clashes with an old-fashioned understanding of scientific neutrality. Environmental ethics (as part of philosophy) aims at justifying and challenging nature protection and reflects on criteria for and ways to protection based on valid scientific insights and philosophical argumentation. This can be illustrated using the example of so-called 'relational values'. This concept has been intensively discussed since the last IPBES as a way towards a better understanding of the moral significance of nature. It aims at overcoming shortcomings of the traditional distinctions between 'intrinsic value' and 'instrumental values'. This distinction is the fundamental basis for differentiating between various types of environmental ethics (anthropocentric to holistic). The new concept tries to highlight the importance of relations between humans and nature. But what does this term 'relational value' mean? Are not all values 'relational' since they depend on a valuing subject? Are relations within nature tangible with the idea of relational values? Can this concept lead to the promised goal and how? What are its strengths and weaknesses? Are values in general linked to responsibilities? And more specifically, how are the values embedded in larger contexts? ('earth stewardship' instead of business as usual, green economy and degrowth)? Are there alternatives or ways of improving the concept? This talk will address these and related questions to show what philosophy can and can´t do with regard to nature conservation especially as a normative discipline to reflect political terms as well as scientific goals of ecology.

NC5
03

Eco-cultural comparison of alpine farming methods in Val Senales and Verçenik Valley under traditional ecological knowledge

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Transhumance is one of the oldest traditional agricultural methods in Val Senales, Italy, and in the Western Pontic Mountains, Turkey, and plays a huge role in shaping the intangible cultural heritage in mountain areas. In Turkey, shepherds implement components of thousands of years of knowledge of pasture management and in Val Senales, pasture management was implemented on a similar landscape since Ötzi time. This study focuses on the relationship between the grazing activity of the flocks under different management and the browsed plant species and vegetation types in alpine landscapes. The study is based on comparative ecological and ethnographic research of Val Senales, Italy, and Verçenik Valley in the Western Pontic mountains in Turkey. These two regions have similar alpine climates, but different cultural backgrounds and pasture management methods based on shepherds' knowledge. This bi-disciplinary project analyses how traditional ecological knowledge and scientific knowledge are coherent in transhumance and alpine farming systems. Staying with the shepherds in both valleys in the summer months, the monthly and daily grazing routes of the flocks were mapped, and the dominant plant species were determined along the path from barns to the high pasture areas. The coherence of anthropological and ecological results might help to create new policymaking of pasture management which shapes the alpine landscape and shepherds' lives.

NC5
04

Joint environmental and social benefits from diversified agriculture

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Agricultural simplification continues to expand at the expense of more diverse forms of agriculture. This simplification, for example, in the form of intensively managed monocultures, poses a risk to keeping the world within safe and just Earth system boundaries. Here, we estimated how agricultural diversification simultaneously affects social and environmental outcomes. Drawing from 24 studies in eleven countries across 2655 farms, we show how five diversification strategies focusing on livestock, crops, soils, noncrop plantings, and water conservation benefit social (e.g. human well-being, yields, and food security) and environmental (e.g. biodiversity, ecosystem services, and reduced environmental externalities) outcomes. We found that applying multiple diversification strategies creates more positive outcomes than individual management strategies alone. To realize these benefits, well-designed policies are needed to incentivize the adoption of multiple diversification strategies in unison.

NC5
05

Promoting insect appreciation in urban areas: Combining social and natural sciences to improve system and transformation knowledge

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The impacts of anthropogenic activities on biodiversity are manifold. In the ecological sciences, however, these effects are largely examined by means of causal relationships disregarding societal implications and without the integration of social sciences. How the promotion and protection of biodiversity reaches the societal mainstream and encourages action has been addressed less in classical biodiversity research. In view of the biodiversity crisis, new knowledge is needed on how ecological and social aspects can be combined. This includes a better and broader understanding of social-ecological interactions between human actions and biodiversity (systems knowledge). On the other hand, we need to identify approaches for promoting biodiversity among the general public (transformation knowledge). I will share insights from the inter- and transdisciplinary research project SLInBio that aims to contribute to the improvement of insect diversity in urban areas by increasing its appreciation. We combine information from social scientific data on practices with empirical data of toxicity and eDNA sampling. I will present a typology of different types of gardeners incl. their respective practices and perception of insect diversity. This typology helps to get a better understanding of the motives and barriers to implement insect conservation measures in their own garden.

06

Bridging ecological, interdisciplinary research and public engagement: Insights from the BioDivKultur project

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Ecological research is important for studying biodiversity loss and its consequences. However, for a transformation towards a more sustainable and biodiverse future, these findings must also be communicated and applied. On the one hand, environmental sciences must be considered together with social sciences to be able to take realistic and effective measures. On the other hand, close collaboration between scientists and practitioners can help to engage the public and communicate science. Together with environmental ethics, we have attempted an example of an interdisciplinary approach. A perspective on how urban green refuges can serve as refugial areas over space and time for both humans and arthropods. For a transdisciplinary approach, we have developed an online tool to provide a kind of 'statistics for everyone': An insect calculator, that can be used to predict the insects in a meadow based on a large amount of suction sampling data using mowing and environmental variables. This tool is intended to contribute to decision science and can be used by practitioners or just interested people. In addition, the insect calculator is promoted by practitioners who set up Nature Points 'points of insects' in the city, a kind of outdoor exhibition.

NC5

P1

The WiNoDa knowledge lab – data competence training for object-centered natural science collections research

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Natural science collections contain a large number of objects that help us to gain information about the history of the earth and humanity. The increasingly complex data obtained from them requires researchers to have the appropriate skills, for which insufficient learning resources are available so far. The project WiNoDa (Knowledge Lab for Natural Science Collections and Object-Centered Data) aims to counteract this by providing a place for learning, research and networking. It includes the development of a platform for collaborative work with object-centred data as well as events and other opportunities for transdisciplinary networking. As a project partner, the German Federation for Biological Data (GFBio e.V.) is responsible for the learning content, training and support in the form of a helpdesk. For the knowledge lab, various (self-)learning courses are being designed on a modular basis so that researchers can put together the desired competences according to their needs. The poster presents existing offers, planned offers and encourages dialogue with those present.

NC5
P2

Exploring the role and participation of local communities in forest fire management in the Western Himalayan Eco-Region

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The forest fires have been an integral driver of change in the forests and forest dependent traditional communities in the Western Himalayan Eco-Region(WHER). Historically, traditional communities have relied on fire for grass regeneration in the forests and to dispose farm wastes in forest-agricultural boundaries. In return, communities have often volunteered in forest fire fighting and protection of forests when fires ravaged forest landscape. Under the ongoing global level economic transition and climate change crisis, the forests of WHER are at potential risk of extreme forest fire events. The communities' ability and preparedness to manage these fire events are also threatened under an uncertain future. Therefore, this study explores the current management strategies and factors driving community level forest fire management in Uttarakhand, one of the federal Indian states in the WHER. The elevational zone of Uttarakhand, between 800–2000 m, is exposed to regular forest fire events. Communities and the forest department have the onus of managing these forest fire. The current scholarships have minimally explored this socio-ecological issue of Western Himalayan forest fires. Hence, this study appraises the current practices and socio-economic and institutional aspects of local communities that could potentially determine the community level participation in forest fire management. For the purpose, semi-structured household surveys and key informant interviews were conducted in 15 fire prone villages in the state of Uttarakhand between December 2023 to April 2024. Preliminary results will be available by July 2024. The outcomes of the study could be used to develop policy recommendation for fostering adaptive capacity of communities against forest fire in the WHER.

New developments in the field of insect declines in Central Europe

Short title: Insect declines

Chairs: Roel van Klink, Jörg Müller

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Insects are the most ubiquitous and diverse animals on the planet, providing multiple critical ecosystem services (e.g. pollination and decomposition) and disservices (e.g. crop pests and disease vectors), and forming a crucial part of terrestrial and freshwater food webs. Since 2017, the decline in the number and biomass of insects has been an important topic in ecology and conservation. Over the past few years, we have attained new insights, thanks to the publication of papers on previously poorly explored time series, resampling campaigns, causal analyses and data syntheses. It is now well established that there are fewer insects that there used to be, and that there are multiple causes for this phenomenon, all of which are related to human activities. However, the mechanisms behind most of the patterns observed are still unclear. In this session, we will bring together leading scientists to present the state-of-the-art in the field, to further our understanding of the patterns, processes, and causes of insect declines, and to stimulate new collaborations for future interdisciplinary research on this topic.

NC6
01

Temperature stress for overwintering ground-nesting bees

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Climate change leads to long-term changes in temperature. This results in changing habitat conditions. Species can react on changing conditions by either moving away or adapting to the new conditions. Bees in general benefit from warmer temperatures and longer vegetation periods in Germany, but local population may be hampered by rapid changes. To identify the influence of overwintering temperature changes on the survival of a common ground-nesting bee, *Colletes cunicularius*, we experimentally tested the influence of three different temperature regimes on bee survival. Bee cocoons have been digged out in the field and reared in climate chambers with different temperatures. The results will be set in relation to a common cavity-nesting bee *Osmia cornuta* with the assumption that ground-nesting bees are more sensitive to changes as they live in an environment generally buffered against rapid air temperature changes than our cavity-nesting model species *Osmia cornuta*.

NC6
02

Neonicotinoids negatively affect life history functions of widespread dung fly species

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The use of pesticides has increased globally over the years and has been shown to affect the health of ecosystems and organisms. Neonicotinoids are a widely used insecticide that have been shown to be toxic to non-target organisms. They have been reported to have both sub-lethal and lethal effects on the development, survival, or physiology non-target insects. However, most studies to date have investigated their effects on pollinators. In this study, we experimentally quantified the effects of larval exposure to imidacloprid (neonicotinoid) on the life history of four non-target species of Black Scavenger flies, which are important decomposers of vertebrate dung. Our study showed negative sub-lethal effects of imidacloprid on the larval development and adult reproductive performance of Sepsid species. With higher imidacloprid concentrations in the dung, we found higher larval to adult mortality, an extended development time and smaller body size. The hatched adult flies, which were paired for mating in full factorial combination to investigate sex-specific effects, were adversely affected in all measured reproductive traits, e.g. days to oviposition, hatching success, and number of offspring. However, the effects varied between species and were subtle for some. Our study demonstrates subtle to strong lethal and sub-lethal effects of imidacloprid on life history traits after exposure of juveniles as well as subsequent carry-over effects in surviving adults of four Sepsid species. Based on these results, we are currently delving into the effects of imidacloprid on adult Sepsid flies and unraveling its potential transgenerational implications, thereby contributing to a deeper understanding of pesticide-induced ecological dynamics.

Perception and effects of pesticides in the food of *Bombus terrestris*

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The decline of pollinators and its causes have been intensively investigated in the last few years. Most causes for the declines are known, i.e. pathogens, urbanization, habitat fragmentation, climate change, intensification of agriculture, etc. As part of agricultural intensification, pesticides were found to play a prominent role, as they are ubiquitous in crop plants and beyond, with sub-lethal to lethal effects on insects. While it is known that pesticides affect insects, it is hardly known whether insects can detect pesticides and potentially learn to avoid them. To address this question, we tested whether the bumble bee *Bombus terrestris* can 'taste' three systemic pesticides, i.e. Sivanto (Bayer), Closer (Corteva), and Amistar (Syngenta). We performed chemo-tactile PER-conditioning assays on *Bombus terrestris* workers to determine if bumblebee workers are able to perceive pesticides in pollen, with the help of associative learning. We additionally investigated the importance of larval feedback, the main consumers of pollen, which might alternatively or additionally inform the workers about pollen contamination. We performed long-term feeding experiments (over one complete brood development cycle) with queenless *Bombus terrestris* micro-colonies in which the workers were exposed to field-realistic concentrations of pesticides in their pollen and nectar. Two different setups were used, ‘choice’ and ‘no-choice’. During ‘choice’, the workers had access to two different treatments, and in ‘no-choice’, only one treatment was presented. We report our findings for pesticide effects on the feeding behaviour, brood development, and mortality of colonies.

NC6
04

New insights into the impact of land use on taxonomic and phylogenetic insect diversity

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The decline of terrestrial insect communities is a global phenomenon occurring in different habitats and climatic zones. Understanding the complex mechanisms driving these declines is crucial for implementing effective conservation strategies. In the past decade, numerous studies have investigated temporal trends in insect populations across diverse regions worldwide. However, despite thorough temporal analyses using a range of diversity metrics and community trends, our current knowledge does not usually allow us to unambiguously attribute different effects to specific underlying drivers, such as land use or climate change. Furthermore, sampling methods for insects and other diverse groups often fail to detect certain species. Consequently, insect samples are inherently incomplete, with varying degrees of completeness influenced by factors such as habitat types, sampling methods, years, and species communities. We analysed the effects of local and regional land use, controlling for climate and weather, on insect taxonomic and phylogenetic diversity to achieve standardised sample coverage. Using 39k Operational Taxonomic Units from 400 insect families, we showed that land use affects the efficiency of malaise traps. We found a reduction in insect taxonomic diversity from forest to agricultural environments for rare species, and even more pronounced reductions for typical and dominant species. Our findings underscore the significant role of agricultural environments as a primary driver of spatial insect diversity loss, even after accounting for sample coverage biases.

NC6
05

Simplification of insect communities across land-use and elevational gradients: conservation insights from an alpine region

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In Europe, agricultural intensification and land-use change are causing a widespread decline in insect diversity, which requires an impact assessment of land-use practices. Furthermore, climate change is expected to pose an additional threat in altering the climatic niches, community compositions and trophic interactions. Butterflies and orthopterans are considered important ecological indicators, especially in grasslands, where human intervention is the main cause of both their demise and conservation. In this study, 180 butterfly and orthopteran communities were compared across six dominant land-use types in the mountainous region of South Tyrol, Italy. These land-use types, which extend from lowlands to alpine grasslands (214–2455 m), include meadows and pastures of varying land-use intensity as well as vineyards, arable land, and apple orchards. For both butterflies and orthopterans, we found that high nature value (HNV) grasslands support high species diversity, with species numbers ranging from double to one-third more than in non-subsidized sites. Furthermore, these grasslands host more specialised and threatened communities than all other land-use types. Community compositions varied across land-use types and were influenced by plant-based indicator values reflecting site management. The climatic environment exerted a significant influence on community composition, yet its overall impact on biodiversity scores (especially for butterflies) was less pronounced than that of land use type and intensity. These findings reinforce the efficacy of regional agri-environmental measures and the European conservation strategy, which aims to preserve HNV grasslands. Furthermore, the interaction between management and climatic gradients raises questions regarding future climate change responses.

NC6
O6

Pitfalls in measuring insect populations and biodiversity trends

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The loss of biodiversity in insects has triggered an intense scientific debate about underlying mechanism. Notably in recent years, various studies have been published on the spatial and temporal trends in insect diversity. Measures used to describe such trends vary greatly and range from (total) biomass and abundance to different indices of biodiversity. Our contribution highlights the various pitfalls and ambiguities that may arise when analysing and evaluating such insect data. In particular, we show that results based on biomass may lead to different conclusion than results based on biodiversity indices. Furthermore, we show how sampling effort can influence the conclusions drawn from the data. Finally, recommendations for the design of future insect studies are presented.

NC6
P1

What controls the demography of open forest insect species? – A primer for evidence-based habitat management

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The abundance and diversity of terrestrial insects have declined sharply in recent decades in both open and forested landscapes across Europe and North America. The declines are likely due to substantial changes in habitat conditions, such as reductions in light and host plant abundance, in Central European forests following the introduction of so-called 'close-to-nature' forest management in the late 1900s. Sunlight is thought to be an essential component in the life cycle of forest lepidopterans, especially those that are specialists of open forest habitats. However, the actual effects of solar radiation on lepidopteran population demography, particularly female host selection and survival of different larval stages, are poorly understood. We mapped four endangered open forest lepidopterans, two butterfly and two zygaenid moth species, and correlated oviposition site selection, larval survival and habitat use with microhabitat parameters, in particular solar radiation. Our data show that solar radiation at the host plant is a key factor for oviposition site selection and larval survival. In addition, we found that species demography is influenced by several other habitat parameters, such as host plant abundance, local vegetation structure, conspecific density, and habitat patch connectivity. From our data we derive management recommendations for open forest lepidopterans and we present first practical examples of how these recommendations can be integrated into forest management.

NC6

P2

Radio telemetry of butterflies: research under challenging circumstances

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Radio telemetry, a widely used method in ecological research, has traditionally been applied to monitor movement patterns, behaviours, and habitat use mainly of larger animal species such as mammals and birds. Recent technological developments have led to the miniaturization of transmitters, enabling their application to insects. This taxonomic group presents methodological challenges when studying their activities due to their small size and elusive behaviour. Considering the concerning decrease in insect numbers worldwide, it is crucial to understand the complex movements and their habitat needs. In a study conducted near Tübingen, Germany, and around El Zota Field Station, Costa Rica, over 30 butterflies from eight different species were equipped with NanoPin transmitters weighing 130 mg. Radio telemetry was employed to track the movements of these butterflies. The study aimed to evaluate the feasibility of this method for investigating resource and habitat use patterns among butterflies and to identify the requirements for its broader application. The butterflies were tracked up to six days. Flight distances of up to 9 km were recorded. Our experiments shows that the success of radio telemetry does not only depend on the weight ratio of transmitter and butterfly but on morphological factors, such as thorax structure and their flight ability. Furthermore, vegetation density, obstacles and topography of the landscape can have a huge impact on the success of butterfly radio telemetry. The results suggest that radio telemetry could be an effective method for studying butterfly life history traits, especially in terms of movement patterns and habitat use. In this way the insights gained from our study contribute to a more targeted conservation strategy of butterflies and their habitats.

Temporal biodiversity change analyses to support sustainable land management and conservation

Short title: Temporal biodiversity change

Chairs: Thore Engel, Klára Klinkovská, Eva Katharina Engelhardt, Martin Friedrichs-Manthey

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Systematic and statistically meaningful time series data on biodiversity are essential in developing efficient conservation strategies and informing sustainable land management practices. Yet, such data is vastly unavailable for many species, assemblages, and regions of the world. Here, we aim at bringing together researchers and practitioners to discuss the use of biodiversity data from structured monitoring and opportunistic recordings, and ideally time series data to inform conservation management and action. Presentations are welcome from a variety of perspectives, including theoretical, experimental and applied research. We look for contributions for all taxon groups or habitat types and any type of approach, ranging from observational data to modelling. We are particularly interested in contributions focusing on the mobilisation of so-far untapped data, development of methods for data analysis and synthesis, and the integration of systematic and opportunistic data from a wide range of sources, including nature conservation societies, federal and state agencies and citizen science platforms worldwide. We also welcome contributions on how different approaches might inform decision makers and policies. We welcome both oral and poster presentations and encourage contributions from early career researchers. We look forward to a lively and engaging discussion in this important topic.

NC7
01

MonA: Mobilisation and analysis of raw vegetation data from German federal monitoring programs

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In Germany, several monitoring programs is carried out to evaluate the state of landscape, habitats and nature. They encompass terrestrial, river and marine ecosystems. Some programs are focussed on managed ecosystems, like forests and agricultural fields. These programs are often related to reporting obligations towards the European Commission, for example the Habitats Directive, the Water Framework Directive or the High Nature Value Farmlan indicator. In many programs, the evaluation and the reported quantities are based at least partly on vegetation. In these cases, the programs involve recording species occurences or abundances. Mostly this data is collected in the databases of the monitoring program but not evaluated further. In the project MonA, we aim to research and mobilise vegetation data from eight German monitoring programs which are coordinated by federal institutes and authorities (BfN, UBA, TIW) and carried out in all federal states with a harmonised methodology. The project is funded by Bundesamt für Naturschutz and carried out in cooperation with the iDiv-project sMon. In the presentation we give an overview over the monitoring programs and the types of vegetation data recorded. One research question is how the data can be utilised for biodiversity trend analyses. We will present first results from exploratory analysis.

Consistent species trends across three federal states in Germany revealed by repeated habitat mapping data

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To determine the winner and loser species of biodiversity change, systematic monitoring data are needed that cover all habitat types, extend into the last century, and are geographically representative. However, such data are lacking, but species trends might be obtained from so far untapped data. Here, we make use of plant species occurrences records that were recorded in habitat mapping programs, with the aim to derive species trends. In Germany, almost all federal states carried out such programs over the past decades, mapping all protected habitat types while also recording plant species occurrences within those habitats. Based on such data, we derived temporal trends within the three federal states Schleswig-Holstein, Hamburg, and Baden-Württemberg from 1977–2021. In addition to trends across all habitat types in each state we also derived trends within broadly defined habitat types. We found consistent negative trends across all states for species that prefer heaths and semi-natural grasslands, meadows and pastures, and coastal and marine habitats. Consistent positive trends across all states were found for species that prefer scrubs, copses and field hedges, and forests. Furthermore, species mostly showed negative trends within their preferred habitat type, while shrub encroachment occurred within most habitat types. We however also found some regional variation in trends between the states. Overall, the mostly consistent trends of species groups across the states point to common drivers of biodiversity change across the studied parts of Germany. Our findings are a conservative estimate of change, as our study included almost exclusively sites that kept their protection status over the study period. Thus, more and stronger species trends can be expected for sites that experienced severe habitat degradation.

NC7

03

Half a century of vegetation changes across temperate non-forest habitats: minor changes in species richness, considerable shifts in taxonomic and functional composition

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Natural ecosystems and their biodiversity have been seriously impacted by global changes and anthropogenic pressures in recent decades. The most threatening factors contributing to biodiversity change globally include land-use changes, climate changes, eutrophication, overexploitation, and the spread of alien species. However, the effects of these factors differ among ecosystems and habitat types. We present a comprehensive, large-scale analysis of long-term changes in plant communities of different non-forest habitat types in the Czech Republic. Based on vegetation-plot resurvey data, we explored changes at both community and species levels and focused not only on changes in taxonomic diversity but also on functional and ecological characteristics. We did not identify many significant temporal changes in plant species taxonomic diversity, however, the plant species composition of all vegetation types changed considerably through time. Trees, shrubs, taller plants, stronger competitors, species successful in colonization of new habitats, and species with higher nutrient requirements increased significantly in all non-forest habitats. In contrast, insect-pollinated, light-demanding, highly specialized, and threatened species became less represented in plant communities. Moreover, we identified considerable differences in temporal trends between habitats. Moisture-demanding species decreased in wetlands, springs and mires, whereas mesophilous species increased in dry grasslands. The increase of taller species with larger leaves, competitively strong species, trees and shrubs was most pronounced in dry grasslands, ruderal and weed vegetation, and sand and shallow-soil vegetation. The decline of insect-pollinated species was most pronounced in the alpine and subalpine vegetation, meadows, mesic pastures, *Nardus* grasslands and heathlands.

NC7
04

Effects of habitat age and ploughing on ground-dwelling arthropods in perennial flower strips

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Flower strips are a well-established measure in agri-environmental funding schemes. The primary goals of flower strips are to enhance biodiversity, promote ecosystem services, and mitigate environmental degradation associated with intensive agricultural practices. More recently the establishment of perennial flower strips has received attention to provide an undisturbed and constant nesting habitat for ground-dwelling arthropods, including important pollinators such as wild bees. Perennial flower strips are less frequently ploughed and soil disturbance is reduced, which may favour ground-dwelling arthropods. Temporal continuity and management practices, such as ploughing, may be important factors influencing the effectiveness of perennial flower strips to conserve arthropod diversity. To study these factors, we assessed the ground-dwelling arthropod community on ploughed and unploughed perennial flower strips in a two-year replicated field experiment in the upper Rhine valley, using a custom-designed type of emergence trap. We investigated the effects of temporal continuity, specifically the age of flower strips, as well as the effects of ploughing as a tillage practice on the biomass and community composition of ground-dwelling arthropods. Previous studies have indicated the negative impacts of ploughing on ground-dwelling fauna, particularly macroinvertebrates. Our study seeks to determine whether these impacts are amplified on older flower strips due to changes in ground-dwelling arthropod biomass and community composition. Understanding these factors helps to optimize the ecological functions of perennial flower fields and maximize their contributions to biodiversity conservation in managed landscapes.

NC7
05

Herbivore community stability coupling with dynamics of tree communities in a subtropical forest

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Dynamics of herbivore communities link key ecosystem functioning in forests, which is important to human-beings. Understanding mechanisms of herbivore community stability is a key challenge and is still understudied in ecological research. Based on a comprehensive data from the largest tree diversity experiment in the world, we finger out the key drivers and relevant mechanisms of herbivore community stability according to the changes in herbivore communities and host trees over time. Our study unravels the contribution of herbivore diversity, abundance asynchrony and population stability in determining the temporal stability of herbivore communities and shows that these dynamics, in turn, are strongly coupled with the functional diversity and growth asynchrony of their host tree communities. However, the effects of this bottom-up regulation differed between generalist and specialist herbivores, unveiling a clear stabilizing impact of tree species richness on the abundance stability of specialist but not of generalist herbivores. Unexpectedly, for the overall and generalist herbivore community this altogether resulted in less stable abundance dynamics at higher tree species richness, while the latter consistently promoted herbivore species richness stability. Our results thus suggest that the loss of tree species richness due to global environmental change and forest management strategies will propagate to affect the stability of communities at higher trophic levels, which might particularly destabilize community dynamics of specialists with a higher pest potential and, at the same time, compromise biodiversity conservation by reducing species richness stability over time.

NC7
06

Archived natural DNA samplers reveal four decades of biodiversity change across the tree of life

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Detecting the imprints of global environmental change on biological communities is a paramount task for ecological research. But due to a lack of standardized long-term biomonitoring data, patterns of community assembly in the Anthropocene are still not well understood. Novel sources of data for the analysis of biodiversity change across time and space are urgently needed. Here, we use metabarcoding of highly standardized biotic samples from a pollution monitoring archive in Germany to analyse community diversity for tens of thousands of species over four decades. The samples, namely tree leaves, marine macroalgae and marine and limnic mussels, serve as natural community DNA samplers, which preserve a taxonomically broad imprint of the biodiversity associated with them at the time of collection. Using these sampler organisms, we generate highly standardized 4-decade time series data for communities of tens of thousands of prokaryote and eukaryote species. Based on a newly developed statistical model, we then explore common patterns of biodiversity change across ecosystems and from microbes to animals. We show that no localized diversity declines, but gradual compositional turnover and biotic homogenization emerge as universal patterns of temporal biodiversity assembly across the tree of life in Germany's terrestrial and aquatic ecosystems. Our work highlights the immense promise of alternative sample sources to provide standardized biodiversity time series data to advance our understanding of biodiversity change in the Anthropocene.

Analysing bird population trends from monitoring data with highly structured sampling designs

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Population trends derived from systematic monitoring programmes are essential to identify species of particular conservation concern and to evaluate the efficiency of conservation measures. However, monitoring data pose several challenges for statistical analysis, including spatial bias due to an unbalanced sampling of landscapes or habitats, variation in observer expertise, frequent observer changes, and overdispersion or zero-inflation in the raw data. An additional challenge are so-called 'rolling' survey designs, where each site is only visited once within each multi-year rotation cycle. We developed a GAMM-based workflow that takes these challenges into account, exemplified for the highly structured data Ecological Area Sampling (EAS) in the German federal state North-Rhine Westphalia (NRW). First, we derive a routine that allows informed decisions about the most appropriate combination of residual families (Poisson or negative binomial), model covariates (e.g. habitat characteristics), and zero inflation formulations to reflect species-specific data distributions. Second, we develop a correction factor that buffers population trend estimates for variation in observer expertise as reflected in variation in total bird abundance. Third, we integrate model weights that adjust for between-year variation in the representation of habitat or landscape types within the yearly subset of sampled sites. In a consistency check, we find good match between our GAMM-based EAS trends and TRIM-based trends from the standard German Common Bird monitoring scheme. The study provides a template script for R statistical software so the workflow can be adapted to other monitoring programmes with comparable survey designs and data structures.

NC7
P2

Biodiversity changes in forests after cessation of management: the role of forest succession, woody biomass and saproxylic food webs

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The cessation of forest management leads to an accumulation of woody biomass and altered light conditions, which fundamentally affect forest biodiversity and ecosystem processes in forests. Unmanaged forests, characterized by an increase in live trees, dead wood in various stages of decomposition and diverse structural characteristics, provide a starting point for studying changes in biodiversity. These expected changes will alter the habitat conditions for many organisms. Varying light regimes will affect forest floor vegetation, and increased woody biomass, a primary energy resource for saproxylic organisms, will affect trophic interactions in saproxylic food webs. Such processes will be governed by the turnover of tree species driven by natural disturbances and will ultimately affect species composition and diversity. A key component to explain such changes are the concepts of forest succession and gap dynamics, which are expected to determine habitat conditions for plants, insects and tree species. We combine the concept of forest succession and saproxylic food webs with forest inventory data and observations of different species groups from more than 500 forest reserves across Europe to gain insights into how interactions in saproxylic food webs change when woody biomass remains after management cessation. Here we present the theoretical framework we use to address these questions, together with preliminary results from our analysis. This study is part of the EU HORIZON project WILDCARD, which aims to investigate how forest abandonment affects biodiversity and carbon trajectories in Europe.

NC7

P3

Small net local temporal changes in taxonomic, functional and phylogenetic biodiversity across European temperate forests

Liping Wei and 39 co-authors

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We face increasing concerns for how the local diversity of native plant communities responds to various drivers of global change, yet often lack comprehensive studies that integrate several components of diversity and effects of both local and regional drivers of change. Here, we analysed changes in taxonomic, functional and phylogenetic diversity across 2,681 (semi-) permanent temperate forest understory plots surveyed and resurveyed for all vascular plants over intervals of 15–78 years spanning not less than 72 regions distributed across Europe. We quantified temporal changes in these diversity indices and how they responded to changes in both local drivers (plot-level canopy cover and soil nutrients, inferred from plant indicator values) and regional shifts in macroclimate and nitrogen deposition. Overall, local changes in taxonomic, functional, and phylogenetic diversity were centred around zero reflecting little net change in forest diversity between surveys. Changes in phylogenetic diversity correlated positively with changes in taxonomic diversity but negatively with changes in functional diversity. Observed diversity changes mostly reflected local conditions such as canopy cover and soil nutrient characteristics rather than regional drivers of large-scale change. Our findings underpin little average net change in the three biodiversity facets in European forest understories, which is crucial information for forest biodiversity conservation, management and policy.

NC7

P4

Invasive species drive cross-ecosystem effects worldwide

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Invasive species are pervasive around the world and have profound impacts on the ecosystem they invade. Invasive species, however, can also have impacts beyond the ecosystem they invade by altering the flow of non-living materials (for example, nutrients or chemicals) or movement of organisms across the boundaries of the invaded ecosystem. Cross-ecosystem interactions via spatial flows are ubiquitous in nature, for example, connecting forests and lakes, grasslands and rivers, and coral reefs and the deep ocean. Yet, we have a limited understanding of the cross-ecosystem impacts invasive species have relative to their local effects. By synthesizing emerging evidence, here we demonstrate the cross-ecosystem impacts of invasive species as a ubiquitous phenomenon that influences biodiversity and ecosystem functioning around the world. We identify three primary ways by which invasive species have cross-ecosystem effects: first, by altering the magnitude of spatial flows across ecosystem boundaries; second, by altering the quality of spatial flows; and third, by introducing novel spatial flows. Ultimately, the strong impacts invasive species can drive across ecosystem boundaries suggests the need for a paradigm shift in how we study and manage invasive species around the world, expanding from a local to a cross-ecosystem perspective.

NC7

P5

Temporal effects on biodiversity and ecosystem function: a microbial perspective

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Rivers are biodiverse ecosystems which play an essential role in the processing of organic matter from headwaters to the lower reaches. The biodiversity within these spatially complex ecosystems is subject to huge seasonal variation, whereby aquatic insect larvae emerge and fish migrate through the network. However, these ecosystems are also subject to strong anthropogenic pressures that affect not only the biodiversity within this system, but the functions this biodiversity provides to key ecosystem processes. Therefore, to effectively assess and understand the biodiversity and functioning within an ecosystem, spatial and temporally dynamics must be considered. Here, we assessed microbial diversity and ecosystem function at a high spatial and temporal resolution across a large river network. Our results reveal significant impacts of both seasonal variations and water chemistry parameters on ecosystem functions, however contrary to our expectations, we found no spatial effects (i.e. site location within the network). Additionally for water chemistry parameters, we identified key indicator taxa which varied over time. These findings emphasize the necessity of incorporating functional indicators into ecosystem assessments and highlight the importance of considering temporal scales to understand fluctuations in biodiversity and ecosystem function.

Evaluating protected areas for biodiversity conservation currently and in the future

Short title: Evaluating protected areas for biodiversity

Chairs: Joan Casanelles Abella, Bertrand Fournier

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Biodiversity conservation has become a hot topic in ecological research. The last international agreements and conventions (e.g. COP15, CBD, EU Biodiversity strategy) are aiming at increasing the extent of protected areas. However, they also have stressed main pressing needs to be resolved to achieve such conservation goals. Two main ones are (i) performing assessments on the success of conservation actions, and (ii) developing tools to aid planning of protected areas under current and future conditions of ecological and social change. The goal of this session is to present ongoing advances in the field of biodiversity conservation with a focus on tools to plan protected areas and evaluate challenges, regardless of the focal taxa, geographic region or the spatial scale considered.

NC8
01

Evaluating ecological representation in protected area networks — metrics and tools from systematic conservation planning

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Global conservation targets such as the Convention on Biological Diversity's Aichi target 11 and the Kunming-Montreal target 3 (30x30 target) have contributed to a dramatic expansion of the global protected area (PA) network. However, protecting a certain share of land and ocean does not guarantee effective conservation, but bears the risks of creating paper parks. A prerequisite for successful conservation, as reflected in the global targets, is the adequate ecological representativity of PA networks. We present a methodology for assessing progress in protecting terrestrial and marine ecoregions, which we use as surrogates for biodiversity. Using spatial analyses and the Mean Target Achievement metric, which indicates the degree to which a given representation target has been achieved, we analyse PA coverage at the national scale. To illustrate our approach, we examine the PA estates in nine countries from all continents as case studies, covering a total of 173 terrestrial and 64 marine ecoregions. Our analyses reveal little progress in ecoregion representation in the last decade of PA expansion, leaving substantial tasks ahead in the period to 2030. Although 170,000 km² of terrestrial and 3 million km² of marine reserves have been designated in the nine countries studied during 2011–2020, about half of their terrestrial and marine ecoregions remain poorly protected in 2020. Data and code for the analyses are available for further use (https://github.com/KerstinJantke). Our findings reinforce the need for targeted action to ensure that ecological representation is adequately considered in the expansion of PA networks in line with the 30x30 target. The methodology presented allows for ongoing evaluation, identification of gaps, and monitoring of countries' progress towards building representative PA networks and is applicable to any biodiversity surrogate beyond ecoregions and any country or region of interest.

NC8

02

Single large or several small: Exploring the effect of reserve size on biodiversity in protected forest areas

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Different strategies, such as the 30x30 target by COP15, aim to designate more of Earth`s land as protected areas to aim biodiversity conservation and restoration. Thus, we need a better understanding of how protected area design can be optimized. A fundamental, ongoing question is whether a single large or several small, protected areas with the same cumulative size can preserve a larger number of species at the landscape scale (SLOSS). Especially for densely populated regions with fragmented landscapes, the SLOSS question is highly important since several small, protected areas may be easier to achieve than few large ones. Here, we study the effect of size and age of forest reserves on biodiversity for different forest types and multiple taxa across a network of forest reserves in Bavaria. Specifically, we studied insects, spiders, birds, and fungi in newly established (since 2020) and older (management ceased >30 yr ago) protected areas covering gradients of reserve size in riparian, upland and mountain forests. The number of sample plots per reserve was proportional to the reserve area and samples were taken in the vegetation period 2023. The results uncover how reserve size, age and forest type affect gamma-diversity across the different nature reserves and taxa. Therefore, we compare Quinn-Harrison curves, which indicate whether single large or several small reserves contain more species at a certain scale. For example, for birds, we find a higher species diversity in several small reserves than in single large ones across all forest types. However, patterns differ between forest types, with a clear dominance of several small over single large for mountain forest, a tendency towards several small for upland forests, and no difference for riparian forest. Additionally, we compare the coverage-based standardized gamma-diversity of single large reserves to sets of small reserves covering the same total area. Further, we test how these patterns are affected by time since management ceased in the protected areas. We highlight the importance of spatial distribution and size in the selection process of new nature protected areas at landscape level. Our results contribute to a better understanding of the SLOSS debate in central European forests, which can support decision- and policymakers in achieving conservation goals in highly fragmented forest landscapes.

NC8 03

Influence of land use on bird communities, taxonomic and functional diversity in the Vjosa River National Park in Albania

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Land use change is a major driver of biodiversity loss globally, impacting protected areas, including national parks. Vjosa River, recently designated as a national park, faces potential increased land use change, necessitating an understanding of its future impact on biodiversity. This study aims to assess the influence of potential future land use changes on bird diversity along the Vjosa River, providing insights for conservation and management efforts. Bird occurrences were recorded along ten transects across three main functional process zones of the river: canyon, braided, and meandering. High-resolution remote sensing land use data were utilized to quantify land use effects on bird communities. Bird traits and community attributes were derived from AVONET dataset, allowing for taxonomic and functional diversity assessments. Environmental variables including landscape composition and fragmentation metrics, river flow dynamics, and climate were analysed. Preliminary findings indicate significant variation in bird community composition among functional process zones. Land use surrounding the river strongly influences bird functional traits composition with urbanization and agricultural intensification around the Vjosa River National Park having a particularly strong impact on biodiversity within the national park. This research underscores the need for effective management strategies to mitigate potential impacts of land use change on bird biodiversity in the Vjosa National Park and contribute to broader understanding of bird community ecology in dynamic floodplains.

NC8
04

The impact of road traffic on protected areas and biodiversity across the globe

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Road traffic is a major threat to protected areas and biodiversity across the globe. Threats include habitat fragmentation, traffic mortality and noise, light, and chemical pollution. Due to these impacts species abundance and richness can decrease in the vicinity of roads. Despite these potentially severe ecological implications, there is very limited knowledge on the magnitude of the impact of road traffic on protected areas and biodiversity. Although few studies in this direction assess the impact of roads, none focus on traffic volume, which is the main driver of the magnitude of the ecological impacts. In this study, we developed a global time-series of traffic volumes on all highways, primary roads, and secondary roads outside of urban areas (i.e. extra-urban roads) for the years 1975, 1990, 2000 and 2015. With this dataset we subsequently estimated the impact of road traffic on Protected Areas (PAs) and Key Biodiversity Areas (KBAs) across the globe. In these areas, we calculated the size and change of the traffic-dependent road effect zone as well as the fragmentation. Although we found that absolute traffic volumes were generally lower within PAs and KBAs than outside, the growth of traffic volumes was significantly higher within these areas than outside. The traffic-induced fragmentation of KBAs has strongly increased in the past decades. Whereas nearly 10% of the KBAs in the Americas and Asia was severely fragmented by traffic in 2015, this percentage was over 25% in Europe. We conclude that road traffic is a considerable and growing threat to the effectiveness of protected areas and to biodiversity conservation. Findings from this research can be used to develop urban, transport and conservation planning strategies that minimise impacts on natural habitats.

NC8
05

Identifying conservation and restoration potential of biodiversity under climate change

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The world faces a global biodiversity crisis, with many species and their habitats under threat. Addressing this crisis requires effective conservation and restoration efforts targeted at locations suitable under both current and future environmental conditions. Using data from the Bavarian biotope mapping program and the Maxent distribution model, we analysed the present and future distribution of 29 biotopes (landscape elements characterised by primarily specific plant species communities) in Bavaria based on environmental variables such as climate and soil properties. Our findings indicate that currently, nearly 70% of biotope observations occur under suitable conditions, with 22 biotopes displaying greater restoration potential than their current distribution suggests. However, due to climate change, many regions may become unsuitable for these biotopes in the future, particularly under higher emission scenarios. At the same time, some locations will develop conditions suitable for biotopes where they were previously absent. We calculated the net gains and losses of suitable areas, revealing that only seven biotopes might see an increase in suitable areas, while the majority are expected to face reductions. These results highlight the urgent need for a dynamic conservation and restoration strategy incorporating future climate changes, enabling conservationists to preserve existing biotopes and plan for new suitable locations6

NC8
O6

Climate change is expected to severely impact protected designation of origin olive growing regions over the Iberian Peninsula

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Olive (*Olea europaea* subsp. *europaea* L.) is a major crop, especially in Mediterranean regions. In the Iberian Peninsula, several regions have been classified as Protected Designation of Origin (PDO) for their olive products, due to their distinctive environmental characteristics. Although climate change will likely impact future olive distribution, there is still a knowledge gap regarding both the impacts on environmental suitability for olive growing within PDOs and on how well current PDOs will keep their environmental distinctiveness. Using an Ecological Niche Modelling approach, we projected the potential future distribution of environmentally suitable areas for olive growing within the Iberian PDOs. Moreover, using Random Forests modelling, we evaluated the ability of PDOs to maintain their environmental distinctiveness. Our results demonstrate that climate change will reduce the environmental suitability for olive growing within southern PDOs, while northern PDOs will benefit from more favourable conditions. Moreover, southern PDOs are less likely to retain their environmental distinctiveness, while in northern PDOs there will be a smaller effect of climate change. We conclude that the Iberian olive industry could be more vulnerable to climate change than previously thought. Exploiting the environmental diversity already found within the cultivars could increase olive climatic resilience, but this strategy will only be feasible provided that the relevant stakeholders are willing to accept new cultivars adapted to future conditions.

NC8
07

Future climate and land use changes threaten the effectiveness of Swiss protected areas

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Protected areas play a pivotal role in biodiversity conservation, with international targets aiming to protect 30% of the Earth's surface by 2030. However, protected areas are exposed to climate and land use changes, with approximately 27% of them situated in regions projected to undergo high climate and land-use changes by 2050. Because protected areas have fixed borders, there is concern about their ability to accommodate species with dynamic distributions that shift in response to changes in climate and land use. Here we combine land use, climate, species traits, and species occurrence data to (i) quantify the sensitivity of Swiss protected areas to climate and land-use changes, (ii) predict the separate and combined (additive) effects of climate and land-use changes on multiple biodiversity facets (taxonomic, functional, and phylogenetic diversity) under different scenarios of future changes, and (iii) compare the responses across protected areas, scenarios, biodiversity facets, and taxonomic groups. We found that protected areas are strongly exposed to climate and land use changes. This exposure is predicted to lead to significant but contrasted shifts in biodiversity across facets of diversity and taxonomic groups. While species richness might locally increase because of climate and land use changes, functional and phylogenetic diversities can follow opposite trends with potential negative consequences for ecosystem functioning. The observed spatial mismatch among biodiversity facets and taxa complicates the evaluation of the effectiveness of protected areas. Quantifying local effects of climate and land use changes is key to managing protected area capacity to maintain habitat for a large number of species. Modelling frameworks such as the one presented here emerge as essential tools for future biodiversity conservation efforts.

NC8
08

Where to do what – identifying focus zones for Swiss agricultural priority birds

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Much of European biodiversity is linked to traditional extensive agricultural management. The intensification of agriculture has severely affected biodiversity, as the majority of priority species depend on extensive land use and mosaic structures. As agricultural land surface is steadily decreasing due to urbanization and other pressures, the conflict of interest between efficient food production and habitat quality for biodiversity is increasing. One approach to preserve priority species, could be to adapt agricultural management to optimize according to the regional potential. In this Swiss-wide study, we used a life-cycle-assessment method to assess the direct impacts of field-based management on national protected priority birds, as an indicator species group. We also used stacked species distribution models of these species to estimate their theoretical distribution potential. Using hotspot analyses, we identified areas of significantly low and high management impact as well as species potential, and combined them spatially. The result is a high-resolution Swiss-wide spatial analysis of the utilisation of the potential of Swiss agricultural priority species in relation to agricultural land use. This allows for spatially explicit comparisons across regions and land uses, to identify areas of interest for adaptations. Our results highlight areas with high or low potential for agricultural priority species, combined with the impact of the respective land use on the different indicator groups. This is important to assess the potential of different regions, and to optimize management regionally, with the aim to safeguard protected species. Our spatial analysis approach could also be applied for conservation planning of other species groups or other thematic contexts.

NC8
09

Evaluating German development co-operation's approaches to support protected areas, their biodiversity and their people

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Numerous reports have recently highlighted conflicts surrounding protected area in countries in the Global South. Interests to use and economically benefit from natural resources in protected areas seemingly collide with the objectives to preserve biodiversity as such. At the same time, many of the world's biodiversity areas are in either volatile, fragile, or even conflict-stricken contexts. Against this background, the German Institute for Development Evaluation (DEval) has evaluated the Federal Ministry for Economic Cooperation and Development's (BMZ) bilateral support of protected areas between 2016 and 2021. BMZ strategies and projects aim to preserve biodiversity, in line with the CBD, the Agenda 2030, and other global agreements. However, its engagement also aims to address the socio-economic goals of the Agenda 2030. This duality in strategy is also a result of possible synergies between environmental protection and economic activity. However, in practice, different stakeholders, including national partner governments and rightsholders, might have diverging interests resulting in tensions over natural resources at the local, national, and global level. The BMZ engagement in protected areas was reviewed against the OECD-DAC evaluation criteria, applying a mixed-methods design, and focussing on a sample of nine partner countries. German development agencies have used different approaches to mitigate these challenges, such as participatory methods, or by aiming to create alternative livelihoods for communities affected by regulations surrounding the use of protected areas. In this presentation, the team will shed light on how it has evaluated BMZ's efforts, methodological challenges it faced and which lessons learned may be drawn for future evaluations in the field.

NC8
O10

Habitat associations of day-flying Lepidoptera and their foodplants: Lessons for the selection and management of protected areas

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Species often display patchy distributions, which can reflect associations with specific characteristics of an ecosystem. These can include both biotic and abiotic factors, which can interact with each other in ways that result in only a small fraction of the landscape being suitable for each species. Understanding which resources species associate with is therefore important for informing and prioritising conservation of species and landscapes. We investigated the associations of a community of day-flying Lepidoptera (eleven species) in protected areas in the UK, at scales relevant to both the insects and land-managers, and whether ecological traits influenced the strength of associations. We found high variation in associations, highlighting the value of highly heterogeneous landscapes in terms of topography and vegetation structure. We found that species that overwinter at non-adult life stages had particularly strong associations, indicating this group may be particularly vulnerable to environmental change. We highlight specific species with conflicting associations with their foodplant, which will require alternative management approaches. As topography has limited capacity for manipulation, land already containing variable topography will be of higher conservation value for protection than homogenous landscapes, whereas vegetation can be manipulated by land-managers to create and maintain diversity, that will then better support more diverse and climate-resilient insect communities.

NC8
011

Efficacy of the Mexican protected areas network in representing species' ecological niches

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Protected areas are designed to safeguard species, communities, and ecosystems worldwide. Despite being bastions of nature conservation, few studies have analysed to what extent they represent species' ecological niches to ensure their survival, both currently and under global climate change. In this study, we analyse how well the bioclimatic conditions of Mexico are represented by its terrestrial protected areas, both currently and under future climate change scenarios. Additionally, we assess the extent to which these protected areas represent the ecological niches of different mammal species inhabiting them. Results indicate that many environmental combinations lack representation in the protected areas network, particularly when considering their arrangement at the ecoregional level, while the ecological niches of mammals are poorly represented. This analytical framework could be useful in generating a classification of species as gap species versus covered species, thereby enhancing our decision-making capacities in conservation.

NC8

O12

Mapping 30% by 2030: An evidence base for creating resilient landscapes in Scotland

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NatureScot, Inverness, UK

More than 100 nations have agreed to the international commitment to protect or conserve 30% of land and sea by 2030. To have an impact, this expansion of conserved land must be more than a target; these areas must effectively protect the biodiversity within them. This can only be achieved within the context of a resilient landscape, using flexible safeguards that target healthy ecosystems. In Scotland, one approach we are using to achieve this is mapping biodiversity hotspots at a national scale, with the aim of creating a tool to inform decision making around potential new protected or conserved areas. By individually mapping each criteria of the IUCN guidance on Other Effective Area Based Conservation Methods (OECMs), and then combining these into one 'Big Biodiversity Layer', we will provide an evidence base for the establishment of a new suite of OECMs and other protected areas. We are achieving this by combining a wide variety of species, habitat, and land use data into indicative heatmaps that will direct users to areas of potential interest for conservation, thereby taking an evidence-based and ecosystem approach to increasing our percentage of safeguarded land. This will enable the development, in conjunction with local stakeholders, of a nationally resilient landscape, applicable at a national, regional, and local scale. When combined with Nature Networks, which promotes connectivity between protected 'nodes', our work aims to set Scotland up to be environmentally, climatically, and socially sustainable into 2030 and beyond.

Land use drives the unfavourable conservation status of biodiversity in Natura 2000 sites in Germany

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Biodiversity continues to decline despite international efforts to put 30% of the world's land and marine surface under protection. Protected areas in densely populated regions like Central Europe are often small and exposed to influences of human activities, which may hamper their effectiveness. Evaluations are rarely conducted, but for Natura 2000 sites protected under the EU Habitats Directive regular reporting using standard data forms is mandatory. We compiled information from 1,049 standard data forms representing 23% of sites in Germany, in which conservation status of habitats and species is assessed as either 'favourable', 'inadequate' or 'bad'. Further, we used regression analyses to investigate whether conservation status was related to protected area size, age or human influences reported on data forms. We found that only 6% of habitats and 4% of species were in the favourable conservation status required by law. Most data forms reported negative impacts from agriculture and forestry which was confirmed by our analyses while area size was positively related to conservation status. These results indicate that the Natura 2000 protected area network is not yet reaching its goal of conserving Europe's wildlife, and land use may not be sufficiently adapted to local conservation objectives.

Protected area's importance for biodiversity conservation: a case study on ground beetles (Coleoptera: Carabidae) in Germany

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Protected areas are considered refugees for species that suffer from habitat loss and other threats. However, strictly protected areas represent only 7% of the terrestrial landscape in Germany. Effectiveness of the currently protected areas for long-term conservation of species may be questioned. Ground beetles are a well-studied group of insects and Germany has a high responsibility for species inhabiting forests. We compared ground beetle richness from eight German forest national parks to evaluate the parks contribution to the protection of this taxa group. Seventy-three % of the forest-inhabiting ground species occurred in the investigated areas. A large number of species (95 species) occurred in only one park compared to 42 species that were found in all parks. Our findings suggest that German national parks provide important habitats for ground beetles and thus promote biodiversity maintenance. Future designations of protected areas to reach the 30% target of the EU should focus on underrepresented habitat types such as alluvial forests to enhance effectiveness of biodiversity conservation.

NC8
P3

On the edge: Biodiversity effects of administrative boundaries of forest reserves

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Facing global biodiversity loss is one of the greatest challenges for humanity in the 21st century. Protected areas are one important approach to tackle this challenge, and an increase in protected areas to 30% of global land area was agreed upon in the Kunming-Montreal Global Biodiversity Framework in 2022. Yet, how to best design new protected areas remains a topic of debate. Discussions revolve around whether singe large or several small, protected areas are more effective. The majority of SLOSS research focuses on protected areas >500 ha, which are rare in the densely populated areas of Central Europe. The comparatively small reserves in Central Europe have a disproportionally large area close to the reserve boundary, rendering the question of potential edge effects highly important. Here, we study tree-related microhabitats (TREMs), deadwood amount and diversity along transects perpendicular to reserve boundaries. Reserves were selected within three important temperate ecosystems (i.e. riparian, upland and mountain forests), range from 17 to 107 ha and cover two age-classes (established 2020 vs. being unmanaged for >45 years). Our specific objectives were (i) to assess whether edge effects exist at the reserve boundaries, and (ii) to test whether reserves protected 45 years ago differ significantly from recently established reserves. We sampled 264 randomly selected transects across reserve boundaries, surveying a total of 10,137 trees (live and dead) and 1116 downed deadwood objects. Over all systems, 80% of indicators show edge effects, with diversity generally decreasing towards reserve boundaries; 45 years after protection reserves in riparian and upland systems had significantly higher levels and diversity of TREMs and deadwood. Our results add an often-overlooked perspective to the debate on the optimal shape and size of protected areas and underline the importance of timely implementation of protection to counteract accelerating biodiversity loss.

NC8

P4

Ex-situ regeneration of rare forest herbs – the case of *Chimaphila umbellata* and *Pyrola media*

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Chimaphila umbellata and *Pyrola media* (Ericaceae) are endangered herbs occurring in near-natural pine forests in C Europe. In these remnant populations, the plants show clonal expansion and produce seeds, but no generative regeneration. This might be due to failure of germination or seedling establishment. Ericaceae live in a specific fungal symbiosis already during the seedling stage, but this relationship is not poorly understood. Thus, after germination in an incubator and establishment of leafless shoots in Petri dishes (A. Wimmelbücker, Neumarkt), 60 seedlings of *C. umbellata* were planted into 5-l pots filled with six substrate types (n = 10) to investigate potential soil preferences. The substrat was collected near a population of *C. umbellata* close to Siegenburg (Bavaria). Some pots were filled with soil monoliths from the upper 20 cm of humus and mineral soil, including all existing vegetation dominated by *Deschampsia flexuosa* and *Vaccinium uliginosum*. The other pots were filled with homogenized sand and humus of varying percentages from the same site, with pH 3.8 or 6.0. After two years in a greenhouse highest survival (70%) was found on undisturbed soil, compared to 0–30% on the other substrates. In *P. media*, 90 leafless seedlings were planted into 30 pots (10 l) filled with soil monoliths as above. Three individuals per pot were inserted into depressions filled with sand (100 ml), humus (100 ml) or commercial soil mixture (100 ml). After two years still one third of the seedlings were alive despite heavy competition, and independent of the starter substrate. The shoots of both species grew slowly, i.e. in *C. umbellata* 1–5 leaves of 2 mm, and in *P. media* leaves of 5–10 mm. Transferring the young plants into their natural environment seems only promising when they have sufficient belowground organs. This shows that ex-situ regeneration is possible in these species but needs a lot of patience.

Soil fauna and vegetation respond to similar land use drivers but in non-congruent patterns

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Many pesticides are known to negatively affect non-target organisms, including non-weed vegetation and non-parasitic soil fauna. Alongside individual substances, mixtures of pesticides can further harm communities due to additive and synergetic toxic effects. However, little is known about how pesticides and pesticide mixtures affect sites adjacent to agricultural fields, including protected areas. Here, we assessed pesticide contamination, abiotic soil parameters, as well as communities of plants, nematodes and oribatid mites on arable fields and adjacent dry meadows in two regions of Germany. The arable fields generally had higher pesticide numbers and concentrations compared to dry meadows, as well as lower species numbers for all groups. Pesticide number was negatively correlated with species number of nematodes and plants in the agricultural field as well as on the edge of the dry meadow. While pesticides and abiotic parameters separated the communities, responses of organism groups to land use drivers differed. Although they were non-congruent, negative effects of pesticides on communities and species numbers of different groups of organisms could be shown in our field situation, especially regarding pesticide number.

Plant Ecology (PE)

PE1

Plant responses to the environment across scales

Short title: Plant responses to the environment

Chairs: Benjamin Hafner, Emma Sayer, Thorsten Grams

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Plant responses to the environment involve functional and morphological mechanisms at different evolutionary and ecological scales ranging from within species to among communities. To predict how plants respond to environmental change, we therefore need an integrated understanding of the interplay of the many traits involved in plant responses. This challenges us to elucidate how multiple 'species' traits integrate into a whole-organism phenotype adjusting to its environment. The focus of this session is on the responses of individual plants, stands and ecosystems to their environment. This includes responses to both abiotic impacts such as radiation, temperature, elevated CO_2, drought, and nutrient availability, as well as biotic interactions with other plants, animals, and microbiota. Contributions may also focus on anthropogenic impacts and disturbances, such as land use change, air pollution or climate change. We particularly welcome studies that integrate multiple scales or are relevant to ecosystem processes, functions and services. This may include experimental studies with mechanistic insights, observational or modelling studies, and work ranging from resource allocation and growth dynamics in individual organisms to whole ecosystems.

PE1
01

Dryland mechanisms – Do temperate ecosystems copy deserts when adjusting to a warming and drying climate?

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Dryland ecosystems and their organisms are adapted to multiple short or long periods of dryness, during which they continue to function, albeit often at a reduced rate. In the course of evolutionary time scales, specific mechanisms were developed ensuring the survival of organisms and continued operation of ecosystem processes. These 'dryland mechanisms' (Grünzweig et al. 2022, Nature Ecology & Evolution) are normally absent, operate at minimal rates or are considered irrelevant in more humid regions. However, climate change might raise the relevance of these mechanisms, especially in temperate regions where extreme droughts occur at an ever-increasing pace. When rains become scarce or stop altogether, various components of the ecosystem can utilize alternative water sources. Plants can absorb fog and dew to sustain their functions, while microorganisms can continue decomposing litter and soil organic matter which get moistened by these non-rainfall water sources. Litter decay continues in the absence of water by abiotic mechanisms, by photochemical and thermal degradation driven by solar radiation and heat. An additional adjustment to rain scarcity is water stored in deep soil layers, which can be passively translocated through the root system to the dry topsoil layer. Such hydraulic redistribution along a water potential gradient can prevent hydraulic failure and prolong the lifespan of fine roots. The redistributed water can also benefit rhizosphere microbes and understory plants without access to deep water. Tree canopies with low aerodynamic resistance and experiencing hot and dry weather can undergo air-cooling through convective heat transfer, which saves precious water. Upon the occurrence of intermittent rain events, soil hydrophobicity can create preferential flow paths of rainwater into the soil, keeping part of the topsoil dry. Thus, water loss by evaporation gets drastically reduced, while simultaneously refilling deep soil water reserves available for hydraulic redistribution. Some of the dryland mechanisms have already been observed alleviating the effects of a warming and drying climate in temperate forests and grasslands. They could eventually turn out to be critical mechanisms of adaptation to dryness and heat, much like they are in drylands.

PE1

O2

Plant functional composition buffers productivity loss in semi-arid rangelands under drought and high grazing intensity

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Drylands worldwide are facing desertification due to global environmental change, particularly land-use intensification and more pronounced droughts. Desertification is associated with a loss of herbaceous forage production, threatening local livelihoods. Unfortunately, the combined effects of land-use intensification and drought on forage production are poorly understood. In a field experiment, we combined grazing and drought treatments in a semi-arid Namibian rangeland to test whether the treatments reduced productivity and altered plant species composition. Drought was simulated via rainout shelters reducing ambient rainfall by 66%. Grazing treatments simulated low, moderate and heavy grazing via clipping. Effects of grazing history were addressed by replicating the experiment in two distances to the cattle watering point. Aboveground net primary productivity (ANPP) was determined destructively, and plant species composition via vegetation relevés. Dry mass for grasses, forbs and legumes, was determined via biovolume calculations. Under moderate grazing, we found that one year of drought combined with an intensive grazing history reduced ANPP by 65% compared to ambient rainfall with a less intensive grazing history (from 249 ± 16 to 86 ± 10 g dry mass m^{-2}; $p < 0.001$). High grazing pressure resulted in stable ANPP, regardless of drought and grazing history. However, this response was accompanied by a pronounced shift in the functional composition of plant communities. For example, under drought and less intensive grazing history, forb biomass increased by 63%, from 50 ± 7 to 128 ± 12 g dry mass m^{-2}, at the cost of 26% of grass biomass compared to low grazing. Since grasses are the main source of cattle fodder, such functional shifts will have considerable implications for forage availability, even if ANPP remains stable. These *in situ* experimental results underline the importance of understanding plant community responses to joint effects of global change drivers.

PE1
03

Drought resistance and seed dormancy drive population temporal stability

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Understanding population temporal stability is essential, particularly given the expected climate variability increase. Traits respond to abiotic and biotic environments and should therefore provide mechanistic insights for the drivers of stability. However, which traits drive stability can vary across climates as a consequence of changes in abiotic stress and biotic factors, such as competition. We studied the year-to-year variation in abundance, measured by the coefficient of variation, of 91 populations (covering 66 species) of winter annuals over 13 years. We carefully selected traits known to be involved in buffering against dry conditions in temporally unpredictable environments: seed dormancy, seed size, and drought resistance (i.e. RGR, SLA, LDMC, turgor loss point, carbon isotopes ratio). We worked in a biodiversity hotspot in Israel in three climates along a steep rainfall gradient of decreasing mean and increasing interannual variability: Mediterranean, semi-arid, and arid. We expected higher dormancy and/or bigger seeds and/or higher drought resistance to lead to higher population temporal stability. We expected this relationship to be more pronounced towards drier environments with higher unpredictability, where the need to buffer against bad years should be stronger. We found that higher drought resistance increased stability throughout the gradient, with a more pronounced relationship towards the arid. Dormancy predicted stability in the arid climate only, enhancing it via higher dormancy. Our findings reveal the overlooked diversity of ecological strategies within annuals, so far considered functionally equivalent, and how it shapes population temporal stability in the context of changing abiotic and biotic conditions.

PE1
04

Relevance of osmotic adjustment during drought in mature temperate trees

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Temperate forests have been experiencing increasingly hot and dry climatic conditions over the last decade, altering European forest structure and composition. Given this trend, it is crucial to understand water-related mechanisms that enable trees to cope with future droughts. Trees can adjust their leaf osmotic potential in response to drier conditions, allowing their leaves to continuously work with decreasing water supply due to delayed turgor loss. There is however little evidence of the extent to which mature trees can adjust osmotically and the role this plays in their species-specific drought vulnerability. We addressed this at the Swiss Canopy Crane II site where we had canopy access to mature trees of nine temperate species that experienced a 50% reduction in precipitation from April to November 2023 as part of an ongoing rain exclusion experiment. We measured osmotic potential at full turgor (π_o) of leaves using freezing point osmometry throughout the 2023 growing season, characterized by extended warm and dry periods. To assess tree hydration status pre-dawn and midday leaf water potentials (Ψ_{leaf}) were measured. Pre-dawn and midday Ψ_{leaf} decreased significantly during the growing season. Pre-dawn Ψ_{leaf} reached considerably negative values in the rain exclusion treatment ensuring drought stress responses across species. In response to increased soil drought, we observed a significant drop of π_o in all species at the start of the growing season, suggesting osmotic adjustment to increased drought stress. Interestingly, we could not observe significant differences in π_o between the rain exclusion and control plots for most species suggesting a species-specific limitation to how much a species can osmotically adjust. Although additional data is needed to draw more robust conclusions, a pattern is emerging that osmotic adjustment during short-term droughts may not be as important as previously thought.

PE1
05

Effects of climate, stand structure, soil characteristics and topography on leaf unfolding in Switzerland

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Plant phenology is the science that investigates the timing of periodically recurring growth and development stages of plants, such as leaf unfolding. While temperature is a major driver for the timing of leaf unfolding of trees, other environmental factors such as stand structure, soil and topography also play a role. However, there are only few studies that have investigated the compound effect of multiple environmental factors that may affect the timing of leaf unfolding. In particular, the influence of soil characteristics, such as water-holding capacity and the resulting soil water balance, on the phenological timing of adult trees is largely unexplored. This study aims to understand how the compound effect of multiple environmental factors, including climate, stand structure, soil, and topography, influences the phenological timing of *Fagus sylvatica, Picea abies, Larix decidua* and *Tilia cordata*. To understand the effects of these factors, high resolution gridded weather data and field data on stand structure (competition and tree height), soil characteristics (depth, texture, bulk density and organic carbon) and topography (elevation, relief type, slope aspect and slope inclination) were collected at long-term observation sites from a homogeneous phenological network across all biogeographic regions of Switzerland. We analysed the data using linear mixed-effects models. Preliminary results confirm the importance of temperature across species but indicate that the effects of stand structure and elevation are species specific. Both low and high individuals of *Fagus sylvatica* seem to unfold their leaves later than medium high individuals. In contrast, *Larix decidua* appears unaffected by tree height but seems to unfold leaves notably later at high elevations, even when temperature is accounted for. However, there is limited evidence for an effect of soil water balance on the timing of leaf unfolding. This study considerably improves our understanding of the compound effect of established as well as rarely investigated environmental factors on the timing of leaf unfolding across species throughout a wide range of environmental conditions.

PE1
06

Smoothing out the misconceptions of the role of bark roughness in vascular epiphyte attachment

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Vascular epiphytes represent c. 10% of all vascular plant species. In epiphytes, attachment is essential for survival throughout consecutive ontogenetic stages of their life, starting with: (i) initial propagule attachment to the host; followed by (ii) the development of first root-substrate connections; and (iii) maintenance of this attachment despite increased size and mechanical disturbances by rain, wind, or crossing animals. Although structural dependence on a host is a defining characteristic of an epiphyte, the fundamental mechanism(s) of how these plants initially attach and remain attached to their hosts remain poorly understood. Bark characteristics such as stability and roughness have been highlighted as keys to an understanding of this connection. Here, we stress that the understanding of how an epiphyte attaches itself to the substrate is central for a meaningful quantification and interpretation of bark roughness. Without explicit information on the attachment mechanism or the relative sizes of the attaching structures, simply linking a haphazardly chosen index of bark roughness to epiphyte establishment is flawed. This research has achieved its goal if future studies will be carried out with an awareness of all the raised issues. Knowledge of the relevant attachment mechanism defines the relevant scale of any analysis of bark roughness and is essential for accurate cause–effect conclusions. Although we highlighted just one specific case in functional ecology, where we emphasized the lack of awareness of the relevant scale, collection of low-resolution data followed by generalized interpretation is a problem in quite a few ecological studies.

PE1

07

Arctic tundra ecosystems under fire – potential trajectories for stable state shifts

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Climate change can drive Arctic tundra ecosystems to instability. The increasing fire occurrence in high-latitudes has the capacity to trigger irreversible changes and thus stable state transitions of tundra vegetation. A stable state shift of the tundra vegetation may not only impact the local ecosystem, and the livelihoods of people and the habitat of animals depending on the ecosystem. It might also contribute to surpassing the tipping point of permafrost degradation and thereby increase greenhouse gas emissions. With an increased predicted fire frequency in the Arctic, the question of whether such a scenario is conceivable for the tundra is a pressing research topic. Post-fire vegetation patterns in field studies can inform possible stable states. The recovery of different species and functional groups after a tundra fire depends on their abilities of coping with the post-fire environment. Woody plants and grasses can profit strongly from tundra fires while lichen cover is generally lower after fire . Based on existing studies, we identify two directions to other stable states that are most likely for different tundra ecosystem types. The first direction assumes that after an unprecedented and destructive fire event, woody plants can gain a head start in growth, a few decades post fire, and stay more dominant under a warmer climate a few decades post fire. The second direction hypothesizes that increasing fire frequency can stabilize a graminoid dominated state because the time interval before the next fire is too short for other functional types to recover. Depending on the tundra ecosystem and fire characteristics, these paths can vary in course. Vegetation's interconnectedness with permafrost, hydrology, nutrient cycles, and other ecosystem components means alterations to its cover profoundly impact ecosystem functioning.

PE1
08

Quantifying the changes along the shrub encroachment gradient in sub-alpine grasslands

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Shrub encroachment is a global process that has strong effects on ecosystem functions. In sub-alpine areas, shrub colonisation is mainly driven by climate warming and land-use change since the 1950s. Additionally, warmer future temperatures might facilitate the upwards migration of shrub species above the climatic tree-line. This increase in woody biomass is expected to lead to increases in aboveground and belowground carbon (C) stocks, to slower decomposition rates and lower soil nutrient availability. Yet, our understanding of the mechanisms and interactions of aboveground and belowground processes with shrub encroachment is limited. We hypothesized that increasing shrub biomass results in nonlinear changes in plant community traits with cascading effects on soil properties and nutrient availability. We investigated these effects along an encroachment gradient at two sites in the Alps using a trait-based approach. Our results from structural equation modelling support our hypothesis that changing community-weighted mean in plant resource economics traits with increasing shrub biomass flow on to changes in soil properties. Contrary to our expectations, we found no indication of nonlinear trends. These results suggest that shrub encroachment results in a gradual shift from nutrient-rich plant communities with less resistant tissues in grasslands and sparsely shrubby communities, to nutrient-poor plant communities with harder tissues at higher shrub density. These changes have cascading effects on soil stoichiometry and nutrient availability. At high shrub densities, the increase in recalcitrant tissues leads to an accumulation of poorly decomposable litter and to acidic, phosphorus-poor soils. This study provides novel insights into the response of plant community traits to shrub encroachment and underlines the importance of integrating aboveground-belowground interactions in future research.

PE1

09

The role of functional plant traits in grassland recovery from drought

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The ability of an ecosystem to recover from drought is crucial for the resilience to future disturbances. Temperate grasslands were shown to recover well from drought, with formerly drought-stressed grasslands even outperforming the productivity of well-watered controls after rewetting. However, the mechanisms underlying this capacity, along with the role of different plant functional traits in this process, are yet unknown. In this study, we tested the effect of rewetting after a 2-month experimental summer drought on plant aboveground productivity, soil microbial activity, and plant nutrient availability in an intensively used perennial ryegrass stand in 2019 and 2020. To test how plant functional traits related to nutrient acquisition determine post-drought productivity dynamics, the experiment was repeated in two extensively managed, species-diverse grassland sites in 2021, and the productivity dynamics of the functional groups grasses, leguminous forbs and non-leguminous forbs were examined. Our results show that rewetting after drought increased plant aboveground productivity, N, P and K availability, and N mineralization compared to controls in the intensively managed system. In the perennial ryegrass stand, we found that post-drought productivity outperformance was driven by a rewetting-induced pulse in N mineralization of soil organic substrates that had accumulated during drought and increased post-drought N availability and thus plant nutrition and performance. Similar effects were found in the extensively managed grasslands. However, of the three tested groups, only the fine-rooted grasses profited from the N pulse and showed post-drought productivity outperformance, while the thicker-rooted forbs were not significantly affected by drought and rewetting. Our findings suggest that post-drought productivity outperformance in temperate grasslands is mainly mediated by the greater capacity of grasses to compete for nutrients mineralized upon rewetting.

PE1
O10

Bryophyte functional traits are highly responsive to small-scale environmental changes in temperate forest ecosystems

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Although often overlooked, bryophytes are a crucial component in many ecosystems, contributing substantially to biogeochemical cycles and ecosystem functions. They are an important layer between the surface and the subsurface, influencing water, carbon, and nutrient inputs to the subsurface. However, how species respond to small-scale environmental gradients is rarely studied, especially in terms of functional traits. Yet, this knowledge becomes important when trying to understand and predict ecosystem responses to climate change and disturbance. Therefore, we investigated bryophyte species composition and functional trait responses to small-scale environmental variation within and between two temperate coniferous forest stands. We established six small-scale environmental gradients, each consisting of five adjacent plots ranging from near the stem to under a canopy gap, in two temperate coniferous forests in the Saale-Elster-Sandstein Observatory near Jena, Germany. We weekly recorded bryophyte species composition, and measured ten functional traits, that are linked to productivity and water balance, for all occurring species. We used multivariate statistics and mixed effect models to detect bryophyte responses to small-scale environmental change. A Detrended Correspondence Analysis revealed that bryophyte species composition differed more strongly between than within forest stands which was mainly linked to light intensity, relative humidity, and temperature. Soil variables such as pH or nitrogen content rather led to distinction within the forest stands. (Generalized) Linear mixed effect models showed that the responses were context dependent, demonstrating that bryophytes are sensitive bioindicators, even at a small scale. Our results suggest that the high plasticity of bryophytes in temperate forest understoreys could help to cope with future climate change and disturbance and thereby mitigate their impact on ecosystems.

011

Physiological response of a mixed forest stand to stress conditions assessed by a novel cuvette system

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Environmental stressors such as drought and heat severely affect the functionality of forest ecosystems in Central Europe. Therefore, a better understanding of species-specific physiological responses to extreme conditions is crucial to improve predictions about future forest resilience. Yet, we are still lacking experimental data on mature forest trees under ambient conditions in a high spatial and temporal resolution. In our ECOSENSE Forest, we establish a novel cuvette system in combination with a Pulse-amplitude modulation (PAM) fluorometer measuring system (Micro-PAM by Walz) in the canopy of a mixed, mature *Fagus sylvatica* and *Pseudotsuga menziesii* forest, which continuously assesses leaf gas exchange (carbon assimilation, transpiration and stomatal conductance) and chlorophyll a fluorescence *in-situ*. Both measurement systems are minimally invasive and enable a high temporal resolution of measurements over a period of several months. Additionally, the novel leaf-wearable cuvette system will be highly distributed in the canopy and therefore provides also a considerable spatial distribution of measurements that cover both shade and sun crown. We combine these canopy measurements with continuous measurements of radial increment, sap flow and leaf and stem water potentials to gain insights into whole-tree carbon and water fluxes. With our novel, continuous measurement approach we will be able to better understand whole-tree water and carbon fluxes and the interplay between light use efficiency and physiological activity of a mature forest under varying environmental conditions.

PE1
012

Hydraulic constraints at low root temperatures as cause for the cold limit of tree growth

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Although the restriction of plant water uptake by low, non-freezing, soil temperatures is a well-known phenomenon, it so far received only little attention with respect to the ongoing search for a physiological mechanism behind the cold limit of tree growth. In a series of recent experiments, we quantified the effect of low root temperatures on the water uptake and transport in seedlings of 16 European temperate tree species by pulse labelling with deuterated water. Although all seedlings received the same warm air temperatures and identical VPD conditions, decreasing the root temperatures from 15 to 7 or 2 °C significant reduced the speed of water transport from roots to leaves, accompanied by significant reductions in plant water potentials. We also explored the tree species' ability to adapt their root water uptake to low temperatures in short- and long-term acclimation experiments but found no cold acclimation with respect to the sensitivity of root water uptake against low root temperatures. Most interestingly however, the severity of the hydraulic constraints (i.e. the decrease of water uptake and plant water potential at 7 or 2 °C relative to 15 °C) correlated with the species-specific natural high elevation distribution limits. Species that naturally occur at or close to the alpine treeline showed significantly less reductions in water uptake and plant water potential at low root temperatures than species that reach their upper distribution limits at lower elevations. Our experiments revealed significant hydraulic constraints for tree seedlings exposed to lower root temperatures in a temperature range (around 5 °C) that has been previously identified as a general threshold for tree growth. We propose that low soil temperatures induce hydraulic restrictions for cell-expansion of growing tissues below- and above-ground, that might resemble a fundamental physiological mechanism behind the cold limit of tree growth.

PE1 013

Do functional composition gradients mimicking land-use intensification affect grassland performance under and after increasingly severe drought?

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Land-use intensification is changing the functional composition of temperate grasslands by shifting the vertical distribution of roots towards the surface and promoting fast-growing, resource-acquisitive species with high specific leaf area (SLA). At the same time, climate change is subjecting grasslands to more severe drought. We aimed to clarify how maximal rooting depth (MRD) and SLA affect the ability of grassland species to resist and recover from increasingly severe drought. To address this question, we simulated a drought gradient from 0–220 days without precipitation in a common garden experiment that included temperate grassland species covering wide ranges of MRD and SLA values. Drought effects on plant performance increased with drought length, reducing the survival of green tissue and annual biomass by up to ca. 50% across all 32 species considered. Our results suggest that deep roots can mitigate the adverse effects of increasing drought intensity on plant performance under drought, namely when plant-available water is lacking in upper soil layers but remaining in deep soil layers. The SLA trait gradient among the 16 graminoid species seemed to represent alternative survival strategies, rather than drought sensitivity. Variable drought responses along the SLA gradient of forbs imply that multiple other traits are related to drought resistance across evolutionarily distant species.

014

Natural root grafting: A vector for hydraulic redistribution?

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Natural root grafting is a common phenomenon in many woody species. Through functional root grafts, i.e. fully fused root tissue, trees can exchange resources such as water. Mapping the frequency and size of connected trees in a black mangrove forest showed that the grafting frequency increased with increasing salinity, but group size decreased. These results suggest that there is a mechanism controlling group characteristics, possibly related to physiological drought. Here, we hypothesize that root grafting may be an additional vector of horizontal and evaporative hydraulic redistribution that mitigates water stress. We developed a mechanistic, individual-based model to quantify the amount of water that can be exchanged (relative to whole-tree water uptake) and to identify the driving mechanisms. In the model, water exchange is driven by the water potential gradient between connected trees. The exchange can be bidirectional, i.e. it can flow from tree A to tree B or vice versa, depending on, among other things, temporal and spatial differences in water availability. We apply the model to a forest site, where changes in hydroperiod can increase soil salinity, which has similar physiological effects in mangroves as drought stress has on terrestrial trees. Simulation experiments allow us to assess the role of water exchange in maintaining the water balance under different environmental scenarios. Mangroves are particularly suitable for investigating the ecological effects of root grafting because the extent of their roots is visible above ground and grafting is relatively easy to detect. Since our individual-based model can be transferred to terrestrial forests, the study provides a good opportunity to investigate the consequences of root grafting for terrestrial trees. Therefore, we would like to find collaborators to further investigate this topic in terrestrial forests and to verify the simulated exchange patterns, e.g. with sapflow measurements.

PE1
015

From root to shoot: Understanding plant hydraulic regulation across different soil moistures

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A precise coordination of hydraulic conductance in plants above- (K_{ab}) and belowground (K_{be}) hydraulic conductance is crucial for meeting leaf evaporative demands as plants grow in diverse environments. This study examines how maize adjust hydraulic conductance during growth in response to varying soil water content. We hypothesize that maize modulates their K_{ab} and K_{be} in response to plant age and soil moisture, balancing water loss with uptake. Maize plants were grown in loamy soil under optimal (OWC) and water stressed conditions (SWC). At four growth stages (14, 26, 35 and 55 days) we assessed both K_{ab} and K_{be}. K_{be} was determined by applying incremental pressure to soil and roots in a pressure pot, collecting sap to measure water flow. To calculate total aboveground hydraulic conductance ($K_{ab,tot}$), effective internal aboveground xylem hydraulic conductance ($K_{ab,x}$), and stomatal conductance ($K_{ab,s}$), we measured transpiration, leaf water potential, temperature, and vapor pressure. K_{be} was two orders of magnitude higher than $K_{ab,tot}$. Both K_{be} and $K_{ab,tot}$ increased linearly with plant age correlating with root length and leaf area, respectively. Plants grown in OWC showed greater K_{be} and $K_{ab,tot}$ than those in SWC. Coordination between K_{be} and K_{ab} was linear at early developmental stages, after which K_{be} plateaued with increasing K_{ab}. Results showed that for a given $K_{ab,tot}$ plants grown in SWC developed lower K_{be} than plants grown in OWC and reached an earlier plateau. This study provides insights into the complex hydraulic regulation mechanisms in maize plants under varying water conditions. The findings highlight the critical role of water availability in shaping plant hydraulic traits, growth dynamics, and adaptive responses. Variability in hydraulic conductance across water treatments and plant ages highlights the complexity of plant-water relations, emphasizing the necessity for a comprehensive approach to managing water use efficiency in agricultural systems.

PE1
O16

Modelling dry-season response of two tree species in a tropical dry forest in Costa Rica

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The diversity in drought-response strategies of (sub)tropical trees is still under-studied. The present study investigates drought adaptation of several species in a secondary tropical dry forest in northwestern Costa Rica by means of plant hydraulic modelling. The climate at the study site is characterised by high temperatures, distinct wet and dry seasons as well as strong interannual variability in total precipitation. During the pronounced dry season, with low relative humidity and temperatures up to 40 °C, different tree adaptation strategies are observed. Using the trait-based plant hydraulics model SurEau-Ecos, we test two hypotheses on adaptation strategies of two tree-species with differing traits: (i) Caoba (*Swietenia macrophylla*), reducing transpiration during dry season due to its facultative deciduousness, and (ii) Guapinol (*Hymenaea courbaril*) with evergreen phenology, continuing transpiration during dry season when access to deep water is available. The model has been extended to account for deep-water access as well as leaf shedding during drought. For model calibration and validation, continuous high-resolution measurements of soil water content and sap flow are used. Model results support the formulated hypotheses. Caoba specimens indeed steadily reduce transpiration with commencing dry season due to leaf abscission and increase transpiration during the early wet season in agreement with leaf flushing. Despite an observed depletion of soil water in the sampled top two metres, Guapinol specimens seem unaffected by the dry season in their transpiration behaviour due to root water uptake from the deep soil layer, which is supported by root excavations and water isotope investigations. The postulated hypotheses on adaptation strategies are supported by the alignment of observed and modelled data as well as the increased deviation when the model extensions are deactivated. Further model developments to consider other response strategies are discussed.

PE1 017

Does climate constrain woody species distribution according to their phloem anatomical properties?

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Studying the anatomical structure of phloem contributes to our comprehension of how phloem transport plays a role in the ecological success of species. Additionally, integrating both xylem and phloem traits enhances our understanding of how plants strategically adapt their morphological and anatomical features to diverse climates. In recent years, the importance of the scaling relationship between stem length and the size of xylem and phloem conduits has been highlighted for conducting more precise ecological studies. For some species, it has been observed that the intra-specific variance in vessel and sieve element size is more influenced by stem length than by climate. Further, stem length dominates inter-specific variance of vessel traits compared to species habit climate. However, the extent to which climate contributes to the inter-specific variability of phloem anatomical traits is not well investigated. The aim of our study is to examine stem anatomical traits of woody angiosperm species in relation to sample distance from apex and their native climate factors across different biomes. We collected stem cross-section images of species from a wide range of climates. We measured the size and frequency of sieve elements and vessels of outer layer rings. The optimum climate for species was extracted from CHELSA V2.0 based on their occurrence records on GBIF. Our preliminary result shows that when data from all species are aggregated, the radius of sieve elements follows a power law with distance from the apex. After correcting for the scaling factor and phylogenetic correlation, both temperature from the wettest quarter and precipitation in the warmest quarter are related to the radius of the sieve tube element. Our study demonstrates the importance of considering scaling geometry when conducting ecological research on anatomical traits. It also suggests that different phloem traits enable various species to cope with distinct environmental conditions.

018

The effects of elevated CO_2 and phosphorus limitation shaping fine root functioning in Central Amazon forests

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The Amazon rainforest's response to rising CO_2 levels is a key concern in terrestrial ecology. Given that much of the Amazon grows in phosphorus-poor soils, grasping the effects of nutrient limitations on forest dynamics in a changing environment is crucial. We installed eight Open Top Chambers (OTC) in an understory forest in Central Amazon in Manaus, Brazil, with four controls with ambient CO_2 (aCO_2) and four treatments with +200 ppm CO_2 (eCO_2). In each OTC, Inga edulis, a common N-fixing tree in the area, was grown in six pots, three with control soil from the study area and three with the same soil with added 600 mg/kg of phosphorus (P). After two years, total root dry mass, root nodulation, root diameter, specific root length (SRL), specific root area (SRA), root tissue density (RTD), root arbuscular mycorrhizal fungi (AMF) colonisation and root phosphatase activity were measured. Total dry root biomass with eCO_2 was twice that of aCO_2, with no effect of P addition. No nodules were detected in control plants, whilst 75% of plants growing in P+eCO_2 displayed nodulation. An interaction between eCO_2 and P was found for fine root diameter, with diameter increasing with eCO_2, only without P addition. SRL significantly increased with eCO_2, and RTD increased with P addition, with no changes in SRA. Root phosphatase activity significantly decreased with eCO_2. AMF colonisation decreased with P addition; however, this effect disappears with eCO_2. Greater allocation towards root biomass translated into overall greater root length, phosphatase exudation and AMF colonisation at the plant level with eCO_2, independently of P. With eCO_2, plants might acquire P directly by exploring higher soil volumes themselves and via AMF whilst allocating extra C to N-fixing bacteria in this scenario. We demonstrate how eCO_2 and P availability can shape belowground plant traits, pointing to important links between both affecting ecosystem-scale changes in future climate scenarios.

PE1

019

Nutrient dynamics and potential limitations of *Quercus petraea* L. under experimental canopy nitrogen deposition

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In the light of rising global air pollution levels, it is important to better understand the effects of increased Nitrogen (N) deposition rates in forest ecosystems. While most experimental N deposition studies have been utilizing conventional ground fertilization, in our research we adopted an improved approach of above canopy N application, with a conservative rate of 20 kg N ha^{-1} yr^{-1}, which may better simulate true deposition and feasible future scenarios. Unmanaged, pure and mature Sessile oak (*Quercus petraea L.*) stands have been treated continuously between 2015–2022 with NH_4NO_3 applied to either above the canopy, or to the forest floor directly (for comparison between the two methods), alongside unfertilized control plots. After 8 years of consecutive N application with no apparent effects on tree growth, we set out to explore possible productivity inhibitions in the stands. To assess the nutrient state of the system in this context, we collected and analysed foliage and soils for total and plant available elements, annually since 2015. The soil was further analysed for enzymatic activities. We found sub-optimal N, phosphorus (P), and potassium concentrations in the leaves, with a general increase in N:P ratios in recent years, that was significant only in both N treatments, to different extents. Soil analysis showed decreased inorganic P under both treatments compared to the control, with enzymatic stoichiometry pointing to an overall P limitation. In addition, aluminium was on the higher range, suggesting potential harmful levels. Thus, our results indicate imbalanced elemental conditions, which may prevent a prosperous growing environment. With these findings, we emphasize the importance of describing a wider nutrient status of when evaluating potential future impacts of atmospheric pollutants. At the same time, we debate the relevance of distinguishing between the different N application methods for defining proper conclusions.

PE1
O20

The underground economy: Reassessing the ecological impact of trade imbalances in common mycorrhizal networks

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Common Mycorrhizal Network (CMN) can connect neighbouring plant roots, promoting biodiversity and enhance intercropping productivity by facilitation. Trade imbalance in CMNs is suggested as a critical component, where one plant invests more carbon (C) into the network than the other but doesn't receive proportional nutrient benefits. Despite increasing research on trade imbalances within CMNs, the underlying mechanisms and their ecological significance for participating plant species remain poorly understood. Our hypothesis posits that trade imbalances influence plant productivity within CMNs, particularly favouring plants with a positive trade imbalance (low C investment, high nutrient return) benefit more in terms of mycorrhiza-driven increase in productivity – a concept termed mycorrhizal dependency (MD) than plants with a negative trade imbalance. Additionally, how CO_2 supply and altered nutrient demands of plants affect the trade imbalance in a CMN and MD were studied by growing them at different CO_2 levels. Greenhouse trials with C3 and C4 plants were grown in monoculture on a monotypic mycorrhizal network (MMN), and mixed, connecting with a CMN. We assessed the C contribution of plants to the CMN in the mixture by analysing the C isotopes of fungal lipids due to the distinct isotopic signature. At low CO_2, a notable trade imbalance existed between C3 and C4 plants, where C4 plants dominate the carbon supply to CMN, while C3 plants gained in productivity and nutrients. Interestingly, the trade imbalance did not affect MD in both plants, consistent across MMN and CMN conditions. Rising CO_2 triggered strong productivity effects only in C3 plants reflecting their strong dependency on AMF. This implies that under high CO_2 levels, C3 plants increase their nutrient demand and carbon investment in the CMN, unlike C4 plants. Consequently, trade imbalances decrease, showing a strong environmental influence on CMN dynamics. However, changes in carbon contribution and trade imbalances don't affect a plant's MD in MMN/CMN suggesting that trade imbalances have no discernible effect on growth or nutrient uptake within CMNs.

PE1

021

How grassland plant-soil relationships shift under moderate and extreme climate change

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Plant–soil feedbacks are a critical process for ecosystem function and are thought to drive patterns of resilience to environmental changes. Despite ample evidence indicating important interactions of soil microbes, soil chemistry, and plant communities for ecosystem function, little is known concerning how these interactions will shift with current trends in climate. We performed a downslope translocation experiment of soil + plant mesocosms to test how novel climate restructures plant-soil linkages in central Europe. We found that in absence of environmental changes, shifts in plant community were often linked with shifts in soil chemistry (pH, NH_4^+ etc.), but not directly by soil microbial community. Moderate changes in environment (warmer, drier conditions) led to a stronger link between soil chemistry and soil microbes as well as a stronger link between soil microbes and plant communities. Large changes in environment decoupled the relationships between plant community, soil chemistry, and soil microbes. Our findings indicate that the importance of plant relationships with abiotic and biotic soil conditions increase with moderate change in climate, but that larger changes in climate can potentially disassociate plants from abiotic and biotic soil conditions. This indicates that while plant–soil links can be important under moderate climate change, more drastic conditions may surpass a threshold where links between plant and soil conditions become disassociated resulting in degraded plant communities. Loss of plant-soil relationships under severe climate change will likely lead to higher vulnerability to subsequent ecological stressors.

PE1
O22

Exploring the influence of floral chemodiversity on alpine plant-microbe-pollinator dynamics

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Traditionally, research on floral scent emission has predominantly concentrated on the effects of individual compounds on specific interactions between flowers and other organisms with a focus on pollinators. However, recently phytochemical diversity (chemodiversity) is discussed as an important component of the plant's phenotype but we still lack knowledge about the ecological relevance of floral scent chemodiversity. Our study tests the effect of chemodiversity emitted by alpine flowers on associated bacterial communities and flower-visitors. We collected samples from various alpine plant species in their natural habitats to assess the diversity and composition of floral scent compounds, their bacterial microbiome, and recorded flower-visitor interactions. Our results show that plant species display substantial differences in chemodiversity of floral scent. Further, we found a significant increase in flower-visitor diversity with floral chemodiversity, aligning with the hypothesis that chemodiversity attracts diverse pollinator assemblages. However, bacterial diversity decreased with higher chemodiversity aligning with hypotheses that a more diverse scent bouquet may harbor various compounds that inhibit bacterial growth. Our study contributes to a more thorough understanding of the functional importance of chemodiversity and how it mediates ecological interactions between plants and associated organisms.

PE1
O23

Causes and consequences of phenotypic variation in plants

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Plants show a high degree of phenotypic variation in traits because of their continuous growth and modular structure. This variation occurs within and between individuals, genotypes, and species. It may be coordinated among traits to varying degrees. The main causes of phenotypic variation in plants are genetic factors, development, and internal and external environments. These can be studied and dissected in common-garden and transplant experiments and, to a lesser extent, through genomic approaches in natural settings. Genotype-by-environment interactions observed in experiments show how different plant genotypes respond to environmental variation, potentially indicating adaptive plasticity. Consequences of plant phenotypic variation in response to the environment may differ between individual, population, and community levels and between the short and long term.

PE1
O24

A developmental perspective on phenotypic plasticity of tree xylem traits: how life history trajectories in the species' morphospace define opportunities and risks for tree acclimatization

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The relationships between genotype, phenotype and environment are complex, yet very important for our ability to predict the response of trees and forests to climate change and to carry out appropriate silvicultural planning. Some traits governing specific types of developmental behaviour and the resulting phenotypes are under strong genetic control. Tree populations and forests can adapt over generations by natural selection, migration or assisted migration and other types of silvicultural interventions. However, with the current speed of climate change and its large-scale impact, the potential of already established trees to cope with changing environmental conditions by phenotypic plasticity is of very high interest. The plastic response of some tree species, such as beech, suggests that local climatic conditions may be more important for developing drought-resistant phenotypes than the genetic predisposition provided by potentially drought-adapted provenances. Besides resource allocation-induced phenotypic adjustments that manifest in changes in the allometry of plant organs, responses at the whole plant level are also mediated by variations within the species' leaf and wood economic spectrum. This contribution aims to illustrate the importance of considering a developmental perspective on phenotypic plasticity, specifically of tree xylem traits. It provides a concept linking genetic predisposition to (i) the location and extension of a species' morphospace, which depicts the developmental potential of two or more phenotypic traits, and (ii) the behaviour with which individual trees 'move' within this morphospace, e.g. the velocity of trait changes induced by environmental conditions, the role of life history on the formation of individual stable states, and their effect on further plastic responses, including the velocity and overall ability to develop towards new stable states forced or required by changing climatic conditions in a later phase in a tree's life.

025

Genetic response of a perennial grass to warm and wet environments interacts and is associated with trait means as well as plasticity

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Potential for rapid evolution is an important mechanism allowing species to adapt to changing climatic conditions. Although such a potential has been largely studied in various short-lived organisms, to what extent we can observe similar patterns in long-lived plant species, which often dominate natural systems, is largely unexplored. We explored potential for rapid evolution in *Festuca rubra*, long-lived grass with extensive clonal growth dominating in alpine grasslands. We used field sowing experiment simulating expected climate change in our model region. Specifically, we exposed seeds from five independent seed sources to novel climatic conditions by shifting them along a natural climatic grid and explored genetic profiles of established seedling after 3 years. Data on genetic profiles of plants selected under different novel conditions indicate that different climate shifts select significantly different pools of genotypes from common seed pools. Increasing soil moisture was more important selective pressure than increasing temperature or interaction of the two climatic factors. This can indicate negative genetic interaction in response to the combined effects, or that the effects of different climates are interactive rather than additive. The selected alleles were found in genomic regions likely affecting function of specific genes or their expression. Many of these were also linked to morphological traits (mainly to trait plasticity) suggesting these changes may have a consequence for plant performance. Overall, these data indicate that even long-lived plant species may experience strong selection by climate, and their populations thus have the potential to rapidly adapt to these novel conditions.

PE1

O26

The great trait debate

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Over the last 20 years, trait-based approaches to ecological research have become increasingly popular. Trait-based approaches have demonstrable potential for understanding and predicting numerous ecological processes and phenomena, but the trait concept is also often misused. Despite Violle et al.'s (2007) laudable attempts to provide clear definitions for different types of plant traits, numerous issues remain in applying those definitions (especially to other organisms). Importantly, the relationships between traits and response, performance, process, or function are often nebulous. However, it is precisely these relationships that determine the potential value of trait-based approaches. In 'The Great Trait Debate', leading researchers will present their views on the use and misuse of the trait concept in ecology, and debate them in a moderated Q&A with the audience. Collectively, we will attempt to answer questions such as: When is a trait 'functional'? How does phenotypic plasticity differ from or contribute to intraspecific trait variation? How do we ensure that trait-based approaches are robust and meaningful? In tackling these questions, The Great Trait Debate will be relevant to most delegates at the GfÖ Conference 2024, and all are welcome to attend.

PE1

P1

Climate and plant invasion: effect of drought on native and invasive *Prosopis* species in arid environments

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One of the major threats to the ecosystem functioning worldwide is the presence of invasive species due to their ability to grow and spread faster than the native ones. Moreover, ingoing climate change, e.g. drought, increases the risk of these invasive species. In the current study, we studied the effects of climate (drought) on the performance and productivity of the native *Prosopis cineraria* and the invasive *Prosopis juliflora* in Oman. We ran a greenhouse experiment under controlled conditions, in which we grew native only, invasive only and a combination of native and invasive species under three different drought schemes (low, medium and high) in addition to a control. Then we measured the productivity (total biomass), the performance in the form of plant functional traits (plant height, specific leaf area (SLA), leaf nitrogen content (N_{mass}), leaf carbon content (C_{mass}) and specific root length (SRL) of native and invasive species as well as the nutrient availability in soil (soil organic carbon (SOC) and soil total nitrogen (STN)) of native, invasive and mixed species under the four irrigation schemes. The study showed that invasive species were more productive (higher total biomass and lower RSR) and performed better (taller plants, higher SLA, N_{mass}, C_{mass} and Chl_{total} and lower LDMC) under drought conditions in both mono and mixed communities than the native species. These results provided a deeper understanding of the interplay between climate and biological invasion, which is crucial for predicting the consequences of changes in functional composition on ecosystem functions and consequently restoration of arid environments in Oman.

PE1

P2

Chemodiversity of *Tanacetum vulgare* affects aphid colony growth regardless of the presence of below-ground herbivores

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Plants serve as hosts for complex insect communities both above- (AG) and below-ground (BG) and these insects influence each other, mediated via the plant. To regulate plant-insect interactions, many plants produce an intriguingly high number of specialized metabolites, such as terpenoids, which can differ among individuals within plant species. Though this intraspecific chemodiversity has been found to strongly affect insect interactions, little is known on its role for AG-BG-interactions. We used common tansy (*Tanacetum vulgare*), a plant with highly diverse terpenoid profiles, to investigate whether chemodiversity mediates aphid colony growth in the presence of BG herbivores. We infested a subset of tansy plants from six different chemotypes with wireworms (*Agriotes* sp., Coleoptera: Elatiridae) as BG herbivores before infesting them with the specialized AG aphid *Macrosiphoniella tanacetaria* (Hemiptera: Aphididae). We found that aphid numbers differed significantly between chemotypes and that this was consistent over time, with highest numbers on a chemotype characterized by a highly diverse blend of terpenoids, expressed in low concentrations. Due to a high level of pupation in the wireworms, the effect of this treatment was variable. Still, the number of recovered wireworms affected aphid performance; aphids performed better on plants that had two wireworms, compared to those with one or zero. Interestingly, we did not find that chemotypes mediated the effects of BG herbivory. However, chemotypes did differ strongly in the impacts AG and BG herbivory had on their growth and health status. Our findings suggest that there is no direct mediating effect of plant terpenoid profiles on interactions between herbivores feeding on different plant parts, but that plant chemistry is linked to different growth traits that might mediate the effect of AG and BG interactions on the plant itself.

Future climate conditions amplify the effects of drought intensity on grassland functioning

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Multiple factors of global change, such as elevated atmospheric CO_2 concentrations, warming, and drought, are progressively affecting the ecosystems worldwide. Future drought events are likely to intensify, possibly leading to non-linear responses of ecosystem functioning. However, while of high ecological relevance, ecosystem responses to drought intensity have rarely been studied, and even less is known on whether future conditions, involving a combination of elevated CO_2 and warming, can affect such responses. In an in-situ multifactor global change experiment on managed mountain grassland, we investigated the resistance and recovery of ecosystem functioning in response to drought intensity under current versus future (+300 ppm CO_2, +3° C) climate conditions. With increasing drought intensity, above-ground biomass, specific root length, ecosystem carbon uptake and water use, and the leaf-level stomatal conductance and quantum yield of dominant species were increasingly reduced, while the root mass fraction as well as canopy surface temperatures were enhanced. These drought effects were more pronounced under future compared with current climate conditions. The studied parameters recovered to the pre-drought state within two months after drought exposure, except for the root mass fraction, which remained higher when previously exposed to the highest drought intensities. Our results suggest that in a future warmer climate the effects of drought intensity on grassland functioning will likely be amplified.

PE1

P4

Effect of nurse crops on photosynthesis of underplanted silver fir trees

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Silver fir is in the early stages of growth a shade-tolerant species, which makes it difficult to regenerate it on large-scale clear-cuts. However, it can artificially regenerate under the shelter of a nurse crop stand which improves the site's microclimate. Here we compare the physiology and morphology of silver fir seedlings growing in small gaps or under the shelter of nurse crop stands of birch or aspen with various densities, all under favourable water availability. We measured light-saturated photosynthetic rates and light curves of photosynthesis on young needles. After two years of measurements, a portion of denser nurse crops was thinned, and the response of the fir trees was measured. We compared differences in area, length, and width of fir needles, which also corresponded with spectral reflectance. Within all sites and species composition, we found that photosynthetic performance was higher in small gaps than under the shelter of nurse crops. The photosynthetic performance negatively correlated with canopy density. Firs under the shelter of nurse crops had the needles flatter when compared with more spatially distributed needles around the twig of firs in gaps. Also, the colour was different, which corresponded to the amount of chlorophyll and photoprotective pigments. Results indicate that small gaps provide the best microclimate for the artificial regeneration of silver fir, as suggested by the highest growth increment of silver fir in gaps than even under the sparsest nurse crop. However, better growth of silver fir in gaps comes at the cost of no wood production of biomass in the overstory.

PE1

P5

Linking drought, tree growth, and rhizosphere microbial communities in forests of beech, spruce, and pine in Bavaria

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The preservation of forests under climate change with increased frequency and duration of drought periods is a critical problem. Therefore, a better understanding of the aspects involved in the resilience of forests is key to adopting management strategies that can counteract climate change. The belowground system is crucial in the uptake of water and nutrients and is thus closely linked to tree growth. Factors such as the association between ectomycorrhizal fungi (EMF) and roots are known to be essential for this role and have proved to be involved in drought adaptation of forest ecosystems. However, the role of other rhizosphere microorganisms in this intricate network remains unknown. The present study intends to uncover the interrelationships between tree growth and different rhizosphere microbial components (bacteria, fungi, and protists) in pure and mixed stands of beech, spruce, and pine under different precipitation regimes. To achieve this, forest monitoring data (growth increment, nutrient status, soil, and meteorological data) of pure and mixed stands will be combined with molecular diversity data of the soil-rhizosphere microorganisms. To advance the taxonomic resolution of the microbial community, third-generation sequencing using Oxford Nanopore Technology (ONT) will be implemented. In addition to differences in the microbial composition between tree species, we hypothesize keystone microbial taxa associated with drought conditions and tree growth.

PE1

P6

Investigating the causes of the central dieback in Namibia's ring-forming tussock grass *Eragrostis nindensis*

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A central dieback in tussock grasses that grow in arid regions can be observed worldwide. One of these grass species is *Eragrostis nindensis*, which is a palatable climax grass that occurs in many regions of southern Africa. In Namibia, it often forms conspicuous rings in the western part of the country, particularly in areas where mean annual precipitation (MAP) is below 250 mm. However, under moister conditions, *E. nindensis* is a densely tufted grass. The reason for the formation of the central dieback and ultimately for the appearance of a doughnut-like ring is commonly attributed to water stress and the associated depletion of resources in the inner area of the tuft. However, this may not be the only reason as the presence of phytopathogenic microbes is increasingly reported to be involved in the formation of grass rings. Here we show some first results of fieldwork on *E. nindensis*, which was conducted in March 2024 near the Namib Desert, where MAP is only about 170 mm. At first, we measured the diameters of 10 grass rings which ranged from 12 to 41 cm. In these rings, we also measured the speed of water infiltration using a mini-disc infiltrometer. Our data show that the speed of infiltration increased with ring diameters. This is likely a result of finding a higher proportion of sand in larger rings but less root and rhizome material from the mother plant. Then, we also analysed the microbial composition of the top 10 cm of soil taken from the interior of grass rings and the matrix soils between 40 to 200 cm away from the rings. We applied a metagenomic approach using Next Generation Sequencing of 16S (prokaryote) and ITS (lower eukaryote, fungi) amplicon sets. Our new results will shed light on the question to what extent the soil metagenomic DNA extracts revealed putative phytopathogenic microorganisms that could be involved in the ring-formation, in addition to water stress and inner resource depletion.

PE1

P7

Xylem anatomical and hydraulic traits vary within crown but not respond to water and nitrogen addition in *Populus tomentosa*

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Nitrogen (N) and water availability are the two crucial factors confining tree growth and forest productivity. Irrigation, fertilization, and combined fertigation are commonly applied to plantation forests for improving productivity. However, how xylem vasculature responds to these management practices remains poorly understood. Here we investigated the responses of tree growth, xylem anatomical structure, and hydraulics of the upper, middle, and lower canopy branches in a 6-year-old *Populus tomentosa* plantation subjected to four years of irrigation and fertigation treatments. The results showed that an improvement in tree growth only occurred in the irrigation treatment while the addition of N in fertigation treatments did not have a cumulative effect on tree growth. Most of the xylem anatomical traits, including vessel hydraulic diameter (D_h), vessel density (VD), vessel fraction (VF), double vessel wall thickness (t), potential specific sapwood hydraulic conductivity (K_p), fiber wall to lumen ratio (T_f/D_f), vessel wall reinforcement $(t/b)^2$, and wood density (WD) all showed conserved plasticity to long-term irrigation and fertigation, despite different tree growth rate, implying that aboveground biomass accumulation may have decoupled from the branch-level xylem traits. Besides, the alterations of other factors, including stomatal regulation strategy and crown structure with soil water and N availabilities, might better explain the variation in tree growth. In contrast, greater variations in branch xylem traits were detected across canopy layers. The upper canopy showed greater hydraulic safety characterized by narrower and denser vessels, higher cell wall to lumen ratio, and higher wood density compared to the lower canopy, while hydraulic efficiency (K_p) remained constant across the crown, thus highlighting the priority of hydraulic safety over efficiency in the construction of branch xylem. Overall, our study revealed the response pattern of *P. tomentosa* xylem structure to long-term water and N management, which facilitates a comprehensive understanding on the mechanisms underpinning the influence of water and nutrients regulation on the performance of fast-growing tree species' plantations.

P8

Effects of the surrounding landscape on hedgerow-associated plants

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Hedgerows in agricultural landscapes provide resources, such as habitat and food, for a variety of species and thereby contribute to agricultural biodiversity. The effects of local characteristics of hedgerows on various species are well-studied. For many organisms, it is therefore known which hedgerow characteristics, for example in terms of height, width, shrub species or presence of trees, support them best. However, the impact of the surrounding landscape is less well studied. In the biodiversity working package of the project 'CatchHedge – Carbon sequestration of hedgerows and field copses' we investigate the plant, carabid, spider, harvestman and ant diversity at hedgerows in differently characterised landscapes. To this end, vegetation surveys were carried out and funnel traps were installed at the hems of hedgerows in 7 and 8 study areas, respectively, distributed all over Germany. In total, 32 and 34 sampling points at hedgerows bordering agricultural fields were investigated, respectively. Plant surveys were done twice, once in spring for the early-flowering plants (spring geophytes) only, and once later in the vegetation period comprising all plant species found in the plot. Each vegetation plot had a size of 1 m (from the hedge in direction of the field) x 25 m (along the hedge). The landscapes surrounding the locations differ in terms of total amounts of hedgerows and of hems and field margins as well as other factors, such as amount of forest, field and grassland. In a first step, we are going to model the impact of a variety of local and landscape factors influencing the species diversity and groups of species (plants: characterised by different habitat preferences, dispersal mechanisms and life cycles) using GLMM. The results of these analyses for plants are to be shown on my poster.

PE1
P9

The ECOSENSE project – Spatio-temporal dynamics of ecosystem processes assessed and modelled by smart autonomous sensor networks across scales

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Recurrent stressors, such as heat and drought events, increasingly impact European forests, with potentially cascading effects on their carbon sink capacity and drought resilience. Knowledge of the impacts on the many processes that drive soil-plant-atmosphere interactions within complex systems is largely lacking, and uncertainty about future changes is high. Predicting the response of forests to climate change will require an improved understanding of the processes of carbon and water cycling across temporal and spatial scales, including the atmosphere, hydrosphere, biosphere and pedosphere. Many processes occur at small scales and high spatial heterogeneity and their interactions and feedback loops can be key players to amplify or buffer a system's response to stressors. Currently, we lack the appropriate measurement, data and modelling tools to comprehensively quantify relevant processes in real time at high spatio-temporal scales. Climate change impacts are highly uncertain, and future research will need novel mobile, easy deployable, and cost-efficient approaches. Our interdisciplinary project ECOSENSE investigates all relevant scales in a next generation ecosystem research assessment. Our vision is to detect and forecast critical changes in ecosystem functioning based on the understanding of hierarchical process interaction. ECOSENSE develops, implements, and tests a new versatile, distributed, cost-effective, autonomous, intelligent sensor network based on novel microsensors tailored to the specific needs in harsh forest ecosystems. These sensors will measure the spatio-temporal dynamics of ecosystem states and fluxes in a minimally invasive manner. Data will be transferred in real-time into a sophisticated database which can be explored for process analysis, deep learning approaches, and enhanced simulation models for now- and forecasting applications. Our novel ECOSENSE toolkit will open new horizons for rapid assessment in large and remote ecosystems.

PE1

P10

Effects of limitation of nutrients N, P, and cations on resource allocation for physical defense in canopy leaves in a central Amazon rainforest

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Herbivory plays a significant role in influencing nutrient cycling and ecosystem productivity, particularly in environments where nutrient availability constrains plant performance. Herbivores tend to prefer plant species with high palatability and low levels of structural defense compounds. However, the exact impact of herbivores on tropical forest productivity, carbon balance, and nutrient cycling remains uncertain, especially in the Amazon region. The focus of this research is to understand how the availability of soil and litter nutrients influences herbivory on canopy leaves, considering losses by herbivory and leaf investment in structural defense compounds in a 'terra firme' forest in Central Amazonia. The study site was the AFEX (Amazon Fertlisation Experiment) project, a large-scale experiment that aims to understand ecosystem responses to soil nutrient limitation. The treatments consisted of the addition of nitrogen (N), phosphorus (P), Cations (Potassium, magnesium, and calcium), and their interactions (7 treatments plus control). The treatments were distributed in four blocks, each block contains eight plots representing the complete factorial design (n = 32 plots). Litter was sampled biweekly for 2 years (between July 2017 and September 2019), using five evenly distributed litter traps at 1 m height, with an area of 0.25 m^2 each, 160 traps total. Litterfall biomass, leaf area and leaf area consumed by herbivores, macro and micronutrients, lignin, and cellulose were determined. After 2 years of fertilisation, we observed an increase in leaf litter biomass production in the presence of P, leading to greater nutrient input returning to the soil through litterfall. There was a significant increase in leaf palatability, demonstrated by higher carbon and phosphorus concentrations in the litter leaves ($P < 0.001$), as well as a strong relationship between higher leaf area and higher cellulose content ($P < 0.001$). This resulted in a strong cellulose content relation with both leaf P nutrients ($P < 0.005$) and a larger area consumed by herbivores ($P < 0.001$). The initial responses of fine litterfall production suggest rapid changes in litter nutrient inputs, palatability with leaf nutrients, and cellulose, which can positively affect the leaf area consumed by herbivores.

P11

Unveiling the ecological drivers of flower morph frequencies in heterostylous plant

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Heterostyly is a genetically determined floral polymorphism of style length promoting outcrossing between individuals of different morphs, which usually coexist within populations at equal frequencies. Loss in the area and connectivity of suitable habitats may cause deviations from the expected equal morph frequencies as shown in our previous study. The exact underlying mechanisms of the prevalence of one morph over the other, are, however, not clear. Here, we aim to elucidate the factors contributing to the differences in morph frequencies within population of *Primula veris*, plant species typical for European semi-natural grasslands. We conducted a comprehensive field survey to collect data on plant size, demographics, seed production, and inflorescence characteristics at multiple sites in five different European countries. We also recorded locality characteristics such as their size and land use. Additionally, we recorded the floral morph for each individual plant, allowing us to compare fitness metrics between the morphs. By analysing these fitness components across morphs, we aim to identify the key ecological factors driving the observed patterns. Our findings will contribute to a broader understanding of floral polymorphism and its ecological implications for plant populations.

PE1

P12

When and how: measuring thermal sensitivity in three temperate Central European timber species across a growing season *in situ* and in the lab

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Rising global temperatures and the increasing intensity of heatwaves represent mounting threats to trees and forests globally. Determining the critical temperatures at which damage occurs in the leaves provides insight into thresholds at which declines in the health and productivity of trees begin or become irreversible. Studies on the thermal sensitivity of leaves are already available for some trees, mainly from tropical regions, but temperate species are still understudied. Specifically, knowledge about potential changes in thermal sensitivity throughout the growing season between needle age classes in conifers is lacking, and results are often reported for excised leaves only. In this study, we determine critical temperatures at which the photochemical efficiency of PSII, the ratio between the variable and the maximum chlorophyll fluorescence (F_v/F_m), is impaired. We use an established water-bath method to produce temperature response curves for excised leaf and needle samples treated in the lab, and an *in situ* heating method to measure the same response in the canopy of mature trees in the field. We hypothesize that older leaves of the deciduous *Fagus sylvatica*, and year-old needles of coniferous *Picea abies* and *Pseudotsuga menzesii*, will tolerate higher temperatures than new leaves or same-year needles before damage to leaf photochemistry occurs. Results from the water-bath method in the lab are expected to indicate a higher sensitivity than results from the *in situ* leaf heating due to the potential for increased leaf resistance to and recovery from heat events while still attached to the rest of the tree. Our results will deepen the understanding of thermal sensitivity and climate vulnerability for these three species as well as provide a comparison between results measured on excised samples and those measured directly in the field.

Root traits across biomes - links between belowground traits, species diversity and ecological implications

Short title: Root traits and ecological implications

Chairs: Laynara F. Lugli, Lucia Fuchslueger, Nathaly Guerrero Ramirez

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Fine roots are a dynamic interface connecting plants and soils. They are pivotal in plants' water and nutrient uptake and transport, affecting soil organic matter formation and accumulation, mineral weathering and plant-soil microorganism interactions. In particular, many plants can adapt their fine root morphological physiological, biochemical and molecular features and facilitate inter-kingdom associations, such as interactions with root-associated bacteria or fungi, like mycorrhiza. Hence, the trait diversity of fine roots in an ecosystem can strongly influence ecosystem biogeochemistry (carbon and nutrient cycling) and biogeophysical processes (water and energy fluxes). Despite the undeniable significance of fine root traits in shaping plant and community functioning globally, a notable gap persists in our understanding of root ecology, especially compared to the wealth of existent knowledge for leaves and stems. Gaining a comprehensive understanding of root trait diversity, from individual species to the broader biome level, is crucial for predicting the impacts of resource shifts under future climatic conditions. In this session we want to bring together scientists investigating the diversity of root traits, root trait-trait relationships and inter-kingdom associations of individuals, species or community level. We are particularly interested in studies extending our understanding of the 'root economic space', linking root trait variation to ecosystem functions from different biomes around the Globe at local or regional scales, reporting on natural distributions, or adaptations to experimentally induced spatial and temporal resource availability gradients. Furthermore, we invite the presentation of innovative methodologies and promising approaches to foster the inclusion of root traits in future ecological research.

PE2
01

Root traits across biomes — links between belowground traits, species diversity and ecological implications

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The rhizosphere world is one of the final frontiers in terrestrial ecology. Fine roots are a dynamic interface connecting plants and soils and are pivotal for plants' water and nutrient uptake and transport, affecting soil organic matter formation and accumulation, mineral weathering, and plant-soil microorganism interactions. Many plants can, to some extent, adapt their fine root morphological physiological, biochemical, and molecular features and facilitate inter-kingdom associations, such as interactions with root-associated bacteria or fungi, like mycorrhiza. Hence, the trait diversity of fine roots in an ecosystem can strongly influence ecosystem biogeochemistry (carbon and nutrient cycling) and biogeophysical processes (water and energy fluxes). However, many open questions can only be answered through a communal effort. By sharing and compiling hard-won observations into large harmonized publicly available databases, we can advance our scientific understanding. These large databases play a crucial role in facilitating ecosystem or vegetation model development and serve as a tool to identify major data gaps and uncertainties in our knowledge of root functional and rhizosphere ecology. In this article, we will provide an overview of the root functional ecology, emphasizing its contribution and the new research frontiers. Additionally, we will introduce major root trait databases currently available, such as the Fine Root Ecology Database (FRED), the Global Root Trait (Groot) database, and a more recent initiative focusing on the tropics, the Tropical Root Trait (TropicalRoot) database.

PE2
02

Rhizosphere engineering: Mind the soil textures

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Soil drying poses a significant hurdle to plant growth. In response to this stress, plants develop diverse root and rhizosphere traits that enhance their access to water and nutrient resources. Root exudates, particularly mucilage, have garnered considerable attention for their role in modulating soil properties under drought conditions. Despite this interest, the mechanisms through which mucilage influences water and nutrient uptake and the regulatory needs tied to varying soil textures remain insufficiently understood. This study assessed the effect of maize root-derived mucilage on water and nutrient-related properties of soil with contrasting textures (sand, sandy loam, loam). These soils were treated with different concentrations of maize mucilage (0, 2.5, 5.0, and 7.5 mg dry mucilage per gram of dry soil). We conducted a soil evaporation experiment, coupled with neutron radiography and advanced water flow modelling, to investigate mucilage's impact on soil water retention and flow across various textures and mucilage concentrations. Concurrently, phosphor autoradiography was used to track the diffusion of ^{45}Ca in simulated rhizospheric soils at different moisture levels. Finally, we examined soil-plant-water and nutrient relationships in contrasting soil textures using maize lines distinguished by rhizosheath formation, which served as a proxy for the rhizosphere engineering through mucilage exudation. Our findings revealed that the water-holding capacity, hydraulic conductivity, and effective diffusion coefficient of soils improved in simulated rhizospheric soils which were significantly influenced by soil texture and mucilage concentration. A critical mucilage concentration was necessary to observe substantial improvements. Furthermore, rhizosheath amplified the performance of the maize line known for rhizosheath formation. This enhancement was greatly influenced by both soil texture and moisture levels. To sum up, Simulated rhizospheric conditions enhanced soil water and nutrient retention and flow, with notable improvements influenced by soil texture.

PE2
03

Dynamics of fine root biomass and morphology of European beech (*Fagus sylvatica*) in sandy soils with different moisture regimes

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Fine roots are the essential organ for water and nutrient acquisition of a tree. Key morphological attributes that contribute to efficient water and nutrient uptake include specific root length (SRL) and specific root area (SRA) of fine roots. Despite their importance for tree growth and productivity, little is known about how fine roots respond to climate change and thus changes in the soil moisture regime of forests. Given that European beech (*Fagus sylvatica* L.) is the predominant broadleaved tree species and timber supplier in Europe, yet highly susceptible to drought, it is crucial to determine the impact of drought on beech fine roots. Drought results in crown dieback, leaf and fine root shedding, and reduced growth rates in mature beech. There are few long-term in situ observations on the plasticity of beech fine roots under recurrent drought. Hence, we conducted an intensive observational study of fine root biomass and morphological changes along a gradient in soil water availability in a near-natural mature beech forest of the Dübener Heide, Germany. We hypothesized that: (i) Soil moisture has a dominant effect on root biomass and morphology, leading to lower fine root biomass and higher SRL, SRA and root tip frequency (RTF). (ii) The influence of soil moisture on fine root biomass and morphology is related to soil depth and more pronounced in the topsoil. A sequential root coring approach with accompanying soil moisture measurements is carried out every three months starting from April 2022 ongoing to January 2025. First analyses reveal significant differences in fine root biomass and morphology between seasons for the organic and mineral layer. However, within the soil moisture gradient, only fine root biomass exhibits a significant difference. Results imply loss of biomass and low morphological adaptability of fine roots during recurrent summer droughts, which may be an early indicator of the drought inflicted growth reduction and dieback of beech.

PE2

04

Tree carbon allocation to root exudates in temperate biomes under varying environmental conditions

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Root exudates shape the formation of soil and the microbial community thus play a fundamental role in plant belowground dynamics. Carbon allocation to root exudates may tightly relate to plant belowground responses to environmental conditions. Root exudation patterns may change depending on plant interactions, plant susceptibility to and recovery from drought, soil N availability or soil pH. Investigating how exudation varies among trees throughout seasons, with different nutrient availability and soil moistures can improve our understanding of belowground C allocation in response to the environment. We tested if root exudation is upregulated under adverse environmental conditions, i.e. drought, N limitation or low soil pH and for how long C allocation to exudates remains altered upon drought release. We further coupled exudation to root non-structural carbohydrates (NSC) across a seasonal cycle. We sampled exudates from mature trees in two long-term field experiments, a N x pH manipulation site in New York, USA and a throughfall exclusion site in Bavaria, Germany. We quantified root exudation in dependence of soil N and pH across a seasonal cycle and over several years during and after drought release. Especially under drought and N limitation we found that trees tended to exude more C under adverse conditions. Trees significantly reduced exudation rates in the winter but did not cease to exude C despite the absence of C assimilation, indicating usage of stored C for exudation during the winter. In accordance, root NSC followed a similar seasonal cycle. After the experimental drought ended, C allocation to root exudates was altered for several years before being comparable to control tree exudation. Our results demonstrate a dynamic regulation of root exudation in correlation to environmental conditions. Ongoing and future studies focus on understanding the correlation between exudate quantity and its functions.

PE2

05

Simulating ecosystem adaptation in response to a changing climate by capturing belowground plant functional traits in an eco-evolutionary vegetation model (Plant-FATE)

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In the face of ongoing global crises, such as climate change and biodiversity loss, we urgently need to understand the dynamic and complex adaptive responses of global forest ecosystems. To do so, we need to develop modelling frameworks that account for multiple temporal and organizational scales, and therefore capture functional adaptations of individuals, species, and ecosystems in response to the environment. Here we present Plant-FATE (Plant Functional Acclimation and Trait Evolution) an eco-evolutionary vegetation model that embodies functional diversity by representing plant life-history strategies in trait space, and adaptations by accounting for short-term physiological acclimation, mid-term demographic shifts, and long-term trait evolution. Tested with data obtained from an hyperdiverse site in the Amazon Forest, our model captures plant functional characteristics and therefore correctly predicts emergent ecosystem properties, such as the size distribution and community-composition of the local species pool. As a next step, we are extending the physiological module of Plant-FATE by implementing an optimality-based representation of belowground plant traits that captures the observed trade-offs between water/nutrient uptake and the requisite investment into fine root biomass. At the community level, this means that changes in soil fertility or water content, e.g. during drought, can alter belowground strategies of plants competing for limiting resources. By incorporating a dynamic representation of belowground plant functional traits and capturing the eco-evolutionary niches of plant species coexisting across natural environmental gradients, we are able to represent ecosystem adaptation and community shifts in response to a changing climate and therefore will be able to simulate the functional response of forest ecosystems under future scenarios.

PE2
O6

Experimental warming effects on hyphal growth and depth distribution in a wet-tropical forest of Puerto Rico

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The increased frequency of episodic disturbances (e.g. hurricanes) associated with rising global temperatures threatens the role of tropical forests as major global carbon (C) sinks, yet the forest responses to these interactive global changes are rarely captured. Soil fungal communities are key players affecting the soil C sink as a consequence of their symbiosis with plant hosts, C inputs from fungal turnover, and mediation of litter decomposition processes. However, data on the responses of soil fungal communities to climatic stressors in tropical forests is still scarce and confounding. To address this knowledge gap, we used imaging, microscopic, and biochemical methods to study the growth and depth distribution of saprotrophic and arbuscular mycorrhizal fungi in the soil of an *in-situ* field warming experiment (Tropical Responses to Altered Climate Experiment, TRACE) in Puerto Rico, where a tropical rainforest is exposed to a warming treatment (+4°C above the ambient) for 8 years and endured two hurricanes (category 4+) after one year of the warming treatment started. Our first data show that before the hurricane events, warming initially increased hyphal abundance (mini-rhizotron observations) at 0—10 cm soil depth by 143%, whereas seven years after the hurricane throw, warming reduced soil extraradical hyphal length (soil extractions) by 20%. These results indicate the potential dynamic of hyphal growth in the short and long-term, considering single and multiple climatic disturbance interactions in a tropical forest.

PE2

07

Fine roots in the litter layer: an efficient nutrient acquisition mechanism in the Amazon rainforest

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About 60% of the Amazon rainforest grows on geologically old, highly weathered soils with low phosphorus (P) availability, limiting forest productivity and modulating forest responses to environmental changes, e.g. higher atmospheric carbon dioxide (eCO_2) concentration. The tight and efficient nutrient cycling maintains forest productivity even with limited soil nutrient conditions. In some Amazonian regions, the litter layer is highly colonized by fine roots that enable an efficient interception of the newly mineralized nutrients before they are leached out of the system. Moreover, plants can adapt root morphological traits to more efficiently intercept nutrients by a 'do-it-yourself' strategy increasing the specific root length (SRL) or by 'outsourcing' and investing in symbioses with mycorrhizal fungi. Plants can also adjust root exudation, possibly stimulating microbial activity and enhance organic matter decomposition to increase nutrient availability. In the Central Amazon, this priming process was only observed for more recalcitrant wood debris but not for more 'labile' leaf litter. However, fine roots contributed 43% to phosphatase activity, accompanied by a decrease in the leaf litter P content, which suggests that tree-targeted P hydrolysis of organic P is an efficient strategy for accessing P efficiently. Similarly, we observed a quick understory plant community response to eCO_2 by significantly increasing the SRL and fostering a do-it-yourself strategy within the litter layer. Again, we observed that the intensified root colonization of the litter layer triggered a decrease in litter P without changing litter decomposition. This suggests that P-limited Amazon forest plants may use the extra C obtained under eCO_2 conditions to increase the P mobilization from the litter layer. Our results reinforce the importance of roots growing in the litter layer to maintain a tight nutrient cycling and efficient nutrient acquisition in the Amazonian, with direct implications for forest productivity and the global C dynamic in response to climate changes.

PE2
08

Convergence of leaf and root traits is driven by different environmental factors in Hengduan Mountain forests

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Variation in leaf and root traits is linked to above- and below-ground resource acquisition strategies that influence plant community assembly and mediate the responses to environmental change. However, little is yet understood about the sources of variation in leaf and root traits and their role in community assembly in mountain forests. We measured leaf and root traits of 47 woody species, as well as climate and soil variables, along a 1200 m elevation gradient in Yulong Mountain, Hengduan Mountains region, southwest China. We then examined how resource acquisition strategies associated with leaf and root traits varied along the elevational gradient and determined the relative effects of environmental variables on these metrics of functional diversity. We found that the resource acquisition strategy of roots shifted from a conservative (high root diameter and root tissue density) strategy to an acquisitive (high root branching intensity) strategy with increasing elevation. However, there was no significant change in most leaf traits. Functional convergence was observed for leaf and root traits, and for the total spectrum of traits. The degree of convergence increased with increasing elevation, especially for root traits. Temperature had a negative effect on the functional diversity of leaf and root traits. The convergence of leaf traits was related to soil nitrogen status, while that of root traits was related to soil organic carbon. Our results highlight that patterns of resource acquisition strategies along an elevation gradient are decoupled for leaf and root traits and that the convergence of root and leaf traits is influenced by different environmental factors. This study suggests that forest communities in mountain ecosystems could modify their resource acquisition strategy through multidimensional trait combinations to improve resilience to environmental change.

PE2
09

Impacts of vegetation diversity on invertebrate fauna and microbial communities on agroecosystems

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Agriculture drives biodiversity loss. Monoculture farming in particular strongly filters local species pools, thereby limiting potential biotic interactions. Increasing vegetation diversity in agroecosystems promotes more diverse interactions between plants and heterotrophs, and earlier studies show major impacts on ecosystem functioning with even small increases in vegetation diversity. To investigate how vegetation diversity affects the heterotroph communities in grain monocultures, we sampled fauna and microbes from a field experiment where 1–8 undersown cover crops were grown with barley at different diversity levels (1, 2, 4 and 8 co-occurring species). We use joint species distribution models accounting for phylogeny to test for the effects of richness or identity of crops as well as their functional traits (N_2-fixation or root architecture) on heterotroph communities. We determine which community (above- or belowground invertebrates, root and soil fungi or bacteria) responds most strongly to undersown diversity, which aspect of diversity (species or functional richness vs. specific species or functions) has the strongest effect on communities, and identify which species respond positively or negatively to vegetation diversity. Our preliminary results suggest that cover crop composition shapes heterotroph communities, and that N_2-fixing and deep-rooted undersown affect especially soil faunal and bacterial communities, respectively. Overall, taxonomic groups respond differently to different aspects of plant diversity.

Morphological diversity of the velamen radicum in the genus *Anthurium* (Araceae)

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Epiphytes develop anatomical features to improve the efficiency of the uptake of water and nutrients, such as absorptive foliar scales or a velamen radicum. Despite substantial studies on the occurrence, morphology, development and phylogeny of the velamen, majority of available literature is focused on Orchidaceae, making our current knowledge on velamen clearly biased. A recent publication firmly established that velamina are commonly found in *Anthurium* species. Thus, this study provides further insights by describing the velamen morphology characteristics of *Anthurium* species and classifying them into different velamen types. Furthermore, we investigate if the different velamen morphological traits are clade-specific and phylogenetically conserved within the genus. Using the scanning electron microscope, we performed a morphological study on 89 *Anthurium* species, describing six micromorphological traits of velamen and exodermis, following the traits used to classify Orchidaceae velamen by Porembski and Barthlott (1988). We distinguished nine velamen types, including two that are unique to *Anthurium* and not similar to any type found in Orchidaceae. Comparing velamen morphology within the phylogenetic tree of *Anthurium* revealed clear phylogenetic signals. This work provides detailed morphological description of 89 species of *Anthurium* from the Araceae family and substantially broadens our knowledge of this tissue. However, velamen function has been even studied less, where there is hardly anything known about a functional significance of having secondary cell wall thickenings and perforations on the velamen cell walls. Therefore, a logical next step would be to connect these anatomical features to their function.

PE2

P2

Soil nutrient limitation controls belowground carbon cycling in Central Amazon: the role of fine root dynamics

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Soil nutrient availability is hypothesized to influence net primary production (NPP) in tropical forests, with varying responses between above and belowground components and nutrients. In the Amazon rainforest, where soil nutrients like phosphorus (P) and cations (CAT) are scarce, nutrient manipulation experiments have shown divergent impacts on carbon (C) allocation above and belowground. The Amazon Fertilization Experiment (AFEX) in Central Amazonia, Brazil, located in a primary terra firme forest in Central Amazonia, Brazil, demonstrated that adding P and CAT significantly altered fine root traits and increased root productivity. After two years, P was the only element that increased canopy and root NPP, with no effects on stem growth. However, the fate of belowground C remains less understood. Building on previous AFEX studies, this research aimed to determine if adding P, nitrogen (N), and CAT in a factorial design affected fine root productivity, stocks, and turnover in the 0—30 cm soil layer from 2017 to 2019. The main hypothesis Wis that the addition of the limiting nutrient is expected to reduce biomass while increasing productivity and turnover. Due to the known strong P limitation at this site, we anticipated that the reponses would be strongest for P, followed by CAT and no response to N addition. As a result, P addition increased productivity and fine root turnover in both years, N addition had no effect, and contrary to expectations, CAT addition reduced fine root turnover in the second year. This study supports the hypothesis that fine root dynamics are highly responsive to soil nutrient availability, especially to phosphorus (P) in the Central Amazon. We conclude that nutrient addition prompted a short-term change in C allocation within the root system, leading to investment in cheaper roots for more efficient soil exploration and this rapid strategic response could drive important changes in the forest's carbon and water cycling in a long term.

Species specific fine root morphological traits and their interactions with soil microbial processes

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Tropical forest regrowth success could be related to fine root traits favouring fast soil colonization and nutrient acquisition. However, different plant life-history strategies could lead to trade-offs between plant growth and fine root morphological and biochemical acquisition strategies in a resource competitive environment. In a tropical lowland rainforest reforestation area located in SW Costa Rica, we investigated a variety of fine root morphological traits, nodulation status, and fine root nutrient concentrations of absorptive roots (<2 mm diameter) from plant individuals comprising 20 tree species distributed across eleven families. In addition, we measured root surface phosphatase activities, as well as microbial biomass and phosphatase activity rates in soils in the close vicinity of fine roots, with the aim to identify potential links between root traits and plant growth success. We found clear differences between root traits among the investigated species; fast growing species showed a relatively narrow specific root length spectrum, with long and fine roots having a large area interacting with the soil environment and moreover infer lower production costs but need to be turned over faster. In contrast, slow growing species tended to have a more pronounced root tissue density optimum, which could foster increasing life span and mechanical resistance of roots. This suggests that these opposing characteristics could reflect different plant functional adaptions to cope with potential resource limitation, and edaphic properties, but also may foster collaborations with soil microbial communities. Our findings highlight the need to increase our understanding of belowground root morphological and physiological traits during forest succession, especially when aiming to restore forest ecosystem functioning in formerly intensified land-use systems.

PE3

Carbon allocation in plants and ecosystems under climate change

Short title: Plant carbon allocation in a changing climate

Chairs: Günter Hoch, Benjamin Daniel Hesse, Kyohsuke Hikino

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Climate change potentially alters carbon (C) relations of plants and ecosystems. This is related to the continuing rise in atmospheric CO_2 that alters plant and ecosystem stoichiometry with consequences for functioning. In addition, increasing temperatures and drought events can decrease C uptake and alter C allocation patterns at the plant and ecosystem level. Under extreme conditions this can cause disruptions of the plant and ecosystem C balances as well as tree mortality. However, plant and ecosystems are also able to acclimate to these changes, which might enhance plant and ecosystem resilience to climate change. Against this background, C allocation processes, including reserve formation, growth and respiration in plants and ecosystems have gained increasing attention in plant ecology. However, our current understanding of the controlling mechanisms and the ecological impact of changes in allocation – particularly at the whole-plant to ecosystem level – is still surprisingly patchy. This also involves formation of C reserves and the re-allocation of stored C, as well as defense compounds and the C flux to symbiotic interactions. Moreover, the effect of increases in extreme events such as drought and heat stress and subsequent recovery, on the whole-plant C balance and on C allocation patterns, as well as the significance of C reserves for stress resistance and resilience of plants and possible acclimation responses are a persisting uncertainty. As a consequence, we cannot predict the C balance of terrestrial ecosystems with confidence, and are limited in our understanding of plant plasticity and possible physiological, anatomical and structural adjustments that may alter ecosystem resistance and resilience to climate change. In this session, we aim to bring together researchers working on all aspects of C allocation and storage in plants and ecosystem. In particular, we encourage contributions on quantitative analyses of phloem C transport in plants, C-allocation at the whole-plant and ecosystem level including stress and recovery responses, studies on the ecological significance of C reserves and allocation adjustments for stress resistance and acclimation to new climatic conditions.

PE3

01

Long-term warming effects on carbon allocation dynamics in a subarctic grassland

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Northern terrestrial ecosystems are warming more and faster than the global average, with potentially strong implications for their carbon (C) dynamics. Although C allocation is considered a key process linking above- and belowground C pools and fluxes, its responses to global changes are still poorly understood. Therefore, it is largely unknown how warming affects the fate of recently assimilated C in the plant-soil-atmosphere continuum, and whether long-term acclimation responses to warming occur. On a >60-year geothermal warming gradient in an Icelandic subarctic grassland, we studied how prolonged warming modified above- and belowground C pools and fluxes, and how they are coupled through belowground C allocation. Performing an in-situ $^{13}CO_2$ canopy pulse-labelling, we traced the allocation of recently fixed C ($^{13}C_{excess}$) along the plant-soil-atmosphere continuum. Here, we will show first results of the warming effects on the allocation dynamics of recently assimilated C to aboveground and belowground plant biomass, soil respiration, extractable organic carbon, soil microbial biomass, and soil microbial community structure (PLFA/NLFAs). We will identify how the degree of long-term warming alters belowground C allocation and discuss to which extent these responses compare with those from a shorter-term warming experiment in nearby subarctic grassland.

PE3

02

High vapour pressure deficit hampers carbon allocation in tropical trees through turgor limitation

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Carbon-rich tropical forests are experiencing increasing vapour pressure deficit (*VPD*) conditions, with possible negative impacts on carbon allocation into woody tissue. These *VPD*-induced reductions in tree growth are commonly attributed to carbon limitation due to reduced photosynthetic activity, but can also result from turgor limitation. Here we are quantifying *VPD*-induced impairment of wood formation due to turgor limitation in the cambium. To analyse the interaction between turgor-limited growth and *VPD*, we selected an Asian tropical rainforest site with sufficient soil water availability, to isolate the *VPD* effect. We calibrated a mechanistic tree-growth model to simulate turgor limitation of radial stem growth in mature *Toona ciliata* trees. Hourly sap flow and dendrometer measurements were collected to simulate turgor-driven growth during the growing season. To validate the model simulations, growth patterns were compared to weekly wood formation observations. Simulated seasonal patterns of radial stem growth matched well with growth observations. According to the simulations, growth mainly occurred at night and was limited under higher *VPD* during pre-dawn hours. Across seasons, the nighttime turgor pressure required for growth was negatively related to previous midday *VPD*, possibly due to a relatively high canopy conductance at high *VPD*, resulting in less stem rehydration. Finally, we assessed how these patterns relate to the stomatal behaviour of this species. Our findings provide the first evidence that tropical trees grow at night and that turgor pressure limits tree growth at high *VPD*, likely independent from carbon assimilation. We suggest including turgor limitation of tree growth in models simulating tropical forest carbon dynamics, in particular, if these models simulate the effects of warming and increased frequency of droughts.

PE3

03

No future growth enhancement expected at the northern edge for European beech due to continued water limitation

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With ongoing global warming, increasing water deficits promote physiological stress on forest ecosystems with negative impacts on tree growth, vitality, and survival. How individual tree species will react to increased drought stress is therefore a key research question to address for carbon accounting and the development of climate change mitigation strategies. Recent tree-ring studies have shown that trees at higher latitudes will benefit from warmer temperatures, yet this is likely highly species-dependent and less well-known for more temperate tree species. Using a unique pan-European tree-ring network of 26,430 European beech (*Fagus sylvatica* L.) trees from 2,118 sites, we applied a linear mixed-effects modelling framework to i) explain variation in climate-dependent growth and ii) project growth for the near future (2021–2050) across the entire distribution of beech. We modeled the spatial pattern of radial growth responses to annually varying climate as a function of mean climate conditions. Over the calibration period (1952–2011) the model yielded high regional explanatory power (R^2 = 0.38–0.72). Considering a moderate climate-change scenario (CMIP6 SSP2-4.5), beech growth is projected to decrease in the future across most of its distribution range. In particular, projected growth decreases by 12–18% (interquartile range) in northwestern Central Europe and by 11–21% in the Mediterranean region. In contrast, climate-driven growth increases are limited to around 13% of the current occurrence, where historical mean annual temperature was below ca. 6 °C. More specifically, the model predicts a 3–24% growth increase in the high-elevation clusters of the Alps and Carpathian Arc. Notably, we find little potential for future growth increases (-10 to +2%) at the poleward leading edge in southern Scandinavia. Because in this region beech growth is found to be primarily water-limited, a northward shift in its distributional range will be constrained by water availability.

Tree growth responses to drought – stress type and timing matters

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An often-overlooked aspect in tree drought responses are the direct impacts on seasonal tree growth potentially leading to structural adjustments. Here we assessed how growth in Scots pine saplings responded to differently timed drought stress and how the combination of soil and atmospheric drought affected the carbon balance, allocation and growth of plant tissues. We found that leaf elongation and diameter increment was highly sensitive to drought stress in early summer. Needle elongation ceased already at a leaf water potential of -1.2 MPa, which resulted in an about 30-day earlier cessation of needle elongation, leading to 30% shorter needles compared to the control trees. Overall, this translated in a reduced leaf area and an about 50% reduction of seasonal water-use and lower drought susceptibility later during summer. In addition, the impact on growth is also altered by the type of drought. Scot pine saplings that experienced a combined soil and atmospheric drought compared to soil-drought-only showed an overall larger growth impairment. A continuous $^{13}CO_2$ label revealed that the doubled-stressed seedlings had a much lower in cooperation of the ^{13}C label into root and stem cellulose. Interestingly, we did not find a clear indication of a carbon limitation of growth as the saplings maintained a positive C balance and carbohydrate content in needle and root tissues. Overall, our results show that growth processes in Scots pine saplings are particularly sensitive to moderate drought stress during early summer. Aboveground growth appears generally to be more sensitive than belowground growth but we found no indications of a carbon limitation of growth. In summary, tree growth responses to stress are variable and can result in structural adjustments with consequences for forest carbon storage and future stress performance.

PE3
05

Carbon dynamics in beech and spruce saplings under future climate change scenarios

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As climate change proceeds, altered plant carbon dynamics (C dynamics) will introduce additional uncertainties to the forest's function as a vital terrestrial carbon sink. Previous studies have mostly focused on the effect of single environmental variables on C dynamics, which yielded limited insights into the combined effect of future environmental changes. To elucidate how European tree species may adapt their C dynamics to future conditions, beech and spruce saplings were grown for three years under the present condition (PC, 1987–2016), a mitigation scenario (RCP2.6, 2071–2100) and a worst-case scenario (RCP8.5, 2071–2100). The RCPs, compared to PC, featured elevated CO_2 concentration, which was increased by ca. 30 ppm for RCP2.6 and ca. 500 ppm for RCP8.5, alongside increased air temperature, vapor pressure deficit, irradiance, and O_3 concentration. Successively, the saplings were exposed to ^{13}C-enriched CO_2 in a three-day tracer experiment to assess the allocation of recent photoassimilates. Both beech and spruce grew more biomass under RCP8.5, accompanied by enhanced allocation to the belowground. While the mean residence time of carbon (MRT) in leaf sugar was unchanged among scenarios for both species, the MRT for beech stem respiration significantly decreased under RCPs. Additionally, the arrival time of the ^{13}C tracer in the soil decreased for spruce under RCPs. The non-structural carbohydrates (NSC) concentration exhibited no significant difference among scenarios in leaves or roots for either species. [TG1] The faster use of recent photoassimilates in beech stems and spruce roots suggests a tendency towards faster C dynamics. Specifically for beech, a compartmental model confirmed the shortened MRT of the NSC pool and indicated a boosted carbon use for respiration under RCPs, leading to further accelerated C dynamics. We thus recommend interpreting the relationship between carbon assimilation and biomass growth more cautiously in future changing environments.

PE3
06

Using bomb ^{14}C to study nonstructural carbon dynamics in European beech and Norway spruce

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Stored nonstructural carbon (NSC) is essential for tree survival, but measuring the use of stored NSC is challenging. The steady decline of ‘bomb’ $\Delta^{14}C$ in atmospheric CO_2 provides one approach to measuring storage use – fresh assimilates have the same $\Delta^{14}C$ as current atmospheric CO_2, while NSC synthesized in previous years have higher $\Delta^{14}C$. However, variations in the allocation of fresh assimilates between tissues and NSC pools, and mixing of NSC between pools, complicate the interpretation of $\Delta^{14}C$ values. In addition, and more importantly, relating $\Delta^{14}C$ to storage use assumes 'last in, first out' NSC dynamics that have never been thoroughly tested. In our study, we first developed methods to measure $\Delta^{14}C$ in specific NSC pools. We then followed NSC dynamics in needles, branches, and fine roots of forest *Fagus sylvatica* (European beech) and *Picea abies* (Norway spruce) trees that were forced to tap storage reserves by keeping them alive for two weeks. Our results show that, compared to spruce, beech NSC pools are depleted and mixed faster, but the allocation of fresh assimilates to roots is slower. The expected 'last in, first out' dynamics were not universally observed. Our measurements showed that NSC dynamics are tissue and species specific, a consideration that must be considered when using $\Delta^{14}C$ to infer storage utilization.

PE3

P1

Effects of intra- and interspecific competition between two temperate tree species on carbon assimilation rates and carbon allocation under drought stress

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Severe drought periods during summer lead to decreased plant carbon uptake, increased carbon translocation to roots and changes in carbon storage. The ecophysiological response to drought varies among tree species and might also depend on different tree species combinations. In this study, we investigated inter- and intraspecific competition effects of *Fagus sylvatica* and *Pseudotsuga menziesii* seedlings in pure and mixed species combinations under well-watered and drought-stressed conditions. Particularly, we focused on alterations in carbon use efficiency and translocation of freshly assimilated carbon with progressing drought and species interactions. With the experiment we intent to analyse whether the drought-stressed plants preferentially invest newly assimilated carbon in storage, shoot- or root-growth, or VOC emissions and how the competing neighbour influences these processes. Moreover, we try to disentangle whether decreased assimilation under drought stress is related to water limitation in the xylem, reduced sugar export to the phloem or decreased photon use efficiency under stress conditions. To gain insight into these relations, we conducted a controlled pot experiment and exposed whole tree saplings to a $^{13}CO_2$ pulse-labelling by subsequently measuring translocation pathways of recently assimilated carbon into shoot and root tissues as well as into volatile organic compound (VOC) emissions by measuring ^{12}C and ^{13}C fluxes. Simultaneously, we irrigated plants with deuterium-enriched water.

PE3

P2

Storage capacity for surplus C in parenchyma cell fractions of alluvial forest trees as dependent on flooding frequency

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Estuarine alluvial forests which are characterized by short intensive floods are carbon (C) hotspots which contain large soil organic C stocks. Environmental conditions of alluvial forests are prone to shift with global change, which may affect the dynamics of the C transfer from trees to soil. In my doctoral project, I test the surplus C hypothesis for estuarine alluvial forest trees exposed to increasing flooding frequency, which suggests that trees may have excess photosynthates potentially leading to greater C transfer from trees to soil under these conditions. To do so, I compare mature oak (hardwood) and alder (softwood) trees of two alluvial forests of the Elbe River, which differ in tidal influence and flooding frequency. As an additional control for the release of surplus C, I include observations of wood anatomy, i.e. the radial and axial parenchyma (RAP) cell fractions in the xylem, in relation to non-structural carbohydrate (NSC) storage capacity of the outer sapwood and coarse roots in my investigation. NSCs play a key role in plant performance and functioning, such as in maintenance respiration, osmoregulation, growth, and defense. It comes as no surprise, that more and more studies point out that it is important to include NSC analyses when investigating plant adaptation or recovery towards or from environmental changes. In my presentation I will discuss whether my first results support the hypothesis that increasing flooding frequency leads to a shift in RAP fractions and a rise of root NSC storage in alluvial tree species.

PE3

P3

The fate of surplus C in two estuarine alluvial forest tree species exposed to tidal flooding

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Plant growth is usually more restricted by the availability of nutrients, water, or temperature than by photosynthetic carbon (C) fixation. With the onset of belowground resource limitation, leaf growth fails as a C sink, and surplus photosynthates must be exported from leaves to roots, where they can partly be stored as non-structural carbohydrates (NSC) or released by alternative root respiration or root exudation. Tidal flooding in estuarine alluvial forests induces regular changes between hypoxia (oxygen limitation) and water drainage (moisture limitation), which may lead to particular high levels of surplus C in alluvial trees. In my doctoral project I study the influence of tidal flooding and salinity on surplus C in roots of willow (softwood) and European ash (hardwood) in the nature reserve Schweenssand in South Hamburg. The accumulation of reactive oxygen species and NSCs in root tissues is assayed spectrometrically after ferrous ion oxidation and enzymatic digestion, respectively. Alternative root respiration is determined by continuous-flow isotope ratio mass spectrometry (IRMS). In my presentation I will discuss first results of these investigations and hypothesize on the potential impact of surplus C for the C loss by the alternative oxidase respiration pathway in alluvial forests.

Seasonal changes in bark anatomy and chlorophyll content of five temperate tree species

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Bark photosynthesis contributes to the carbon balance of the whole tree and varies throughout the growing season. Specific anatomical features in the bark play a role in transport and assimilation of photosynthetic substances. The inner bark, protected by the rhytidome, houses the living cortex that contains photosynthetic pigments, which are used for assimilation in the stem. The relationship between the anatomical characteristics and the photosynthetic properties of the living bark is still poorly understood. Moreover, little is known about the effect of changes in chlorophyll content and tissue morphology during the growing season. Bark tissue of five temperate tree species was dissected to investigate how tissue structure and chlorophyll content varies in response to seasonal changes. Seasonal effects on the changing bark structures were quantified by making freshly cut cross-sections using a sledge microtome with consecutive image analysis. The concentration of photosynthetic pigments was investigated by determining the concentration of chlorophyll a and b, and carotenoids in both the bark and wood of fresh material by DMSO extraction. Subsequently absorption spectra were measured using a UV/Vis spectrophotometer. Our findings reveal widespread variation in chlorophyll content between different stem tissues and between different seasons. We show how chlorophyll content correlates with the expected light levels in the bark and discuss how seasonal changes may explain the observed variation.

Water in plants under climate change — From cells to ecosystems

Short title: Water in plants under climate change

Chairs: Richard L. Peters, Romy Rehschuh, Bernhard Schuldt

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Water is a key factor determining the structure and function of plants and ecosystems. Questions regarding plant and ecosystem water relations, the impact of water availability on plant growth and ecosystem biogeochemistry as well as impacts of future climatic changes such as increases in frequency and intensity of severe drought and heat events on ecosystem functions remain largely unanswered. This session brings together researchers investigating plant water relations across scales from organs to whole plant, stand and ecosystem level. We invite contributions covering plant hydraulics and processes related to or affected by water uptake via roots and leaves, transport, transpiration as well as their control mechanisms, from both observational studies and experimental manipulations. Of special interest is the effect of climatic extremes such as heat and drought on the water status of plants. This session aims at elucidating structural, functional and physiological responses of plants to their environments spanning from eco-physiological to flux based approaches from different fields. We plan to assemble a group of scientists who are willing to step out of their disciplinary comfort zone and to discuss emergent topics from organ to ecosystem levels in the scope of climate change.

PE4
01

Climate change sensitivity of Central Europe's major forest tree species – species comparison and options for forestry

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Based on own research and the literature, I compare Norway spruce, Scots pine, European beech, the temperate oaks, and Douglas-fir, Central Europe's economically most important tree species, in their sensitivity to drought and heat in a multi-criteria assessment. All six species have shown signs of climate vulnerability in recent decades, though to different extent. Findings on stomatal regulation stringency, leaf water status dynamics, heat sensitivity of photosynthesis and growth, hydraulic safety, root system properties, climate sensitivity of growth, and recent vitality decline and mortality will be presented with the aim to reach at a climate change-sensitivity ranking of the six species. Their sensitivity is contrasted with that of four more drought-resistant minor timber species (Norway maple, hornbeam, little-leaved linden, ash). From the presented evidence, conclusions on the species' putative performance in a warmer and drier climate and forestry options are drawn.

PE4
02

Drought legacy effects on tree water fluxes in a temperate Scots Pine forest at its tipping point

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In recent years, the re-occurrence of drought and heat events has severely damaged Central European forest ecosystems and led to significant changes in their water and carbon budget. Here, we present data from a Scots pine forest that has experienced over 60% Scots pine mortality since the 2018 hot drought as a consequence of severe hydraulic damage (min. Ψ_{Needle} = –7.5 ± 0.2 MPa). The ecosystem in Hartheim, SW-Germany, is still characterized by Scots pine trees, but broadleaved species, such as hornbeam or lime are emerging. In 2023, which was the warmest year in Hartheim in the last 46 years, surviving Scots pine trees demonstrated a strong isohydric behaviour with reduced water fluxes (max. 57.8 ± 11.8 cm^2 cm^{-3} day^{-1}) and high seasonal water potentials (min. Ψ_{Branch} = –0.8 ± 0.1 MPa), indicating strong drought legacy effects. Sap flux density of hornbeam trees was four times higher (max. 228.7 ± 26.1 cm^2 cm^{-3} day^{-1}) and water potentials more variable (min. Ψ_{Branch} = –2.6 ± 0.1 MPa), pointing towards an anisohydric water spending strategy mostly unaffected by drought legacies. On ecosystem level, net carbon fluxes also showed an increasing influence of the broadleaved understory, with a significant increase in net carbon release in winter and autumn (compared to pre-2018), when trees are leafless. In spring and summer, net carbon uptake of the ecosystem was strongly reduced since 2019 as a consequence of re-occurring drought and heat years and broadleaved understory trees were not able to compensate for the loss in photosynthetic activity of Scots pine. Thus, the ecosystem shifted from an annual net carbon sink to a net source after the 2018 hot drought. In 2024, measurements of water fluxes, water potentials (including continuous stem water potentials), tree water deficits, leaf gas exchange and chlorophyll fluorescence on Scots pine, hornbeam and lime will further reveal species-specific drought responses and legacy effects contributing to the observed ecosystem state.

PE4
03

Tree water status and root water uptake of mature European beech and Douglas fir in pure and mixed stands throughout the drought summer 2022

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In recent years, temperate tree species have been increasingly challenged by hot-drought conditions. In central Europe, the year 2022 exposed forests to remarkably high water demand and low soil moisture throughout large parts of the growing season. To understand if forest stands of given species compositions are viable for future forestry, it is crucial to understand how individual trees respond to these conditions. In our study, we investigated pure and mixed stands of native European beech, and non-native Douglas fir, widely discussed as an alternative to native, drought-sensitive Norway spruce. Throughout the summer of 2022, we monitored tree water consumption, stem water content, growth, and tree water deficit (10-minute resolution), as well as weekly midday twig water potentials and root water uptake depth of 12 trees in intra- and interspecific neighbourhoods. Additionally, we measured foliar pressure-volume and minimum conductance (G_{min}) curves at two time points (mid-June, mid-August). We found that diameter growth declined already early in the season (May/June) in all trees, superseded by phases of high tree water deficit. Interestingly, Douglas fir was able to resume growth in late summer and thereby compensate for some of the loss, which was not the case for beech. Yet, water consumption of beech remained relatively stable, while for Douglas fir it decreased gradually over the season. Soil water was taken up from a range of depth layers (0 – >100 cm), and no spatial segregation by species was observed in the mixed stand. However, Douglas fir in mixture showed a quick adaptation to increased VPD by reducing transpiration through lower G_{min}. We conclude that European beech and Douglas fir share some aspects of drought response (growth reduction, water deficit), while they are distinct in others (water consumption, growth phenology, minimum conductance). Although mixing effects were less pronounced, the combined species-specific traits suggest higher drought resistance at stand level.

Water use and growth patterns of European beech and Douglas fir in pure and mixed stands in wet and dry years, and the role of canopy structural traits and tree neighbourhood

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In recent decades, the global-change-type droughts have increased evapotranspiration rates depleting soil moisture reserves thereby affecting hydrological cycles. Several of Central Europe's major timber species have been found to be especially susceptible to repeated summer droughts. Therefore, the forestry sector is increasingly considering the establishment of mixed stands to increase structural complexity in addition to the inclusion of putatively more drought-resistant non-native tree species. To avoid potential negative competition effects and climate risks, knowledge on species-specific water use and growth patterns for a particular soil, and climate type are essential. In this study, we used a dataset from 16 trees with high resolution band dendrometers and 32 trees with dual-method-approach type sap-flow sensors installed in pure and mixed European beech and Douglas fir stands during two moist (2021, 2023) and one dry year (2022) on deep sandy soil in northern Germany. Additionally, we used canopy structural traits obtained from mobile laser scanning, radial sapflow profile of each tree from heat-field-deformation sensors, soil moisture and soil matric potential sensors at multiple depths and climate conditions to interpret the growth and water use patterns. Compared to moist years, in dry year tree growth was halved and tree water deficit increased threefold in all stand types. Stand-level water use increased in pure beech from wet to dry year by 20% while pure Douglas fir reduced water use by 52% during the drought year; the mixed stands showed a reduction in water use by 15% during the dry year (mostly due to reduction in water use by Douglas fir). The increased water use in beech was related to higher capacitance, canopy structural traits and soil moisture. The observed strategies as a response to higher VPD reflects the isohydric and anisohydric behaviour of Douglas fir and beech, respectively. The findings of this study contribute to the understanding of water cycle dynamics and the role of structural complexity of forests in the face of climate change.

PE4 05

Simulating drought-stress of Lower Saxonian forests under climate change using regionalised climate projections

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During the severe drought in the summer of 2018, Lower Saxony saw a record number of tree mortality due to drought-stress induced xylem embolism. Weakened trees then also fell prey to biological stressors such as the bark beetle. Given that climate change will likely increase frequency and intensity of droughts in Lower Saxony, understanding the development of tree mortality risk across differing climate and soil types in the next century can support forest management in taking action now. In this contribution, we simulate tree mortality risk for different widespread tree species in Lower Saxony's forests on a 5 km grid for the period 2006–2100 using the trait-based plant hydraulics model SurEau-Ecos that specialises on drought stress simulations. Our model is forced by regionalised climate projection data from NIKO. We investigate two IPCC climate scenarios: RCP2.6 (stringent pathway) and RCP8.5 (worst case scenario). Soil texture and soil hydraulic properties are taken from the regional soil map BK50 and are upscaled to the 5-km grid. We investigate the mortality risk of four tree species that are dominant in these forests, namely Norway spruce (*Picea abies*), Scots pine (*Pinus sylvestris*), sessile oak (*Quercus petraea*), and European beech (*Fagus sylvatica*). Tree parameterisations have been taken from a data set curated at INRAE and adjusted by fine-tuning tree total soil available water content (TAW) and leaf area index (LAI). Our results indicate that different tree species showcase different resilience to dry spells. Besides vulnerability curves to cavitation, LAI and rooting depth are major factors determining the probability of plant survival, as they control the amount of TAW and the overall ecohydrological equilibrium of the forest. The results underline the importance of choosing adapted tree species to maintain drought resistant forests in the future. Future research is needed to investigate effects of neighbourhood interactions between species.

PE4

06

Hydraulically redistributed water by mature oak trees is taken up by neighbouring seedlings of three different species during natural drought periods

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Facilitative and competitive interactions between trees may affect the water balance and fluxes in temperate forests. Particularly during drought, hydraulic redistribution (HR) by deep-rooting species like oak (*Quercus* spec.) may play an important role by providing water from deeper soil-layers to shallow-rooted plants and seedlings. We investigated HR of water by mature oak trees under natural drought conditions in temperate regions, testing weather HR water was taken up by surrounding seedlings of three different species. As they use potentially the same mycorrhizal network, oak seedlings were hypothesized to receive more water HR than seedlings of other species. A deep soil labelling experiment was conducted in a mature oak forest in Linde (Brandenburg) during a drought event in July 2023. Over a period of six days a total of 7.2 L of ^2H-enriched water (5 atom%) was added to the soil in 50–70 cm depth, using 30 perforated tubes, each installed around a total of 5 mature oaks. We sampled soil, stem and coarse roots of mature oak, as well as roots from seedlings of *Quercus* spec. (oak), *Prunus serotina EHRH.* (cherry) and an herbaceous plant, *Impatiens parviflora DC.* (impatiens), surrounding the labelled trees. Post labelling, increased δ^2H in the 50-90 cm and 0-10 cm soil depths indicated HR via oak roots. Increased δ^2H in the root water of nearby seedlings compared to the samples taken prior to the labelling, indicating uptake of HR water. We estimated that about 8% (impatiens), 20% (oak) and 22% (cherry) of seedlings' root water originated from HR by neighbouring mature oak. While the two tree seedlings took up similar amounts of HR water, there was a notable increase over impatiens. However, oak seedling did not receive higher amounts than cherry seedlings, rejecting our hypothesis. Future research should focus on transport pathways of HR water from mature trees to seedlings to improve its mechanistic understanding and potential in mixed temperate forests.

PE4
07

Comparing the drought vulnerability of mature and juvenile trees in a mixed temperate forest stand

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Temperate forests are increasingly affected by climate change induced drought stress. Hydraulic models predict large trees to be more vulnerable to drought, due to the increasing flow resistance with tree height. However, since taller trees have deeper rooting systems, the question of whether juvenile trees are equally or more vulnerable to drought is raised. Understanding this is crucial to anticipate future forest structure and function. We used the Swiss Canopy Crane II site to compare key physiological parameters related to drought vulnerability and water use, namely, pre-dawn and midday leaf water potentials (Ψ_{leaf}) and stomatal conductance (g_s) of mature and conspecific juvenile trees of nine temperate species. Ψ_{leaf} and g_s were measured monthly during the growing season 2023, marked by an extended warm and dry period during late summer and autumn. Moreover, we assessed both size classes' root water uptake depth on all dates using stable oxygen isotopes extracted from the soil and branches. Pre-dawn and midday Ψ_{leaf} decreased significantly along the season for both size classes. Notably, mature individuals of some species showed Ψ_{leaf} close to or at the species-specific P_{12} threshold, while juveniles of all species kept Ψleaf above this threshold. Interestingly, in two species, the differences in Ψ_{leaf} between mature and juvenile trees diverged from the hydrostatic effect with the continuous drought in autumn, which was not the case for the other seven species. In broadleaved species, increased drought vulnerability of mature trees might further be exacerbated by less sensitive stomatal regulation compared to juveniles. We found that the microclimate affects Ψ_{leaf} and g_s in juveniles, suggesting additional factors contributing to differences in drought effects between tree sizes. Our results suggest higher drought vulnerability of mature trees; however, we emphasize the need for a better mechanistic understanding of the differences between the size classes.

PE4
08

Pinpointing the shift from environmental to stomatal control of transpiration

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Atmospheric vapor pressure deficit (VPD) is the main driving force for transpiration and therefore plays a major role in plant functioning and ecosystem responses to drought. Under otherwise favourable environmental conditions, transpiration increases linearly with increasing VPD up to a certain threshold, beyond which plants start down-regulating water use by reducing stomatal aperture to avoid excessive water loss and hydraulic impairment. We are currently lacking a standardised approach to define this ubiquitous, important VPD threshold. Here I present a new metric termed the critical VPD (VPD_{crit}), which pinpoints the shift from environmental to stomatal control of transpiration. The VPD_{crit} calculation is based on daily time series of transpiration, e.g. estimated from sap flow recordings. The slopes of the daily traces are derived and their 95thpercentiles are then modeled as a function of VPD using a generalised additive modelling (GAM) framework. The peak of the resulting GAM fit indicates the steepest slope of the transpiration rate and the corresponding VPD indicates the VPD_{crit}. Beyond the VPD_{crit}, transpiration slopes become rapidly flatter due to increasing stomatal regulation. The ongoing rise in VPD fuelled by global warming urgently calls for a better understanding of the variability in transpiration sensitivity to VPD across species, functional groups and ecosystems to support ecosystem management planning in drier future. The novel VPD_{crit} metric provides a valuable contribution in this context by offering a quantitative measure to identify the transition point from abiotic to stomatal regulation of transpiration, which may help improve vegetation model accuracy and facilitate adaptive management strategies.

PE4
09

Continuous monitoring of stem water potential in deciduous forests: Assessing a novel microtensiometer for ecosystem hydraulics research

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Water potential serves as the primary driver of fluxes within natural ecosystems, representing the energy of water and dictating the direction of flow. As climate change intensifies and summer droughts become more prevalent, comprehending the impact on plant hydraulics becomes important. Traditionally, the measurement of plant water potentials has been conducted destructively and intermittently, often employing techniques such as the pressure chamber. Therefore, datapoints were usually scarce and information unsuitable to capture faster-acting hydrodynamic processes. In the studies introduced here, we evaluated the efficacy of a novel microtensiometer for continuous monitoring of stem water potential. Two Florapulse sensors were installed in a beech (*Fagus sylvatica*) and a hornbeam (*Carpinus betulus*) tree, respectively. Stem and leaf water potentials were concurrently measured using a pressure chamber over three consecutive days to validate the functionality of the sensors in these specific species. We found the two methods to agree (R^2 = 0.8 and 0.7 for beech and hornbeam, respectively), which supports the utility of these sensors in these two species. Subsequently, several microtensiometers were deployed in a natural mixed-species forest in mid-Germany, complemented by continuous measurements of sap flow, soil moisture, and soil matrix potential. This comprehensive monitoring effort spanned the entire summer of 2023. Analysis of the gathered data enabled the determination of water flow direction and fluxes throughout the monitored period, revealing minimal to negligible water stress in the ecosystem, likely attributable to the wet summer conditions in the region. This research shows the potential of the microtensiometer technique for advancing our understanding of plant hydraulics in changing climates, providing a valuable tool for continuous and non-destructive monitoring of water potential dynamics in forest ecosystems.

PE4

O10

Can we derive early warnings on tree drought stress intensity from stem shrinkage?

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The severity of droughts increases with climate change, leading to more pronounced tree mortality and a decline in forest ecosystem services. Determining the stress level of trees continuously during drought can give insights into species sensitivity and support mitigating management decisions in urban environments or forest systems. Micro-dendrometers are supposed to provide a simple and low-cost opportunity to monitor such developments, potentially enabling the deviation of pre-warning metrics on early and severe drought. However, links between stem diameter variations and internal stress are still insufficiently investigated. In this study, we provide evidence that stem shrinkage, a direct expression of tree water deficit (TWD), is strongly related to midday water potential and leaf gas-exchange across the full range of dehydration for two widespread temperate coniferous species (*Pinus sylvestris, Larix decidua*). Under controlled greenhouse conditions, we exposed potted seedlings to lethal desiccation by withholding water and closely followed TWD, water potential, stomatal conductance, and net photosynthesis progression. In addition, we tested the impact of stress release and found the predictive power of TWD for water potential limited during recovery phases after severe drought. Besides, we determined TWD thresholds indicating drought-stress-onset, stomatal closure and the loss of instant recovery potential caused by evolving drought damages. Our results highlight the potential of dendrometer networks to provide cost-efficient time series, giving continuous insights into the water status of trees.

City trees under drought – relating functional ecology to remote sensing

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Trees are dying prematurely in cities across the globe before achieving the desired dimension as droughts become lengthier, more frequent, and more severe. A healthy population of urban trees is essential for human well-being and a climate-resilient city. This article gives an outlook on a currently launched project, which deals with the causes and extent of the decline in urban tree vitality. The goal is to elucidate the mechanisms behind premature tree mortality and recommend suitable tree species for specific urban environments. We will identify factors contributing to the vitality decline by employing an in-situ experiment with urban trees, field observation, and time series analysis of satellite imagery of four German cities (Karlsruhe, Heidelberg, Mannheim, and Freiburg). Six broadleaf species growing in the streets and parks of the cities have been selected (N = ca. 1000 observation study, N = 48 for in-situ experiment). We are installing sensors (sap flow meter, dendrometer, soil moisture, and micro-climate station) to monitor the physiological parameters of the trees during the growing period of 2024 and 2025 under the irrigation treatment. Continuous stem growth, sap flow, crown dieback, internal trunk damage, and rooting space will be measured. Soil physical and chemical properties, light and water availability, and micro-climatic parameters will be measured. Terrestrial LiDAR scanning data of single-standing trees (N= 45,000 trees from four cities) will be collected and linked with multispectral remote sensing data to create a vitality map of city trees. This study will link basic plant stress biology to applied aspects of mitigating drought-induced tree mortality in urban ecosystems. The research outcome is thought to prevent tree death by taking proper action by gardeners, landowners, and city foresters.

PE4

O12

SCC II Throughfall Exclusion Experiment: First results indicate high sensitivity and vulnerability of temperate tree species to progressing drought

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Progressing climate change is expected to accelerate warming and drying in the near future. This will expose European forest ecosystems to environmental conditions that have no analogy in the recent past with impacts on forest structure and function. Experiments are now needed, that simulate this future climate to mechanistically understand the physiological and biogeochemical consequences that this warmer and dryer world will have for temperate forests and the different tree species therein. Here we present the first results from a large-scale climate change experiment that manipulates the hydroclimate in a species rich mixed temperate forest at the Swiss Canopy Crane II research site in Hölstein, Switzerland. Using seven 500–600 m^2 rainout shelters we exclude 50% of the throughfall during the growing season to expose nine different temperate tree species to the dryer hydroclimate of the near future. After 5 pre-treatment years, the 2023 growing season was the first season where the treatment was implemented. The experimental treatment significantly affected throughfall and soil moisture in the treatment plots relative to the controls. All species responded to this treatment with lower pre-dawn water potentials, reduced stomatal conductance and reduced increment growth. Interestingly, the species responded differently in specific response variables, indicating species-specific strategies in the trees' response to drought. We also found mortality in *Abies alba*, *Picea abies*, and *Fagus sylvatica*, after only one season with reduced throughfall, attesting the high drought vulnerability of these particular species. In my presentation I will discuss the trees' responses to the first treatment year in the context of species-specific sensitivities and vulnerabilities to a future, dryer and warmer hydroclimate and what the consequences of these responses are for the structure and function of European forests in the future.

PE4
013

Mature beech and spruce under five years of recurrent summer drought – The impact of stomatal regulation and leaf area adjustment on tree water use

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Forests worldwide are experiencing severe droughts caused by climate change, resulting in significant growth reduction, canopy dieback and tree mortality. The survival of forest ecosystems depends on their ability to acclimate to prolonged and repeated droughts. Over a five-year period, the KROOF experiment investigated the physiological and morphological acclimation patterns of mature Norway spruce (*Picea abies* (L) Karst.) and European beech (*Fagus sylvatica* L) to recurrent drought. Drought stress was induced by throughfall exclusion (TE) during the growing season and compared to untreated control trees (CO). Overall, TE beech showed solely a physiological response by reducing their water use through stomatal closure by 10-46% compared to unstressed trees. However, no changes were observed regarding the total leaf area for TE beech, even after 5 years of drought. In contrast, TE spruce demonstrated a more complex response to the recurring drought treatment. Over the initial 2–3 drought summers, TE spruce trees significantly reduced their water use by 80% due to their drought-sensitive stomatal control down to ~6 L per tree and day. Simultaneously, TE spruce produced shorter shoots and needles, with the total needle area decreasing each summer to ~50% compared to CO trees from the 3rd summer onwards. Despite the reduced leaf area, overall water use of TE spruce remained 4—9 L per day and tree. Notably, the water use per leaf area of TE spruce showed partial recovery, with values close to those of CO trees by the 3rd year of drought. Stomatal closure is the decisive mechanism used by beech, during the entire experiment, and spruce, during initial summer droughts, to limit tree water use as a response to recurrent drought stress. Once this had ensured survival, spruce demonstrated effective long-term acclimation by reducing the leaf area per tree, which significantly attenuated physiological stress in subsequent drought summers at the leaf level.

PE4

O14

Mechanistic modelling of extreme drought stress in European forests

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Drought events are threatening forests worldwide with record-breaking forest mortality events in central Europe in the past years. At the same time, more and more experiments are being set up that enable measurements of the state of the hydraulic system of dying trees under extreme drought stress. These experimental data can be exploited by mechanistic vegetation models, offering the possibility to disentangle environmental drought stressors, e.g. atmospheric and soil moisture dryness, and their effects on a plant's hydraulic system, such as stomatal closure and loss of hydraulic conductivity. Here, we show how plant hydraulic modelling can accurately reproduce the water potential dynamics of dying trees. We apply this plant hydraulic model to European drought experimental sites, including the canopy crane experiment II in Basel, Switzerland, and the KROOF experiment in Freising, Germany. We find that soil heterogeneity, rooting depth and stem hydraulic capacitance are critical in determining whether a tree survives or succumbs to drought. Furthermore, good knowledge of these three parameters is crucial to accurately capture the magnitude and temporal development of observed leaf and stem water potential: (i) stem hydraulic capacitance, (ii) psi50 (the water potential at which 50% of a plant's hydraulic conductivity is lost), (iii) saturated xylem hydraulic conductivity, and (4) the reference leaf water potential associated with full stomatal closure. Finally, when implemented into the terrestrial biosphere model QUINCY, our hydraulic scheme produces a clear mortality signal associated with recent drought events, giving confidence in our capacity to project the impact of future droughts on European forests.

PE4

O15

Effect of flooding on physiological vitality and survival of floodplain-forest tree species

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Global change brings along increased frequency and intensity of drought and flood events. While the trees need water to survive, flooding of the root zone results in hypoxia. Different species differ in their flood tolerance. Foresters hypothesize that the increased occurrence of hornbeam and field maple alongside the failing natural regeneration of sessile oak in the floodplain forest links to the lack of floods. They are building an artificial system to reintroduce the floods in the forest hoping to improve the vitality of oaks, elms, and ashes and to suppress the natural regeneration of hornbeam and field maple. To assess the effect of floods, we conducted a greenhouse experiment on the abovementioned five tree species. The vitality and mortality were visually inspected from the day of the year (DOY) 119, when the flooding began, until the end of the experiment on DOY 185. Leaf gas exchange, chlorophyll fluorescence, leaf spectral reflectance, and the concentration of non-structural carbohydrates were also assessed. The experiment confirmed the different responses of different taxa to flooding. Of the tree species studied, the most sensitive were field maples and hornbeams. The most resistant to flooding were oaks, which even benefited from short-term flooding as indicated by the increase in photosynthesis. The stem base of linden swelled which may have been a result of an inability to transport carbohydrates from the aboveground to the roots. Surprisingly, elm turned out quite flood-sensitive, showing high mortality during prolonged flooding, but the physiological parameters of surviving seedlings quickly recovered.

PE4
O16

Rooting for hyphae: Functional persistence of AMF water transport to plants during soil drying

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Arbuscular mycorrhizal fungi (AMF) enhance plant tolerance to water stress by aiding in water acquisition. However, limited research explores their direct water transport to plant roots through hyphal networks, and little is known about how this functionality changes as soil moisture decreases. This study examines the impact of soil drying on the contribution of AMF-transported water to the transpiration of maize plants (*Zea mays* L.). Maize seeds inoculated with R. intraradices spores were cultivated for eight weeks in two-compartment pots (4.5 L), partitioned by a 3.5-mm air gap and 31-µm nylon mesh to restrict root growth to a primary compartment while giving hyphae exclusive access to a secondary compartment. Pots were subjected to one of three soil moisture conditions: well-watered (28—31% vol), moderate drought (14—17%), or severe drought (8—11%). At 58 days old, ^{2}H-labeled water was introduced exclusively to the hyphae-only compartment, enabling the tracing of AMF-transported water. Plant shoots were enclosed in bag chambers connected to a stable isotope analyser to monitor ^{2}H concentrations in transpired water continuously for four to five days. The results showed that AMF contributed to root water uptake across all three soil moisture levels, with the greatest contribution observed under moderate drought conditions. The ^{2}H signal in transpired water appeared 2-3 days post-injection, increasing over time without reaching equilibrium by the experiment's end. Under severe drought conditions, a delayed arrival of the ^{2}H signal was observed due to reduced plant transpiration. In summary, this investigation revealed that AMF contributions to root water uptake were not only maintained but also enhanced under moderate drought. This study expands our understanding of mycorrhizal responses to drought stress and provides valuable insights for future experiments using labeling techniques.

PE4
017

Beyond mean annual precipitation: How rainfall variability shapes tree water use in a semi-arid savanna

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Water is undoubtedly one of the most essential resources for plants but is often not evenly distributed over time. Instead, its availability varies across days, seasons, and years. While semi-arid southern African savannas seem predictable in their pronounced wet and dry seasons, each wet season comprises a diverse array of single rain events, which show a remarkable variation in both frequency and intensity. Each rain pulse provides plants with an opportunity to access water, yet the periods between might pose challenges. In the light of climate change, even though mean annual precipitation might stay the same, rainfall patterns are expected to shift, with rain events becoming more intense and less frequent. We believe that a more profound understanding of savanna plants' water use in response to today's rainfall variability can help to predict their performance under tomorrow's climate change scenarios. To unveil the complexity of tree water use in response to different rain pulses, we conducted extensive sap flow measurements on nine individuals of the abundant *Colophospermum* mopane in a Namibian nature reserve over a two-year period. We assessed the effect of 100 distinct rain events, capturing a wide range of intensities and temporal intervals. We further examined interactions with additional environmental variables such as atmospheric conditions and antecedent soil moisture levels which can modulate the effectiveness of rainfall pulses. Our results show how particular features of rain events shape water use patterns under present and potentially future rainfall regimes. We identify rain size thresholds and response delays and discuss their relevance at ecosystem level, as they can provide crucial niches of water use for co-occurring grasses and herbs.

PE4

018

Effects of forest fires on tree hydraulics

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Global change causes increased frequencies and intensities of forest fires worldwide. Depending on temperatures reached and the duration of fires as well as species-specific resistances, trees may be killed directly by the fire or show various post-fire damages. Also, tree hydraulics may be affected during and after a fire. We studied several European forest species to characterize heat effects on the hydraulic system and respective, species-specific resistances. In burning experiments, impacts of heat plumes on water potentials and resulting rapid embolism formation as well as recovery were analysed. Long-term effects on xylem structures and functions were investigated in further experiments as well as in forest fire field sites, and bark insulation helped to explain observed damage patterns. Atmospheric conditions during fires were demonstrated to cause immediate embolism formation in some species, with drought stressed plants to be most affected. Heat also induced species-specific long-term changes in xylem structures, resulting in reduced hydraulic safety and/or hydraulic efficiency. Damages in stems of trees surviving fires could be detected via electric resistivity tomography with the extent of damage corresponding well to bark thickness and thermal properties. A better knowledge of fire effects and fire resistances regarding tree hydraulics is important to understand fire injuries and post-fire survival of trees under current conditions and to estimate future developments under global change. It will be a prerequisite for the development of forest management strategies considering the increased risk of forest fires which is also expected in European forests.

019

Conifers and broad-leaved trees fundamentally differ in their water storage strategies

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Plant water storage forms an important but notoriously understudied part of plant drought response strategies. Once a plant loses the contact to external water sources, the time it takes to reach critical water potentials at a given rate of water loss directly depends on the size and accessibility of its internal water pools. In this study, we assessed the differences in water storage capacitance and associated wood anatomical and hydraulic traits for nine temperate angiosperm and eight conifer tree species based on whole-shoot dry-down experiments. We found that on average, conifer species had a much larger water content at full saturation as well as a higher whole-shoot capacitance than angiosperms, leading to higher amounts of water accessible during each phase of the dry-down, particularly before the onset of drought stress (i.e. before reaching the water potential at turgor loss). Notably, for conifers hydraulic capacitance was associated with wood anatomical traits such as the percent lumen area but not with the saturated water content, while for angiosperms capacitance was higher for species containing more water at full saturation but largely decoupled from anatomical traits. We conclude that internal water storage plays a much more central role in the water use strategy of temperate conifer than broad-leaved tree species. While this has important repercussions for their behaviour under extreme drought, our results indicate that these differences largely stem from a higher reliance on short-term storage in transient water pools in conifers, likely to make up for the constraints of their vascular anatomy that limit the efficiency of their water transport system.

PE4

O20

Gas movement between xylem conduits can be slow and affects xylem vulnerability curves in flow-centrifuge experiments

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A flow-centrifuge is a standard method used to quantify xylem embolism resistance in vulnerability curves (VCs), offering the advantage of constructing VCs within a relatively short timeframe. While embolism formation in centrifuge experiments is typically assumed to be exclusively driven by pressure, evidence suggests that embolism development within this centrifuge may be time-dependent. The time required for embolism to develop is believed to depend on factors that influence gas movement, including proximity to atmospheric gas sources, vessel dimensions, and local gas pressure and concentration. We employed a combination of flow-centrifuge experiments and gas diffusion modelling to investigate the temporal and spatial dynamics of embolism spreading under constant centrifugal speed conditions, and their implications for shifts in VCs in six angiosperm species. We hypothesise that gas movement between conduits is relatively slow and thus longer spin times would shift VCs towards higher xylem water potential (Ψ) values, leading to reduced values of embolism resistance. Our findings revealed an increase in embolism levels over time in the centre of centrifuge samples, driven by increases in gas concentration in recently embolized vessels in this region. VCs shifted towards more positive Ψ values over time, with values corresponding to 50% loss of hydraulic conductivity (P_{50}) increasing on average by 8.5% for all six species compared to VCs that did not consider spin time. This overestimation of embolism resistance in flow-centrifuge measurements can be minimized by estimating time-stable hydraulic conductivity values at each centrifuge speed. This approach enhanced the statistical significance of VCs in five of the six species studied. While pressure remains the primary determinant of embolism formation in flow-centrifuge VCs, spin-time artifacts are species-specific and likely arise from relatively slow gas diffusion, which is associated with embolism spreading.

PE4

021

Wood anatomical and hydraulic traits of *Tamarix* species across a large geographical gradient: climate and phylogenetic relationships

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Tamarix is the predominant and eponymous genus of the Tamaricaceae family. This taxonomically complex genus comprises up to 90 species in arid regions or at dry sites of Eurasia and northern Africa. We sampled woody shoots of seven species at the eastern margin (NW China; *T. ramosissima*, TR) and the center (Uzbekistan; *T. hispida*, TH) of the Indo-Turanian region as well as at the eastern (Israel; *T. aphylla,* TA, *T. negevensis*, TNEG, *T. nilotica*, TNIL) and western margin (southern Spain; *T. boveana*, TB, and *T. gallica*, TG) of the Mediterranean region, the two diversity centers of the genus. We aimed at assessing whether differences in the anatomical and hydraulic traits among the species are related to climate or phylogeny. We determined wood density, the sizes of conduit areas and cell-wall thicknesses and calculated the hydraulic conductivity (k_t) and the water potential at 50% loss of hydraulic conductance (Psi50). We related these traits to Standardized Precipitation Evapotranspiration (SPEI) indices, temperature amplitudes and to the phylogenetic distances among the species. TNIL, TNEG and, in parts, TR exhibited large mean and maximum conduit areas, large hydraulic diameters and a high hydraulic conductivity, whereas the Spanish species TG and TB displayed a high wood density and a small fraction of large conduits. The phylogenetically distant species TA and TH took intermediate positions. TR, which grows in regions with cold winters and hot-dry summers, exhibited the most negative Psi50 values, indicating that it is least susceptible to a failure of the water-conducting system under drought (and frost). Trait differences among the species were only partly related to the species' kinship but SPEI scaled negatively with PSI50. Maximum conduit area and the conduit area percentage as well as k_t correlated positively with the annual temperature amplitude. We conclude that adaptation to the climate conditions at the sites of growth overrides taxonomic relatedness.

PE4
022

Similarity in hydraulic safety but not efficiency among 81 temperate tree species

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The impacts of climate change on forest ecosystems, particularly drought stress, present significant challenges to the survival and productivity of tree species across Europe. The balance between hydraulic safety and efficiency is central for determining how tree species maintain water transport capacity during drought stress. Here, we present two major hydraulic traits, namely hydraulic safety and efficiency, for 25 coniferous, 38 diffuse-porous and 18 ring-porous temperate tree species across 31 genera. All trees were similar-aged and grown at the same experimental site in Central Europe, the ARBOfun research platform, which was established between 2012 and 2014. We observed no differences in average xylem safety between conifers, diffuse-porous species and – according to preliminary data – ring-porous species, but the variability was much higher in diffuse-porous than coniferous species. Hydraulic efficiency, on the other hand, was on average more than two times higher in diffuse-porous than coniferous species. While we could not confirm a general hydraulic safety-efficiency trade-off, our data provide evidence for a cross-species tradeoff in diffuse-porous trees. Within the scope of a broader phenotyping study, we aim to gather data on additional functional traits to construct one of the most extensive datasets of plant hydraulic traits for temperate tree species measured with consistent protocols. Additionally, our study seeks to identify common axes of variation in species-level drought response traits and investigate their association with trait association patterns observed at the root, stem and leaf level.

PE4
023

Are established non-native tree species better suited for establishing climate-resilient forests compared to their native counterparts within the same genus?

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In order to build up climate resilient Central European forests, one silvicultural option is the introduction of non-native tree species, which have a limited invasive potential. However, in the past neophytes have been selected because of a climate-similarity between their area of origin and the cultivation area in Central Europe. Hence, it remains questionable to what extent non-native tree species from the cool-temperate North American or East Asian region actually exhibit a higher drought stress resistance than native representatives of the same genus. To fill this gap, the drought-stress resistance of non-native tree species was compared with that of native coniferous and deciduous tree species of the same genus, in total 16 species were analysed. We measured ecophysiologically relevant characteristics of their water balance and estimated the lethal desiccation time during dry-out experiments. Altogether, we provide a mechanistically sound characterization of the drought tolerance of young trees and show whether non-native tree species have a higher drought-stress tolerance than the native representatives despite the climate similarity at their place of origin.

PE4

P1

Effects of fire heat plume on hydraulics of young trees

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During forest fires, heat can substantially affect plant hydraulic processes and structures. This study focuses on first-order fire effects, analysing the consequences of heat plumes on plant water status and xylem hydraulic functions in young trees. We hypothesized that heat plumes lead to rapid and relevant formation of embolism, particularly at higher pre-fire drought-stress levels, with angiosperms showing more pronounced effects compared to conifers. We also expected that heat plumes cause species-specific damage to the xylem anatomy. Four Alpine tree species (*Picea abies, Pinus sylvestris, Acer pseudoplatanus*, and *Betula pendula*) were exposed to controlled fires. Before burning, trees underwent dehydration, and water potentials were measured. Trees were then burned by ignition of 40ml fuel (ethanol 96%) filled in a reservoir positioned around the stem base. After burning, we assessed the percentage loss of hydraulic conductivity in both upper and base stem sections. Fire-induced damage to the stem xylem was analysed microscopically. Results indicated angiosperms to be more susceptible to embolism formation in heat plumes. Even at moderate water potentials, angiosperms exhibited up to 98.8% conductivity losses after fire, in both upper and base stem parts. Conifer species displayed overall high resilience against fire-induced embolism formation. Furthermore, fire exposure caused species-specific damage of xylem structures, but the extent of xylem damage did not correspond to observed conductivity losses. In conclusion, burning experiments clearly demonstrated relevant impairments of xylem hydraulics upon heat plumes in young trees. Both embolism formation during fire and structural damages after fire varied across species. Knowledge of species-specific responses thus is a prerequisite to estimating direct and long-term effects of fire on plant hydraulics.

PE4

P2

The combinational effect of fertilization and drought: a case study on three temperate tree species

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Fertilization of seedlings plays a central role in tree nurseries, but knowledge on the impact on seedling hydraulics is limited, especially the possible long-term effects of fertilization combined with drought stress. We, therefore, conducted an experiment with three seedling species (*Pinus sylvestris, Quercus robur, Fagus sylvatica*) grown under three fertilization levels (no-, medium-, high-fertilization), in combination with two cycles of drought stress (three levels: no-, moderate-, severe-drought) for two years. We measured seedling hydraulics, drought tolerance and growth following fertilization and drought treatments. Increases in photosynthesis, stomata conductance and specific leaf area (the ratio of leaf area to leaf dry mass) due to fertilization were found in all studied seedling species, but the differences of the increase between medium- and high-fertilization treatments were not obvious. Growth of height and diameter was observed on fertilized seedlings of *Q. robur,* while the increase of root conductance was detected in *F. sylvatica*. After exposure to two cycles of drought stress, decreases in growth, specific leaf area, photosynthesis and stomata conductance due to severe drought stress were found in high-fertilized *F. sylvatica* and *P. sylvestris*. Their underground dry weight partitioning was very low as well, likely due to a reduction of hydraulic conductance of stems and roots. As a likely result of above impacts, 30% to 40% of seedlings from these two species were dead at the end of the experiments. However, *Q. robur* showed minor influence and no death. Furthermore, the embolism resistance of all studied seedling species showed no impact. Based on our results, the combinational effect of fertilization and drought are species-specific. Increased fertilization might pose a risk for *F. sylvatica* and *P. sylvestris* under a changing climate, while it might help *Q. robur* less affected. It is of importance for future cultivation and management practices.

PE4

P3

Spruce trees exposed to two consecutive drought periods show a legacy effect in seedling growth and physiology

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The occurrence of extreme environmental conditions during the growing season affects the dynamics of forest regeneration, based on the legacy effect carried over from parent trees to seeds and seedlings. We investigated the cone and seed development of 70-year-old spruce trees that were exposed to two consecutive drought seasons in the framework of the Kranzberg Forest Roof Experiment (KROOF). We tracked seedling germination and initial seedling growth before exposing the seedlings to a moderate and severe drought period. After one month, the drought period was reversed, returning all seedlings to a pre-drought water potential. Cone and seed morphology from parental trees exposed to consecutive droughts differed significantly from the control in total cone length and seed mass. Seedlings with a drought heritage (d-seedlings) also had reduced germination rates and germinated later. When seedlings were exposed to moderate, severe, and no drought treatments, the d-seedlings grew significantly slower than seedlings from the control trees (c-seedlings); the latter's total mass and root length growth continued to increase during the drought treatment. Seedlings treated with a severe drought maintained their initial mass or root length. However, the significant morphological differences between d- and c-seedlings were hardly reflected in physiological measurements. After 31 days, all seedlings were irrigated to reach pre-drought water potentials. Both seedling cohorts in the no- and moderate-drought treatment continued to increase or maintained their aboveground mass and belowground root length growth, while c-seedlings recovered much more rapidly. During the 31 days of drought treatment, the growth patterns of the d-seedlings reflected their parental legacy of drought exposure and related growth pattern. However, after the re-irrigation, all seedlings continued to increase in growth and seemed to recover from their own drought experience.

PE4

P4

Tree-water relations of mature European beech and Douglas fir during wet and dry years — the role of structure and neighbourhood

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Climate warming and the associated rise in atmospheric vapour pressure deficit have increased forest evapotranspiration in recent decades and have led to greater soil water depletion, especially during hot droughts. Tree water consumption is a key factor that has to be included in the criteria used by foresters to choose appropriate timber species for future 'climate-smart forests'. Mixed forests are increasingly considered in Central European forestry, but not much is known about their water cycles. To avoid potential negative competition effects and associated drought risks, knowledge on species-specific water use and growth patterns of the main timber species is essential. We measured stem growth and water consumption in pure and mixed European beech and Douglas fir stands during two moist (2021, 2023) and one dry year (2022) on deep sandy soil in northern Germany, using a dataset from 16 trees equipped with high-resolution band dendrometers and 32 trees with sap-flow sensors (dual-method approach). In addition, radial sap flow profiles were measured in each tree with heat-field-deformation sensors, canopy structure analysed with mobile laser scanning, soil moisture content and soil matric potential recorded at multiple depths to interpret the growth and water use patterns. Compared to the moist years, tree growth was halved, and tree water deficit increased threefold in the dry year in all stand types. While the pure beech stand consumed 20% more water in the dry than in the wet years, the pure Douglas fir stand reduced water use by 52% during the dry year and the mixed stands by 15% (mostly due to conservative water use of Douglas fir). The contrasting water consumption patterns in relation to VPD demonstrate the isohydric and anisohydric behaviour, respectively, of Douglas fir and beech. The elevated water consumption of beech in the dry year is supported by a higher stem hydraulic capacitance. We further explore the role of canopy structural traits for tree-water relations. Our results demonstrate, how tree functional traits are influencing the water consumption of forests in the face of climate change.

PE4

P5

The response of shrubs and trees to snow cover changes in the Alps

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In mountain regions with temperate climate, the hydraulic conditions for woody plants vary considerably between summer and winter. In winter, the main form of precipitation is snow, and a protective snow cover can be beneficial, particularly for low-growing shrubs, as it reduces exposure to freeze-thaw cycles and frost drought. However, due to global warming, snow covers are rapidly decreasing in duration and depth, yet our understanding of the related consequences for the hydraulics of woody plants is still limited. We performed a snow manipulation experiment at 1700 m a.s.l. in Praxmar (Tyrol, Austria), with saplings of four Alpine tree (*Picea abies, Larix decidua, Acer pseudoplatanus, Sorbus aucuparia*) and two shrub species (*Rhododendron ferrugineum, Juniperus communis*). Half of the plants were exposed to natural conditions and half to an experimentally shortened snow cover duration. For this purpose, the snowpack was manually removed about four weeks before natural snow melt. Snow removal caused shifts in the soil temperature with a higher number of freeze-thaw cycles, whereas under natural snow conditions the soil temperature remained constant around 0 °C. The percent loss of hydraulic conductivity in the stem xylem differed significantly between the species, but not between the two snow conditions. The effects of snow cover changes on the plant phenology, growth, and several key hydraulic parameters (water potential, percent loss of conductivity, specific hydraulic conductivity, identification of the conductive xylem area) will be regularly assessed until summer 2024. Given the critical role of snow protection, we hypothesise that the risk of frost drought and freeze-thaw induced embolism increases with earlier snow melt, but some species may benefit from a longer growing season. The results are discussed with a particular focus on the potential differences between shrubs and trees and between evergreen and deciduous species.

PE4

P6

Soil water use in drought-stressed forests: A comparative study of six tree species

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Understanding the species-specific relationships between trees and their environment is key to predicting the resilience of forest ecosystems to climate change. Defining water uptake depths for different forest tree species is crucial for understanding how trees access and utilize water resources under conditions with more frequent and intense droughts. In the wake of recent drought events, notable instances of severe crown damage and dieback symptoms have been observed in the Rhine valley region of Rhineland-Palatinate, Germany, prompting the establishment of an intensive monitoring plot at the Lenneberg Forest in a mixed forest stand. This ongoing research project aims to investigate the differences in soil water uptake depths among six tree species (*Fagus sylvatica, Quercus petraea, Tillia cordata, Acer platanoides, Prunus avium, Fraxinus excelsior*) under drought conditions. Several sampling campaigns will be carried out during the next years to collect soil samples from various depths and upper canopy twigs in around 60 trees. These samples will be utilized to analyse the O and H isotope ratios in both soil and plant water, providing insights into water uptake dynamics. Furthermore, canopy transpiration rates will be monitored using thermal dissipation sap flow sensors to assess the water flow within the trees under study. By investigating the responses of trees to extreme weather conditions, we hope to better understand their specific water use strategies and thus their ability to cope with future droughts.

PE4

P7

Xylem embolism resistance of root, stem and leaf/ twig in eight temperate species with contrasting xylem functional types along the degree of isohydriness

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Xylem embolism resistance is a key trait used to characterise the drought resistance of tree species, which is increasingly considered as a factor that determines the drought survival of trees. Several studies have demonstrated segmentation in xylem vulnerability in different plant organs, which may help protecting indispensable organs (such as stem and roots) while exposing more short-lived organs (leaves and needles) to embolism. However, not many studies have so far measured embolism resistance simultaneously in leaves, stem and roots. Recent progress in the development of optical methods to detect xylem embolism enable to visualise embolism development in leaves and roots in vivo. In this study, we determine critical water potential thresholds for xylem embolism (P50 and P88 values, the xylem water potential at 50% and 88% embolism) and the time elapsed to reach them in root, stem and leaf (or fascicles in conifers) tissues of eight temperate tree species. We use the optical Cavicam method to establish xylem vulnerability curves in the different organs of 3—4 year-old saplings, and additionally measure minimum leaf conductance and analyse leaf and stem anatomy to explain the time to reach critical xylem embolism thresholds and the spread of emboli in xylem conduits. We hypothesize that isohydric species show more pronounced vulnerability segmentation with their leaves/needles embolising well ahead of embolism occurring in roots and stems, while anisohydric species have leaf and root tissues with more similar embolism resistance. First results indicate for isohydric *Acer platanoides* strong vulnerability segmentation with leaves embolising well ahead of stems and roots, whereas anisohydric *Fagus sylvatica* showed embolisms simultaneously in leaves, stem and roots. Our results will contribute to the understanding of differences in xylem embolism resistance across the organs of trees and how these patterns depend on the degree of isohydry in temperate tree species.

PE4

P8

Effect of the species-rich mixtures of grass clover leys on flower visitors

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In organic farming, grass-clover leys are cultivated for various reasons. The legumes are mostly used for nutrient supply and soil improvement, but they can also serve further ecosystem services. In particular, they are well suited as a food source for insects but this potential may currently not be fully exploited. The FINDIG project investigates how a more diverse species mixture of grass clover, with additional clover and herb species, affects pollinators. Sampling was carried out by collecting pollinators every 3–4 weeks (May–September 2022) by walking across transects for 30 min with actively collecting using a hand-held net. Initial results of entomological studies in six on-farm trials in Bavaria and North Rhine-Westphalia confirm a positive effect of the species-rich mixtures on flower visitors e.g. substantially higher abundance of wild bee species compared to a red clover dominated reference mixture. In particular crimson clover bloom in May had a positive effect on the abundance of pollinating insects.

PE4
P9

Measurement-based new baselining strategy and distinguishing between nighttime transpiration and refilling

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Our study proposed a novel methodological framework that combines evaporative demand (VPD) and stem swelling (dendrometer measurements) to accurately and continuously distinguish transpiration and refilling from nighttime sap flux density. The empirical validation using evapotranspiration (ET) measurements confirms the effectiveness of our methodology and demonstrates that nighttime transpiration of trees can induce an ET response. Based on the differentiation model, we introduced a more accurate baselining scheme that does not rely on identifying the moment when sap flux ceases entirely, a condition that rarely occur on most nights. Over the season, we observed a decline in both transpiration flux density and refilling flux density after an initial rise. Nighttime sap flux was primarily attributed to transpiration until the summer, gradually shifting to be dominated by refilling thereafter. Using the maximum value of the probe voltage difference per night (ΔVmax) as a baseline severely underestimated both nighttime (Jn) and daytime (Jd) sap flux density, as well as the ratio of Jn to Jd (Ratio). The mean errors for Jn and Jd exceeded 204% and 28%, respectively, while the ratio error could reach 0.16.

Multiple stressors in Global-Change Ecology

Short title: Multiple stressors

Chairs: Malte Jochum, Marie Sünnemann

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Global change is one of the most pressing challenges of our time. A lot of research focuses on this phenomenon with its drivers and consequences. Much of the existing research, however, tends to over-simplify global-change drivers such as climate change, land-use intensification, invasive species, and microplastic accumulation treating them as isolated factors in experiments or along observational gradients. This approach is problematic as these drivers rarely, if ever, occur in isolation in the real world. To effectively mitigate global-change impacts on both natural and managed ecosystems, we urgently need more studies testing effects of multiple, simultaneous stressors. Specifically, we need to (i embrace the multi-factored nature of real-world global change moving beyond single-factor approaches, and (ii be willing to explore novel approaches in multi-factor experimental and observational research. Our session aims to bring together researchers studying multiple stressors in different ecosystem types (terrestrial above- and belowground, freshwater, and marine systems) with experiments and observational approaches and in different parts of the world. There could e.g. be talks about classic field-experiment approaches, new laboratory setups, and novel ways of analysing long-term observational data. We believe that the GfÖ24 conference will be the perfect setting to bring together researchers from diverse backgrounds who are at the forefront of multiple-stressor global-change research to exchange ideas and approaches. Such knowledge is pivotal for designing sustainable land-use strategies that are robust in the face of complex environmental challenges. Additionally, our session could boost the interest and motivation of the junior colleagues attending the meeting to pursue a career in multiple-stressor research because our topic lies at the heart of understanding the future of sustainable land use across ecosystems, landscapes and biomes. Considering the urgency of understanding and mitigating multi-factor global change, a session on this topic would be a vital addition to GfÖ24 in Freising.

PE5
01

Number of simultaneously acting global change factors affects composition, diversity and productivity of grassland plant communities

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Plant communities experience impacts of increasing numbers of global change factors (e.g. warming, eutrophication, pollution). Consequently, unpredictable global change effects could arise. However, information about multi-factor effects on plant communities is scarce. To test plant community responses to multiple global change factors (GCFs), we subjected sown and transplanted-seedling communities to increasing numbers (0, 1, 2, 4, 6) of co-acting GCFs, and assessed effects of individual factors and increasing numbers of GCFs on community composition and productivity. GCF number reduced species diversity and evenness of both community types, whereas none of the individual factors alone affected these measures. In contrast, GCF number positively affected the productivity of the transplanted-seedling community. Our findings show that simultaneously acting GCFs can affect plant communities in ways differing from those expected from single factor effects, which may be due to biological effects, sampling effects, or both. Consequently, exploring the multifactorial nature of global change is crucial to better understand ecological impacts of global change.

PE5
02

Stress-resistant plant communities for urban stormwater management

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Urbanization has increased during the past decades and is continuing to do so. This leads to high rates of soil sealing, habitat fragmentation, biodiversity losses and altered microclimate. Due to these developments, major challenges arise for urban biodiversity and stormwater management, which are amplified by the negative impact of climate change. Infiltration swales are a type of sustainable urban drainage system that have a great potential to support stormwater management while also promoting biodiversity in cities. To realize this potential, plants selected for the implementation of these infrastructures must cope with a multitude of stressors such as heavy metals, particulate substances, trace organic compounds, fluctuating water conditions and heat waves. This calls for developing and testing specifically designed plant communities. Thus, an experiment was performed in an ecotron facility ('TUMmesa') under highly controlled conditions to study the effect of combinations of the mentioned stressors on a gradient of contrasting plant communities. All experimental communities, ranging from 90% mesic grassland species (Arrhenatherion elatioris) with 10% species from fluctuating wet grasslands (Molinion caeruleae) to 10% and 90%, vice versa, were resistant to heavy metals and biocides, while biomass increased under periodic flooding (72 h each). Heat waves of 35 °C for 72 h had no significant effects on plant biomass whereas the largest biomass production was achieved by communities with higher proportions of mesic species. These results show the applied potential of species-rich grassland communities to cope with multiple stressors in infiltration swales while fostering biodiversity in urban settings.

Over 100 years of change: stronger diversity decline in lowland than in mountain grasslands

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Grasslands, especially low-intensity secondary grasslands, which can harbour very high levels of diversity at small spatial scales, are threatened in Europe. Resampling vegetation plots of a larger region and encompassing more than a century offers a unique opportunity to empirically quantify biodiversity and compositional change. We resampled 416 historic vegetation plots (originally sampled between 1884 and 1931) of 0.09 m^2 from grasslands across a wide range of elevations and moisture levels in Switzerland. This allowed us to assess the changes of taxonomic, functional, and phylogenetic diversity and species composition. Specifically, our objective was to test whether the magnitude of change in diversity or composition measures varied with elevation. For each historic plot, we resampled 3–5 randomly distributed new plots in the area where the historic plot was most likely located. We used mixed models to compare the diversity and composition variables between the historic and the new plots, and linear models to test whether the magnitude of change in a diversity or composition measure varied with elevation. Taxonomic, functional, and phylogenetic diversity were significantly lower in the new plots than in the historic plots. This loss in all three diversity metrics decreased with elevation, showing that high-elevation grasslands have changed much less than those in the lowlands. This was linked to higher increases in mean ecological indicator values of nutrient requirements, mowing tolerance, and hemeroby at low than at high elevations. By contrast, mean temperature indicator values increased less and at a similar rate throughout the elevational gradient. This suggests that over the time period of the study, land-use change was the major driver of grassland changes, while climate change played a subordinate role only.

PE5
04

Climate change and management independently affect the nutrition of grassland plants

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Climate change and management are two major drivers altering Central European anthropogenic grassland ecosystems, but little is known about how these drivers interact in their effects on nutrient concentrations and stoichiometry of grassland plant species. This study was carried out in a climate change field experiment in Central Germany comprising species-rich non-fertilized grasslands either managed by mowing (two times per year) or grazing with sheep (three times per year). In spring 2022 during peak growth and before the first management, we harvested leaves of five species per functional group (grasses, forbs, legumes) in the meadows and pastures under ambient and future climate treatment (higher temperature and higher spring precipitation) and determined leaf nutrient concentrations (N, P, K, Ca, Mg, S). In addition, topsoil samples (0–15 cm) were taken at the same time and concentrations of plant available nutrients were measured. Our main hypotheses were that higher temperature and precipitation result in higher leaf nutrient concentrations and that leaf N, K and S concentrations are higher, while leaf Ca and Mg concentrations are lower in pastures compared to meadows due to the return of N, K and S via the urine of the sheep and subsequent leaching of Ca and Mg. We found that future climate treatment led to lower leaf N:P ratios compared to ambient climate in the pastures and meadows. Independent of the climate treatments, leaf N (especially of grasses) and K concentrations as well as topsoil K concentrations were higher in the pastures than in the meadows. In contrast, leaf Ca concentrations were lower and leaf Mg concentrations tended to be lower in the pastures compared to the meadows. Our results show that even at low intensity, the type of grassland management affects plant nutrients under ambient and future climate.

Global change in experimental above-belowground multitrophic grassland communities

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Ecosystems are rapidly altered by global change with climate change and land-use intensification being two of the main drivers. Previous studies have shown how drastically these two drivers can influence ecosystems resulting in declining biodiversity and a potential loss of ecosystem services. However, we still lack information about how above- and belowground invertebrates interact and how their communities and interactions are affected by global change. Additionally, the effects of simultaneously-acting multiple stressors, like climate change and land use, as well as possible mutual interactions between them remain poorly understood. To test these research questions, the Global Change Experimental Facility (GCEF, Bad Lauchstädt, Germany) was chosen as our study site, as it fulfills all requirements to study simulated climate change in temperate grasslands while having different levels of land-use intensity as second stressor. In our project, we will sample a broad spectrum of belowground communities including macrofauna, mesofauna, nematodes, and earthworms as well as aboveground invertebrate communities. Via novel methods such as gut content metabarcoding and amino acid analyses combined with species identification and classification into different trophic groups, we aim to construct comprehensive food webs and run energy flux calculations to obtain detailed information on how climate change and land-use intensification affect multitrophic above- and belowground communities. Understanding and revealing interactions between multiple stressors as well as between different trophic levels above and below the ground could offer key insights into sustainable grassland management and ecosystem conservation.

PE5
O6

Land use modulates resistance of grasslands against future climate and inter-annual climate variability in a large field experiment

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Climate and land-use change are key drivers of global change. Full-factorial field experiments in which both drivers are manipulated are essential to understand and predict their potentially interactive effects on the structure and functioning of grassland ecosystems. Here, we present eight years of data on grassland dynamics from the Global Change Experimental Facility (GCEF) in Central Germany. On large experimental plots, temperature and seasonal patterns of precipitation are manipulated by superimposing regional climate model projections onto background climate variability. Climate manipulation is factorially crossed with agricultural land-use scenarios, including intensively used meadows and extensively used (i.e. low-intensity) meadows and pastures. Inter-annual variation of background climate during our study years was high, including three of the driest years on record for our region. The effects of this temporal variability far exceeded the effects of the experimentally imposed climate change on plant species diversity and productivity, especially in the intensively used grasslands sown with only a few grass cultivars. These changes in productivity and diversity in response to alterations in climate were due to immigrant species replacing the target forage cultivars. This shift from forage cultivars to immigrant species may impose additional economic costs in terms of a decreasing forage value and the need for more frequent management measures. In contrast, the extensively used grasslands showed weaker responses to both experimentally manipulated future climate and inter-annual climate variability, suggesting that these diverse grasslands are more resistant to climate change than intensively used grasslands composed of only a few grass cultivars. We therefore conclude that a lower management intensity of agricultural grasslands, associated with a higher plant diversity, can stabilize primary productivity under climate change.

PE5
07

Fertilization alters resistance but not recovery responses to drought intensity in an experimental grassland community

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Drought and nitrogen fertilization are two important components of global change affecting grasslands worldwide. Despite the ample literature on grassland responses to drought, we lack understanding of how nitrogen availability alters grassland responses to drought intensity, and how these responses are driven by fast- versus slow-growing species. We studied the interactive effects of drought intensity and nitrogen fertilization on community composition and productivity, by exposing an experimental mixed-strategy grassland community to fertilization and a high-resolution gradient of drought intensity. In our experiment, biomass decreased with increasing drought intensity, and fertilization alleviated the negative effects of drought at low and medium drought intensities. During recovery, communities previously subjected to high drought intensities exhibited compensatory growth, regardless of fertilization. Fertilization and drought intensity effects on community composition where stronger during recovery than during drought. The relative abundance of fast-growing species did not change with drought intensity during drought, but increased strongly during recovery from high drought intensities. We conclude that fertilization supports a higher productivity of grasslands when drought periods occur and may therefore increase grassland stability under climate change. We also conclude that drought effects on community composition occur during recovery rather than during the drought itself.

PE5

08

Metacommunity processes shape multi-scale biodiversity dynamics in fragmented landscapes

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Habitat loss and fragmentation are interacting phenomena that are appreciated to shape patterns of biodiversity. While this fact is widely acknowledged, it remains difficult to make statements about their effects on biodiversity generally. This may be due in part to the scale dependent approaches that are taken to understand their impact on biodiversity, where some studies focus on patterns across a landscape, and others on the scale of individual fragments. These different approaches can provide conflicting intuition regarding the effects habitat loss and fragmentation on biodiversity. Here we take an approach that focuses on the underlying ecological processes of the biodiversity to parse apart the mechanisms that create the scale-dependent patterns observed in empirical studies. Using a theoretical approach, we explore how competition and dispersal in metacommunities structure their dynamics in fragmented landscapes. At the landscape scale we find that habitat loss/fragmentation can result in both positive and negative correlations in richness depending on the strength of dispersal in the metacommunity. When dispersal is low, we find a negative effect of habitat loss/fragmentation on richness which is made stronger by increasing the strength of competition, but we find the opposite effect when metacommunity dispersal is high. At the fragment scale we find that dispersal is the main process influencing the relationship between fragment size and biodiversity. We suggest that explicitly taking into account metacommunity processes like dispersal and competition can potentially help parse conflicting patterns of biodiversity response to habitat loss and fragmentation at multiple spatial scales.

PE5
09

Applying metacommunity theory to understand the dynamics of extinction debt

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Habitat destruction is an important consequence of land use change and is considered to be one of the main drivers of biodiversity loss globally. One of the complications in predicting biodiversity response to habitat loss is the fact that species responses are not instantaneous, creating a time lag to extinctions, what has been termed ‘extinction debt’. It has been noted empirically that significant extinction debts can occur during the transient period after habitat loss. A robust understanding of the factors that influence the magnitude (i.e. number of species that go extinct) and the relaxation time (i.e. time-lagged period it takes for the community to reach a new equilibrium) of extinction debts remains elusive for ecologists but has important implications of conservation. Our aim is to understand how metacommunity processes influence the dynamics of extinction debts across a gradient of habitat loss. We used a discrete time spatially explicit metacommunity model to gain a robust understanding of the mechanisms that shape biodiversity dynamics of extinction debts. Our results show that there is an interaction between the amount of the habitat that is lost and the internal processes within a metacommunity (competition and dispersal) which shapes the dynamics of extinction debt in our simulation study. First, we show that the number of species lost following habitat destruction increases with increasing strength of competition in the metacommunity, and that this relationship is strongest when there are large amounts of habitat destroyed. Second, we show that metacommunities with higher dispersal lose fewer species post habitat destruction but that this effect is contingent on the strength of competition in the metacommunity. Finally, we demonstrate that relaxation times ost habitat destruction is larger as the strength of competition and dispersal increase. Our results suggest that explicitly taking into account metacommunity processes could help to associate the dynamics of extinction debt with different types of metacommunities.

PE5

O10

Multi-resource dung beetle networks within the context of forest recovery

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Trophic networks form the basis of many ecosystems, and with the current rate of habitat conversion and biodiversity losses, many of these networks are shifting. Decomposition is a necessary ecological process for nutrient recycling, including carrion and dung from animal communities which is less studied than decomposition of plant litter. Dung beetle communities play a key role in decomposition, mostly for mammalian dung and carrion, and are thereby also relevant for parasite control and secondary seed dispersal. Trophic networks between dung beetles and different kinds of dung have been studied in numerous sites across the globe, but preferences across multiple types of resources have been poorly investigated. Comparisons are particularly lacking in the context of land use change or ecosystem restoration. In this study, we focus on the complexity and specialization in multi-resource dung beetle networks across a chronosequence of a recovering tropical forest. We offered four decomposing resource types (cow dung, carrion, fermented fruit, milliped carcass) in 68 sites, including pasture and cacao plantations, secondary forests of variable age, and old-growth forests. We found that tropic networks became more complex (i.e. the diversity of links increased) when secondary forests recovered from agricultural disturbance, driven by an increase in both dung beetle abundance and diversity and a concomitant decrease in network specialization. This suggests that trophic networks recover with time during natural forest regeneration, which may have positive effects on important ecosystem processes.

PE5

011

Are ant and termite communities dispersal- or habitat-limited along a forest recovery gradient?

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Tropical forests face many threats such as deforestation, habitat fragmentation, and climate change. As many reassembly processes take time, research on forest recovery can be challenging and requires long-term experiments. Chronosequences, or space for time substitutions, can help to overcome these challenges. We investigated the distribution of flying ant and termite sexuals along a forest recovery gradient ranging from pastures and cacao plantations to naturally regenerating forests of different ages and old-growth forests, in a lowland tropical rainforest in northern Ecuador. So far, little is known about the swarming behaviour and potential dispersal limitations of tropical social insects especially under anthropogenic influence. We collected flying insects with light traps and identified dispersing sexuals of ant and termite species using metabarcoding. We explore how species richness, diversity and composition change along the chronosequence in comparison to workers from established nests. Previous investigations in our study area based on ground and tree-dwelling ant workers revealed that ant traits and species composition shift along the recovery gradient becoming more similar to old-growth forest with forest age, whereas species richness remains on the same level along the forest recovery gradient. Our results show that species richness and alpha-diversity of flying ants do not change along the chronosequence whereas termite species richness increases towards old-growth forest. Beta-diversity was highest within old-growth for both taxa. Based on our results we explore potential dispersal limitations and habitat filtering due to anthropogenic disturbances that already apply during nuptial flights before potential colony foundation.

PE5
012

Multiple-stressor impacts on multitrophic interactions and ecosystem functioning – lessons learnt from experimental forest systems

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Climate and biodiversity are changing across the globe with unprecedented impacts on communities and ecosystem processes. Experiments are a powerful tool to assess the consequences of such changes for multitrophic biodiversity, interactions, and ecosystem processes. In 2021, we ran the EcoStressWeb experiment in the iDiv Ecotron assessing the joint impacts of soil moisture and invertebrate predation on multitrophic above-belowground communities and ecosystem functioning in a temperate forest ecosystem. We equipped 48 iDiv Ecotron subunits with soil, leaf litter, treelings, microbial communities, and collembola as prey organisms. We then established three soil-moisture levels and four predation levels (spider, predatory mite, both, no predators), full-factorially crossing these two treatments. During the experiment, we continuously measured belowground organic matter decomposition and soil mesofauna activity, quantified aboveground leaf-litter decomposition, and assessed physiological parameters of the beech and oak trees. After ca. 4 months, we harvested the experiment and sampled invertebrate communities from the litter and several soil layers. We have measured a variety of litter- and soil-related abiotic and biotic properties to gain comprehensive insights into how our treatments affected the above-belowground communities and processes. The resulting invertebrate data will be used to assess how multitrophic interactions, feeding preferences, and energy flux change with the treatments. Here, we will provide insights obtained from this collaborative research initiative, including soil-moisture effects on tree performance, as well as interactive effects of soil moisture and invertebrate predation on litter fauna and decomposition. In addition to these results, we will outline how we aim to further synthesize across our experimental findings regarding global-change effects on above-belowground multitrophic biodiversity and ecosystem functioning.

PE5

013

Earthworm invasion derails belowground multidiversity and ecosystem multifunctionality

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Anthropogenic activities foster global change, thereby threatening biodiversity and natural ecosystems worldwide. Biodiversity loss typically causes a loss of ecosystem functions at the same time. However, most studies have focused on the analysis of single or few facets of biodiversity and ecosystem functions. Only in rare cases, such studies have dealt with multiple biodiversity facets and functions simultaneously which would facilitate a holistic understanding of the ecosystem consequences. Here, we used multidiversity and multifunctionality approaches as well as structural equation modelling to synthesise data from an observational multi-site study on the consequences of earthworm invasion on a belowground northern North American ecosystem. Overall, we found negative direct and indirect effects of earthworm invasion on both multidiversity and multifunctionality. Indirect effects were mainly mediated via environmental variables, such as soil water content. Breaking down multidiversities into different groups, such as animals, plants, and microorganisms, we found animal multidiversity to drive these negative effects. Moreover, zooming into single ecosystem functions, we found soil microbial biomass as well as carbon and nitrogen concentrations to be strongly decreased by earthworm invasion directly. Our synthesis study contributed to disentangling mechanisms by which earthworm invasion leads to substantial changes in native biodiversity and functioning of a recipient ecosystem. Now that species invasions are on the rise, it is particularly crucial to close existing knowledge gaps.

PE5
O14

Centuries of change: The role of climate, pollution, and eutrophication in shaping lake biodiversity

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Multiple drivers of biodiversity change, such as climate change and pollution, have joint effects at least since the Great Acceleration of the Anthropocene. Long-term data might allow to better understand the effects of these multiple stressors, but existing time series are not sufficiently long-term to account for the collinearity of these drivers in the last decades. Here, I reconstruct multiple centuries of lake biodiversity change with ancient sedimentary DNA and analyse biodiversity trends with respect to sedimentary indicators of pollution and eutrophication, and reconstructed global warming. The recorded trends are consistent with a strong increase in lake productivity during the 20th century. This is accompanied by an increase in taxonomic richness and increased compositional turnover during the 20th century. Climate change and phosphorus availability emerge as main drivers of biodiversity change for the entire investigated period, overshadowing effects of chemical pollution with heavy metals and DDT. However, the results suggest a prominent role of heavy metal pollution and eutrophication as driver of biodiversity trends before the 1950's, with global warming (and other collinear factors) taking major role after the Great Acceleration. The results also provide hints about long-term community assembly: regardless of the time period, we found consistently negative relationships between taxonomic richness and the rate of compositional turnover. This suggests that neutral and selective processes interact with spatial and temporal heterogeneity during the assembly of lake communities. The findings underscore the complex interplay of environmental stressors in shaping lake biodiversity over centuries, and highlight the need for integrated long-term approaches to better predict and manage the impacts of global change on ecosystems.

PE5

O15

Eco-phenotypic feedbacks differ in multi-stress environments

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Ecological communities experience multiple environmental stressors, which can simultaneously impact the population density and trait dynamics of the species embedded within these communities. It is known that certain traits, such as body size, can rapidly respond to environmental change either via phenotypic plasticity or micro-evolution. Such trait changes can also strongly influence the density of populations, resulting in dynamical eco-phenotypic feedback. However, so far it remains unclear whether the strength of eco-phenotypic feedback can depend on the environment, and whether stressful environments would enhance or disrupt these feedbacks. To test this, we use two competing freshwater ciliates – *Colpidium striatum* and *Paramecium aurelia* – and expose their populations to a full-factorial design of increasing salinity and temperature conditions as well as interspecific competition. We found that salinity, temperature and competition significantly affect the density and cell size dynamics of both species. We found that cell size changes more strongly influenced density changes. However, the strength of the density-cell size eco-phenotypic feedback was reduced in stressful conditions and with interspecific competition. Our study highlights the importance of studying eco-phenotypic dynamics in a multi-stressor context.

PE5

016

Diversity and climate are main drivers of riverine fish stability across spatial scales

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Freshwater fish represent one-fourth of the world's vertebrates, although rivers and lakes cover only 0.8% of Earth's surface. As key food resources, freshwater fish support the functioning and services of ecosystem through their contribution to biomass production. In recent decades, freshwater fish are faced with multiple threats and especially sensitive to their environment, which influence the continuous supply of resource to the ecosystem. Fish community stability is affected by many factors, such as climate, hydrological characteristics, anthropogenic activity and diversity change. However, how these drivers jointly affect riverine fish stability is still poorly understood, as most studies only focus on one of these factors. Hence, we leverage long-term observational data of riverine fish communities in 51 natural basins across Europe, North America and Asia to determine how these drivers influence freshwater fish stability at both local and basin scale. We found that diversity and climatic factors are the two main drivers of riverine fish stability both at local and basin scale: both increased riverine fish stability. In comparison, hydrological factors and anthropogenic activity contributed less to riverine fish stability. In revealing determinants of fish stability over space, our results offer a roadmap to better develop effective conservation and management strategies.

PE5
017

A mechanistic description of the interplay of soil moisture and soil water salinity as abiotic driving factors for the establishment of vegetation patterns in tropical saltmarshes

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Tropical saltmarshes share the intertidal zone with mangroves. The succession of vegetation types from non-halophytic dune vegetation to saltmarsh to mangroves along the altitudinal gradient, as well as species zonation within the saltmarsh and mangroves, results largely from the spatial and temporal availability of water in the rooted upper soil layer. Both the soil moisture and the soilwater salinity play an important role here. These variables change all the time with tidal flooding, precipitation and evapotranspiration. To comprehend and predict the spatial and temporal patterns of these variables, we introduce the hydrological model SALTFRED. This model aims to elucidate the intricate differentiation of drought and salt stress within the salt marsh. We use a vertical one-dimensional description of the water balance and assume unsaturated soil conditions, i.e. air fills the soil pores along with water. The model explicitly describes processes of infiltration, seepage and evapotranspiration, along with their influence on the salinity of the soil water. Extreme salt and drought stress are defined as 90 ppt and 0.5 vol%, respectively. We apply this model to our pilot study site on the Bragança Peninsula (Pará, Brazil). Utilising complete time series of tidal and meteorological data, we predict drought and salt stress and compare them with observations of dominant vegetation types and saltmarsh species. Mangrove vegetation can be found at elevations where these extreme stress conditions are persistently not reached due to regular flooding by the tides. In the saltmarsh, as elevation increases and the frequency of spring tide flooding decreases, desiccation leads to an increase of the salinity of the soil water. As a result, the duration of salt stress events increases. In the higher parts of the salt marsh, additional drought stress is predicted. Simulated stress patterns within the saltmarsh correlate with dominance of saltmarsh species *Rhynchospora riparia*, *Fimbristylis cymosa*, and *Sporobolus virgincus* at the study site.

PE5

018

Flexible foraging behaviour increases predator vulnerability to climate change

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Higher temperatures are expected to reduce species coexistence by increasing energetic demands. However, flexible foraging behaviour could balance this effect by allowing predators to target specific prey species to maximize their energy intake, according to principles of optimal foraging theory. We test these assumptions using a large dataset comprising 2,487 stomach contents from six fish species with different feeding strategies, sampled across environments with varying prey availability over 12 years in Kiel Bay (Baltic Sea). Our results show that foraging shifts from trait- to density-dependent prey selectivity in warmer and more productive environments. This behavioural change leads to lower consumption efficiency at higher temperature as fish select more abundant but less energetically rewarding prey, thereby undermining species persistence and biodiversity. By integrating this behaviour into dynamic food web models, our study reveals that flexible foraging leads to lower species coexistence and biodiversity in communities under global warming.

PE5

P1

Interacting effects of land-use intensity and temperature on biodiversity and ecosystem functions along an elevational gradient in the German Alps

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Current global change has a variety of drivers which makes it hard to accurately predict its effects on our environment. While many drivers have already been studied in isolation, it remains unclear to which extent interactions between several drivers like e.g. land-use and climate change might impact biodiversity and ecosystem functions. Therefore, we studied 24 grasslands along three elevational gradients in the German Alps, each with an increasing level of land-use intensity (unused, low grazing intensity, intermediate grazing intensity), using the natural temperature gradient along elevation as a space-for-time approach to predict effects of global warming in combination with different levels of management intensity. We tried to obtain a comprehensive picture of what is happening by sampling a diverse set of organisms and ecosystem functions, which comprised: abundance and richness of pollinators and plants, plant biomass, insect biomass, seed dispersal, parasitism of trap nesting bees and wasps, predation of caterpillars as well as soil nutrients and soil microbial communities. Results varied depending on the studied organism group and ecosystem function but overall, both levels of management seemed to support a higher species richness and abundance than unused grasslands in this alpine setting, so that conserving land-use in such a generally extensively used area might buffer climate change effects.

Interacting effects of climate change and land use intensity drive soil microbial biomass and community structure in pre-alpine grassland sites

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Soil microbes are vital for terrestrial ecosystem function and services. They are particularly susceptible to climate change and land use intensity, especially in pre-alpine regions where climate change (CC) is predicted to be severe and land use has intensified. Despite numerous studies on individual effects, there is a gap in understanding combined impacts. We analysed how land use intensity and CC affect soil microbial community and how microbes are related to plant productivity and richness over short- (one year) and long-term (four years) periods. For this study, intact soil-plant monoliths from 1260 m a.s.l. were transplanted to two lower altitudes (860 and 6000 m a.s.l.) to naturally simulate moderate (CC1) and strong (CC2) CC scenarios, respectively. Monoliths from 1260 m a.s.l. were reinserted in the same side as control. Management was either extensive or intensive and was influenced by of organic fertilization application and mowing frequencies, Soil samples were taken at 0—5 and 5—15 cm. Bacterial abundance and diversity were assessed using quantitative real time PCR (qPCR) and 16S rRNA gene sequencing, respectively. In addition, plant diversity and productivity were analysed. At the long-term, microbial diversity was strongly associated with CC but not with management. While the numbers of amplicon sequence variants (ASVs) related to Micrococcales increased significantly, ASVs related to Burkholderiales and Vicinamibacteria decreased due to CC effects. Main driver for these effects were graminoid biomass and C content. Combined effects of management and CC were only observed for CC2 at 0—5 cm depth and influenced mainly Proteobacteria and Acidobacteriota. Our data underscores the need for tailored management strategies in pre-alpine grasslands to counteract simultaneous and interacting CC effects that can affect microbial diversity and therefore alter soil nutrient stoichiometry and plant functional groups.

PE5

P3

Effects of sexually transmitted fungal parasite on mating behaviour of ladybird hosts

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Only a limited number of parasitic fungi species utilizing insect hosts are able to manipulate the host's behaviour. In the present study, we investigated the effects of *Hesperomyces harmoniae* (Ascomycota: Laboulbeniales: Laboulbeniaceae) on mating behaviour of invasive ladybird *Harmonia axyridis* using choice experiments. In each trial, two females (infected and uninfected) were simultaneously offered to a male (infected or uninfected). Females were either alive or freshly killed (by freeze) to switch off their behaviour. Uninfected males significantly preferred mating with infected females. The time to the start of mating was unaffected by either male or female infection status. However, the mating duration was significantly longer when the infected or uninfected males mated the infected female. Missing differences between treatments employing alive or freshly dead females indicate that male rather than female mating behaviour is manipulated by *Hesperomyces harmoniae*. Finally, we compared cuticular hydrocarbon profiles of infected and uninfected females to evaluate one of the possible mechanisms modifying the sexual attractiveness of ladybird females. The fungal infection resulted in significant change in chemical profiles of cuticular hydrocarbons in ladybird females as well as males.

PE5

P4

Effects of larval starvation and adult mating on *Harmonia axyridis* life history traits and haemolymph parameters

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A poor diet reduces the energy resources available to an insect, leading to a trade-off between investing in its immune system and other life history traits, e.g. longevity and fecundity. It is hypothesized that investment in the immune system will decrease with limited food availability and increased reproductive effort. In the present study, we investigated the effects of starvation during larval stage and mating intensity on diverse life history traits and physiological parameters (longevity, fecundity, adult body mass, total protein concentration, total haemocyte concentration, antimicrobial activity against G+/- bacteria) in *Harmonia axyridis*. Physiological parameters were measured repeatedly during adult life cycle to investigate potential effects of senescence. Longevity was significantly reduced for mated individuals, but no effect of larval starvation on adult survival was observed. Interestingly, larval starvation did not affect adult fecundity despite significant negative effects on adult body mass. Total haemocyte and protein concentrations significantly increased during early adulthood (comparison of 1-day and 30-day old adults) but slightly decreased later on (comparison of 30-day and 90-day old adults). Larval starvation negatively reduced antimicrobial activity against G+/- bacteria and total protein concentration for 24-hour old adults, but the difference disappeared at older age. Our results indicate that larval starvation has short-term effects on diverse physiological parameters (e.g. humoral immunity and body mass). Long-term effects were observed rather for mating intensity that significantly affected ladybird longevity.

Ecosystem response to repeated climate extremes — an integrated approach across organizational scales

Short title: Ecosystem response to repeated extremes

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Climate extremes are increasing in frequency, causing more repeated droughts and heavy rainfalls that threaten ecosystem stability and human societies. Ecosystem responses to single droughts have been studied extensively, but the majority of these studies focus on responses of different organisms in isolation. Ecosystem responses to repeated climate extremes are more complex than singular events due to that legacy from past extremes may influence ecosystem responses to subsequent extremes (i.e. legacy effects). So far, around 40 empirical studies have quantified legacy effects. But these studies focus mainly on responses of individual plant species, in particular crop plants, to repeated droughts. Therefore, we know little about how plant communities and organisms at higher trophic level (e.g. soil microbes, aboveground and belowground invertebrates) respond to repeated climate extremes. Understanding legacy effects of complex climate extremes at ecosystem level and the mechanisms may offer insights into increasing resistance of natural and agricultural systems to accelerating climate change. Studies of organisms across longevity and trophic levels are needed to mechanistically understand ecosystem responses to repeated climate extremes. These organisms are important components of ecosystems, they are interconnected, and they can impact one another through multiple pathways. Plants play a key role in ecosystem functioning, because plants form the base of food chains. Past studies have shown that plants can respond and adapt to repeated climate extremes from gene, epigenetics, physiology and morphology, species, and community levels separately. Similarly, organisms at higher trophic levels may directly respond and adapt to repeated extremes through adjusting metabolism, behaviours, and movements. Moreover, plants can impact organisms at higher trophic level through providing food, shelters, and changing local environments (i.e. bottom-up control). In turn, organisms at higher trophic level could impact plants through selective grazing and changing local environments (i.e. top-down control). Importantly, organisms could co-adapt. For instance, under a first drought, plants can change soil microbial community composition that in turn feedback to their own growth during a second drought. Thus, an integrated across-organizational approach is needed to study legacy effects of climate extremes to offer a holistic understanding. The goals of this session are (i Strengthen communication and collaboration among researchers working on legacy effects of climate extremes. (ii Develop better and more realistic methods and frameworks to quantify and understand legacy effects.

PE6

01

Ecosystem response to repeated climate extremes — an integrated approach across organizational scales through functional traits

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Climate extremes are increasing in frequency, causing repeated droughts and heavy rainfalls that threaten ecosystem functions and stability. Ecosystem responses to repeated extremes are more complex than singular events due to legacy from past extremes that may influence ecosystem responses to subsequent extremes (i.e. legacy effects). Understanding ecosystem response to repeated extremes and the legacy effects may offer insights into increasing resistance of natural and agricultural systems to accelerating climate change. So far, around 40 empirical experiments quantified ecosystem response to multiple climate extremes (in most cases two extreme events). But these studies focus mainly on responses of individual plant species. Therefore, we know little about how plant communities and organisms at higher trophic level respond to repeated extremes. Moreover, most existing studies focus on plant genetic, physiological, morphological responses with little consideration of soil processes (i.e. plant adaptation studies). Other experiments focus on soil processes, especially responses of soil microbes and their feedback on plants (i.e. plant-soil feedback studies). Plant-soil feedback studies often do not measure plant traits during the initial extreme and do not compare plant performance during this extreme with that during subsequent extremes. We propose a framework to holistically study ecosystem response to repeated extremes and the legacy effects by combining experimental approaches from plant adaptation and plant-soil feedback studies. The framework links responses of individuals, species, communities of plants, organisms at higher trophic levels, and the ecosystem functioning through functional traits (e.g. fitness, physiological, morphology, and chemical traits). We also propose experimental designs that integrate these approaches to study ecosystem response to repeated extremes and the legacy effects.

PE6

O2

Divergent responses of plant, soil and ecosystem processes to recurrent drought events

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Climate change is expected to enhance the frequency and severity of droughts and is increasingly affecting ecosystems, which have so far been rarely exposed to drought events. Next to concurrent effects, droughts can induce lasting legacies on ecosystem structure and functioning and can thereby also alter ecosystem responses to subsequent droughts. Based on two long-term drought experiments in mountain grasslands in the Austrian Alps we present evidence for the responses of plant, soil and ecosystem processes and properties to recurrent drought events. We found that, compared to single drought events, multiple recurrent droughts increased the proportion of necromass and caused shifts in the plant functional composition. Furthermore, recurrent droughts amplified reductions of ecosystem fluxes of CO_2 and water vapour. Recurrent droughts reduced plant species richness, thereby reducing asynchrony. By contrast, recurrent droughts increased the dissimilarity of microbial communities, buffering detrimental drought effects on soil multifunctionality. At the same time, we observed negative effects of recurrent droughts on soil aggregate stability and pore size distribution, which led to a reduction in plant-available water. In a future drought scenario, under warming combined with elevated CO_2, we found particularly strong legacies of recurrent droughts on post-drought soil water flow and grassland water use. We conclude that grassland responses to recurrent drought events diverge across different organismic groups, organizational scales and processes, leading to simultaneously occurring antagonistic and synergistic effects, which slow down an overall degradation of grassland functioning in an increasingly extreme climate.

PE6
03

Tree diversity decreases the legacy effect of compound climate extremes on forest ecosystems

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Species diversity has widely been documented to provide buffering effects for forest ecosystems when facing extreme climates, but the role of species diversity during the legacy period after the occurrence of extreme climates remains unclear, especially in the face of increasingly severe compound climate extremes. Using forest inventory data from North America, combined with a satellite-derived temporal assessment of plant productivity, this study investigated the role of species diversity on natural forest community stability during and after compound extreme disturbances in forest ecosystems. We found that the larger the resistance in the disturbance phase, the smaller the legacy effect during the legacy phase. Species diversity stabilizes forest ecosystem functioning, even under compound extremes. The ecological benefit of species diversity to forest stability is reflected in the overall response stages. Our findings illustrate that biodiversity may reduce the uncertainty of terrestrial carbon cycle feedback in the context of global climate change in the future.

PE6
04

Resource use strategies of biodiversity can buffer grassland productivity during climate anomalies

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The effects of climate change on the stability of plant communities are a major concern, especially for maintaining ecosystem processes and services. Biodiversity may buffer communities from these disturbances, providing resistance and resilience. Here, we assess the interplay between biodiversity facets on the resistance and resilience of biomass productivity under anomalous dry and wet events in subtropical grasslands. High levels of taxonomic and functional biodiversity components, coupled with the community type derived from functional traits, positively affected resistance under anomalous dry and wet events. Resilience was positively affected during the recovery from wet periods. In summary, we conclude that increased diversity of plant communities can ensure ecosystem stability throughout climatic anomalies. However, this is contingent on the biodiversity component evaluated, the direction and intensity of the climatic anomaly, and the functional structure of the communities.

PE6
05

A win-win global climate change adaptation and mitigation: Evidence from sustainable cocoa management

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Cocoa provide a wide range of ecosystem services, including nutrient cycling, soil formation, wood production and terrestrial wildlife, ecotourism and carbon storage. Their protection and restoration plays a valuable role in climate change adaptation and mitigation. Despite these multiple benefits of cocoa ecosystems are threatened by climate change. The study review state of Ghana's cocoa ecosystem, knowledge of cocoa vulnerability and responses to predicted climate change and consider adaptation options. Multi stage sampling technique was employed to selected 400 households that farm cocoa in the Western Region of Ghana. Data obtained from the respondents and key informants were analysed using descriptive statistics and inferential analysis. Results indicates that climate change components that mostly affect cocoa includes changes in yield level, fruit drops, storminess, precipitation, temperature, atmospheric CO_2 concentration, as well as human responses to climate change. Cocoa vulnerability and responses to climate change was seen to be highly influenced by anthropogenic disturbances. Cocoa sediment elevation can be curbed by avoiding and limiting human activities that reduce cocoa soil organic matter accumulation like mineral exploration. In conclusion rehabilitation of degraded cocoa plantations, and education activities can augment community support for adaptation actions in climate vulnerable environment.

PE6

06

The role of hydrochory in structuring a metapopulation along a fragmented river

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Water mediated dispersal (hydrochory) along streams is vital for biodiversity and connectivity along rivers. Indirect evidence from genetic data of sessile terrestrial plant species supports the importance of hydrochory in recolonization after extreme events (e.g. floods) and for restoration success, also in fragmented landscapes. In this study, the longitudinal connectivity and the metapopulation structure of a characteristic pioneer species of riparian habitat are investigated. We assess the population dynamics of five populations of the shrub *Myricaria germanica* (German tamarisk), using 22 microsatellite markers and demographic data along a 24 km long fragmented stretch of the river Moesa. Sampling was performed in 2020 and repeated in 2023, to contrast the changes in population composition and structure to hydrodynamics events occurring in the river catchment. The results of this study showed major demographic changes of populations with decreases of large populations, but also population establishments in new areas. Genetic differentiation of populations along the river Moesa was apparent despite ongoing gene flow. According to expectations of *M. germanica* being dispersed by water in case of fragmented habitats, especially at long distances that cannot be crossed by wind, higher genetic diversity was found in downstream populations. The role of flood events, which are likely to increase in the future, are discussed with their double impact on the pioneer plant metapopulation: they either lead to local extinction, especially of small populations in proximity to the riverbed, but they also enhanced the colonization of new habitat by hydrochory.

PE6

P1

Satellite detection of legacy effects of the 2018 drought on spring phenology in Europe

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Europe experienced a severe drought and heatwave event in 2018 and 2019, resulting in widespread impacts on terrestrial ecosystems. Such drought events are potentially important mechanisms explaining the interannual variability of spring phenology, however, the legacy effects of the 2018 drought are still poorly understood. In this study, we provide a quantitative assessment of the legacy effects this extreme drought event (in terms of the Standardized Precipitation-Evapotranspiration Index, SPEI) had on spring phenology in Europe. Using long-term satellite observation data, we identify legacy effects by comprehensively analysing the relative change of phenology indicators (start of the growing season, SOS, and end of the growing season, EOS) and greenness index (Normalized Difference Vegetation Index, NDVI). Two methods were adapted to quantify the legacy effects of 2018 drought on spring phenology: (i) the departure from the baseline, and (ii) temporal autocorrelation. Given that such impactful extreme drought events are becoming more frequent and intense in the context of climate change, our results are important to evaluate how plant phenology may be impacted by future extreme drought events and provide valuable information as a basis for accurately quantifying ecosystem resilience.

PE6

P2

Combining models and field observation to explore impacts of drought on amphibians in north-western Europe

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Climate change is already leading to an increase in extreme events, including drought. Drought is projected to increase in both frequency and severity in Europe. One of the taxa most vulnerable to these changes is amphibians, as for most species water bodies are crucial for at least one life stage. Scotland provides an example of a region that is projected to experience substantial increases in drought in the near future, with likely impacts on its amphibian populations. While some species such as *Epidalea calamita* are well adapted to summer drought and may benefit, the remainder of native species are likely to be negatively impacted. All north European amphibians are adapted to occasional drought, however, evidence has shown that more frequent drought leads to declines and population extirpation. Using data on pond water levels and desiccation rate, we found evidence of drought during the breeding season (April–June) between 2014 and 2022. Our analyses combine drought models with field observation and suggest that drought is already a significant concern for amphibian conservation and resilience. These changes are occurring sooner than expected and potentially turning otherwise healthy ponds, including those in nature reserves, into trap habitats for several species. Additionally, drought will not be acting on its own; its impacts will interact with other drivers of biodiversity loss, notably land use change and fragmentation, invasive species and novel pathogens (e.g. chytrid), and pollution. We are now comparing these data to field surveys from other regions in Germany, Spain, and the Netherlands, to find wider evidence of this issue across north-western Europe. Conservation initiatives therefore need to take drought increases into account when designing interventions.

Impact of mixing European beech with conifers on soil microbes during summer drought

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Due to climate change, Central Europe has experienced long periods of drought during the growth season over the last decade. To enhance the stability of forest stands under environmental constraints, it has been suggested to mix pure beech (*Fagus sylvatica*) forests with Douglas fir (*Pseudotsuga menziesii*) or to replace spruce in mixed beech-spruce (*Picea abies*) forests by Douglas fir. Douglas fir is an introduced species from North America. Our knowledge if and how mixtures of native and non-native species influence the diversity and functions of soil microbes is limited. However, this gap needs to be filled since soil microbes are important components in biogeochemical cycles. The goal of the present study was to gain insight into the dynamics of root vitality and soil fungal communities under drought in different forest types. We used rain out shelters to create summer drought in the following forest types (Douglas-fir, mixed Douglas-fir-beech, beech, Norway spruce-beech and Norway spruce). This experimental set up was replicated in three regions in Lower Saxony. Samples were collected before the installation of the rainout-shelters, during increasing drought and after removal of the shelter to inspect recovery. First results about fungal metabarcoding in relation to root biomass, mycorrhizal colonization and root vitality will be presented.

Remote Sensing (RS)

Remote sensing of biodiversity

Short title: Remote sensing

Chairs: Hannes Feilhauer, Antonia Ludwig, Sebastian Schmidtlein

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Earth observation (EO) data are increasingly used to assess biodiversity and related ecosystem properties. Due to the spatially continuous satellite data availability, EO is therefore also considered a core tool to scale local biodiversity assessments. This is even more important in the light of intensively managed landscapes threatened by biodiversity loss. Related studies make use of various sensors and data to model and map species, functional or ecosystem diversity or to develop indicators of such properties. The employed approaches are manifold and include, for example: artificial intelligence and machine learning techniques as well as physical model inversions which enable the retrieval of leaf and plant traits from spectral data and provide insights in functional diversity aspects. The texture of high resolution imagery is frequently exploited towards information on species or ecosystem diversity. Various approaches aim to develop EO-based indicators of essential biodiversity variables that are designed to provide a comprehensive assessment of biodiversity on different spatial scales. These approaches all have in common that their development is still ongoing research and comprehensive assessments of their capabilities and limits are urgently needed. This session hence aims to give an overview on recent developments in remote sensing of biodiversity and aims to foster the discussion of this topic among interested users. We kindly invite all contributions that rely on remote sensing for spatio-temporal analyses of biodiversity and ecosystem properties across all spatial scales, sensor systems and biomes.

RS1
01

Copernicus Data Space Ecosystem is transformative for landscape ecology

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Satellite imagery can contribute in many ways to the science of landscape ecology. This includes data collection for macroecology, upscaling of models, prospection of study sites and operational habitat monitoring. As shown by a wide range of publications and use cases, the Copernicus Sentinel Programme has been a game changer for this field by providing openly accessible, regular, high quality satellite imagery from a complementary set of sensors. However, satellite data processing has several challenges, which often make it out of reach for the regular ecologist who is not a specialist in GIS and does not have access to powerful computing infrastructure. Since the launch of the Copernicus programme, the sheer volume of available data at continental or global scale is simply too much even for server-based processing, but even at regional scale, the data volume is often a limit. Similarly, processing capacity may not be sufficient on most machines. In many cases, image processing has required costly GIS software. Copernicus Data Space Ecosystem overcomes these problems, providing a transformative solution based on cloud computing, API access and online processing. Compared to the regular approach of a rolling archive with limited data availability optimized for downloading images and processing locally, Copernicus Data Space Ecosystem makes advantage of machine to machine interfaces and cloud-based processing. This means that most data analysis tasks can be performed as part of an API request, where calculations are done on the server side. This functionality is available in an on-board Jupyter Lab, but also in graphical interfaces such as requests builder or openEO. The Ecosystem allows instant access to all Copernicus Data over land and hosts additional complementary datasets to support analysis. Code repositories and an onboard code lab support those who are novices to programming, while OGC services such a QGIS plugin connect to traditional desktop analysis systems. Therefore the ecosystem overcomes many of the obstacles encountered by ecologists wishing to support their studies with satellite imagery, maximizing the benefit of the Copernicus Programme for ecological applications.

Exploring the relation of forest height heterogeneity and tree species diversity using Remote Sensing

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Forests with a high overall biodiversity provide a variety of ecosystem functions and service and are associated with greater ecosystem stability and resilience to disturbance events. To identify and preserve intact forest ecosystems across the country, monitoring forest biodiversity on national scale is essential. Here, we used high resolution area-wide LiDAR derived tree canopy height models and a national tree species classification map of Germany based on Sentinel-2 with 20 m spatial resolution to analyse the correlation of forest tree height heterogeneity and tree species diversity on different spatial scales (local, regional, national) and across forest types. Height heterogeneity was derived from the canopy height models whereas biodiversity metrics were calculated from the tree species map. Topographic variables and canopy cover were included in the analysis. The correlation of forest height variation and tree species diversity varies between geographic regions and is partly driven by forest composition. We analysed and evaluated the impact of spatial scale and resolution, as well as forest type specific correlations of structural indices and tree species diversity. We aim to compare our satellite-based findings to results generated from forest inventory data in exemplary regions to provide a comprehensive picture of the potential and the constraints of using remote sensing data products for forest biodiversity assessment. This study contributes to the development of remotely sensed forest biodiversity indicators and facilitates the integration of remote sensing into large-scale forest assessments from a nature conservation perspective.

RS1
03

Reaching new heights: Unraveling the quality of global canopy height maps

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Ecosystem structure, especially vertical and horizontal distribution of vegetation, is one of the six Essential Biodiversity Variable classes and is an important aspect of habitat heterogeneity, affecting species distributions and diversity. Until recently, we lacked comprehensive global data on the spatial patterns of vegetation structure. However, in recent years, the availability of such data has literally exploded. In 2021, the Global Land Analysis and Discovery team at the University of Maryland published global forest canopy height map with a spatial resolution of 30 m. In 2023, EcoVision Lab team at ETH Zurich developed a high-resolution canopy height model of the Earth with a spatial resolution of 10 m. Finaly, in 2024, Meta and World Resources Institute produced a global map of tree canopy height at a 1-meter resolution. The availability of such data is crucial for ecological research. The variation in canopy height plays a critical role in regulating ecosystem processes and supporting the diversity of terrestrial ecosystems. Despite their unprecedented resolution, however, modeled global canopy height maps may suffer from low accuracy. In fact, the reliability of predicted global maps is increasingly questioned. The main advantage and, at the same time, threat of predicted global canopy height maps lie in their easy availability. This contrasts with the time-consuming and, for many ecologists, challenging processing of more accurate airborne laser scanning points clouds. Moreover, with their growing number, it is difficult to choose the most suitable map for a specific purpose. Therefore, we will concentrate on (i) the accuracy of existing global (a local) canopy height maps, (ii) particularly on their sensitivity to changes in canopy height (i.e. how well they represent canopy heterogeneity), and (iii) their usability for biodiversity modelling. Our aim is to show the pros and cons of individual maps and provide users with clear guidelines.

RS1
04

Quantifying tree cover loss across European forests from 1984 to 2023

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European forests are increasingly affected by disturbances, which profoundly impact ecosystem services and biodiversity. Given the acceleration of changes in disturbance regimes in response to climate and land use change, it is crucial to accurately quantify resulting canopy cover changes based on biophysical parameters across large spatiotemporal scales. In this regard, fractional cover time series from remote sensing offer valuable information on tree, shrub, grass, and bare ground cover and their changes over time. Such time series are useful for better characterizing disturbance severity based on the percentage of tree cover loss, for identifying post-disturbance management and for assessing recovery dynamics. Yet, how robust fractional cover time series can be derived at a continental scale and over multiple decades has not been explored. We address this gap by estimating fractional cover time series from the Landsat archive across all European forests for the past four decades to quantify tree cover loss and post-disturbance land cover following different disturbance types (harvest, fire, wind and bark beetle). We use a Landsat data cube containing all available growing season images from 1984–2023 in a ready-to-use format. Annual gap-free composites are built from the image database. We implement a regression-based unmixing approach to predict annual cover fractions for each year. Regression models are trained on synthetic training data generated from a spectral library of pure image spectra representing 100% tree, shrub, grass, and bare ground cover. Applying the models on the annual image composites yields robust, wall-to-wall estimates of relevant cover fractions for all European forests. A more detailed quantification of disturbance severity, post disturbance land cover and recovery of tree cover can help with predicting impacts of disturbances on ecosystem functions and biodiversity.

RS1

05

Plant trait retrieval from spectral data: Collective efforts of the scientific community outperform data simulations

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Plant traits play a pivotal role in steering ecosystem dynamics. As plant canopies have evolved to interact with light, spectral data convey information on a variety of plant traits. Machine learning techniques have been used successfully to retrieve diverse traits from hyperspectral data. Nonetheless, the efficacy of machine learning is restricted by limited access to high-quality reference data for training. Previous studies showed that aggregating data across domains, sensors, or growth forms provided by collaborative efforts of the scientific community enables the creation of transferable models. However, even such curated databases are still sparse for several traits. To address these challenges, we investigated the potential of filling such data gaps with simulated hyperspectral data generated through the radiative transfer model (RTM) PROSAIL. We coupled trait information from the TRY plant trait database with information on plant communities from the sPlot database, to build a realistic input trait dataset for the RTM-based simulation of canopy spectra. Our findings indicate that simulated data can alleviate the effects of data scarcity for highly underrepresented traits. In most other cases, however, the effects of including simulated data are negligible or even negative. This highlights two key observations: firstly, RTM models, such as PROSAIL, exhibit limitations in producing realistic spectra across diverse ecosystems; secondly, real-world data repurposed from various sources exhibit superior retrieval success compared to simulated data. As a result, we advocate to emphasize the importance of active data sharing over secrecy and overreliance on modelling to address data limitations.

Establishing a novel training data set to aid circumboreal AI applications to detect individual trees and species in northern boreal forests and the tundra transition: BorFIT

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Detecting individual trees and their species at landscape scales is crucial to assess the state of a forest and to reveal its responses to climate or environmental changes. Particularly repeated measurements are valuable for highlighting regions experiencing significant alterations. This information serves a dual purpose: Evaluating the crucial ecosystem service of carbon storage and providing useful insights for foresters to detect pest outbreaks and enhance treatment planning. However, based on our experience in northern ecosystems, we know that conventional area-based methods relying on canopy height models tend to oversee trees especially when dealing with thin and overlapping crowns coupled with a dense understory layer. Individual-tree detection methods based on point clouds are more suitable but require a time consuming manual finetuning of parameters for high quality segmentation results. Direct training of Deep Learning approaches would need benchmark datasets such as the recently published FORinstance. However, currently available datasets tend to contain simple forest structures and forests that originate primarily from temperate zones, with complex multi-layered and thin-crowned northern forests not considered. This leads to an only moderate accuracy for northern forest application and underlines the need of a training dataset that encompasses the range of forest structures of the northern forest. Our project therefore aims to create a novel training dataset. Fortunately, for forest structure analyses, we collected drone-based laser-scanning and multispectral data from more than 200 transects (60x500 m^2) along bioclimatic and land-surface gradients in Siberia, Canada and Alaska (2021, 2022, 2023). We will randomly stratified sample ten 10x10 m^2 areas as reference plots covering the different structures (height, density) at each transect. The annotations encompass individual trees within point clouds, along with their corresponding species. The final dataset will capture the diverse forest stand structures and species combinations found in northern boreal forests to enable circumboreal AI applications for the analysis of forest ecosystems.

Phenological heterogeneity and forest stand improvement management in Southern Germany

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Phenology is the study of seasonal changes in the green canopy, which plays an essential role in maintaining environmental health and offering various ecosystem services. The heterogeneity of phenology reflects the plant diversity in the region and could potentially influence the resilience to drought and other extreme events. A research gap lies in the study of the relations between forest management and phenological diversity in corresponding forest regions. For the first time, this study explored the possible influences of Forest Stand Improvement (FSI) treatments on the spatial patterns as well as spatial and temporal heterogeneity of phenology, based on vegetation indices derived from Sentinel-2 satellite data. The study area comprises 22 plots of the Bavarian Growth Monitoring Trials located in southern Germany, administrated by the Bavarian State Institute of Forestry (LWF). There are two central hypotheses: (i) As the level of FSI treatments/thinning gets stronger, the phenology in the corresponding forest stands gets more heterogeneous (higher SD). (ii) The onset date of greening differs among the plots with FSI treatments due to methodological issues of deriving phenological metrics from remote sensing. The initial results show that FSI treatments affect the heterogeneity of phenology in forest stands confirming the first hypothesis. The diversity of length of season (LOS) significantly increases as the level of treatment strengthens ($p < 0.05$).

RS1
08

Fresh leaves in fall: a binary indicator of stress in *Fagus sylvatica*?

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The common beech *Fagus sylvatica* is a dominant species across Europe that is ecologically important as a keystone forest tree, and economically important for its wood. Beech forest ecosystems are increasingly subject to more frequent and intense droughts, and this is projected to contribute to a change in the species distribution, perhaps to threaten beech forests even at the heart of their species range. We recently observed that beech trees in a forest at the southern edge of the species range in la Massane (French Pyrenees) and closer to the range center in Štítná nad Vláří (White Carpathian mountains) displayed a second spring-like flush of green leaves in fall (fall flush, FF), which may be an informative indicator of stress in beech. This study aims first to describe the FF phenomenon and embed it into the existing ecological literature, and secondly to explore evidence of whether and how this is a stress indicator for beech populations. For the second aim, we characterized the traits of FF and old leaves as well as other traits of the trees in the study populations using extensive field observations of beech leaves in terms of their structure, biochemical and optical traits, and UAV imagery, and linked these to topographic information and to NDVI patterns from Sentinel-2. Here we show that (i) fall flush leaves are smaller and have a higher leaf mass per area (LMA), as well as a lower leaf dry matter content (LDMC); and (ii) trees displaying FF are located at the fringes of beech clusters within the forest stand. We posit that these trees at the edge are subject to more competitive stress, because beech typically tends to grow in monodominant stands, leading to the FF. Our combination of datasets and methodologies lends itself to scaling, allowing this phenomenon to be monitored using Earth Observation. Such monitoring data could be used to test more specific hypotheses about the patterns, causes, and indications of FF in beech populations across the species range. Such a binary stress indicator could provide clear input for forestry management decisions. Beyond additional monitoring options for the distribution shift process, it could support the selection of genotypes that are more resilient under changing environmental conditions.

Grassland decline and land cover change in Lower Saxony – classification and quantification

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Grasslands are one of the world's largest biomes providing crucial ecosystem services like food production, carbon sequestration, biodiversity conservation, and soil protection. However, grasslands are under threat facing significant areal loss. In Germany, the area of permanent grassland decreased by around 12% in the last two decades. The Lower Saxon State Department for Waterway, Coastal and Nature Conservation (NLWKN) identifies conversion to cropland, grassland intensification, afforestation, and urbanization as major factors contributing to this decline. In order to establish efficient conservation mechanisms, these threats must be measured and quantified. To this day, a significant research gap in these measurements remains. This study aims to address this gap by conducting a change detection analysis in Lower Saxony over the last four decades using archived earth observation data. By classifying the land cover of past and present days, shifts between land cover classes can be identified. Satellite imagery, especially from the Landsat mission, alongside ancillary land cover information will be utilized to enable accurate classifications. Major drivers of grassland change can be derived by analysing changes from grassland to other land cover classes. By linkage of land cover changes to their drivers, specific threats can be identified and quantified. Hence, further studies can focus on options for minimizing threats.

RS1
O10

Monitoring of eco-hydrological changes following rewetting of European peatlands – Towards the integration of earth observation in restoration management

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In Europe, approximately 52% of former peatland area is strongly degraded due to human exploitation. This makes the EU the worlds' second largest emitter of greenhouse gases from drained peatlands. Rewetting of drained peatland sites has therefore a great climate change mitigation potential, as net greenhouse gas emissions can be strongly reduced in the long term. To assess the success of rewetting actions, there is a strong demand for cost-effective and unified monitoring techniques. We developed an open-access tool to assess the status and changes of European peatlands in terms of vegetation and moisture conditions at individual peatland sites defined by users. Freely available satellite and climate reanalysis data (Landsat, ERA5) was used to generate time-series of vegetation and moisture indices (such as NDVI, NDWI), same as climatic variables. Pre- and post-rewetting, same as overall trends were analysed and anomalies were calculated with reference to the known pre-rewetting time period of selected peatlands. This provides a spatio-temporal overview of eco-hydrologic changes, which allows to derive information even for remote locations and inaccessable or protected areas. In this contribution we exemplary focus on a rewetted peatland in Northwestern Germany (Neustädter Moor) for which we could show a clear signal in NDWI anomalies following a rewetting measure in 2013, indicating that these measures have indeed been effective. We intend to test the application further at multiple sites in cooperation with practitioners and to assess the analysis by comparing results to field-specific data. The fully automatized multi-index approach is provided as a web-based application, which can be used to summarize and compare the advances in peatland restoration at continental scale also in the future. We aim to provide opportunities for new insights by creating synergies between earth observation and restoration practice in European Peatlands.

RS1
011

Ecosystem and landscape restoration across spatial and temporal scales to enhance biodiversity and climate resilience in agricultural landscapes

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Global change strongly affects biodiversity and ecosystem functionality in agricultural landscapes through climate change, land use intensification and related habitat degradation. To counteract these negative impacts, various ecosystem and landscape restoration (ELR) measures have been developed. However, restoration science still lacks a deeper understanding of key indicators of transition to more resilient ecosystems and landscapes, well-designed experiments identifying factors for success or failure of ELR measures, and comprehensive analyses of existing data for evidence-based restoration. Starting in 2024, our DFG research impulse project, AgriRestore, aims to overcome these deficiencies. The project assesses the effects of temporary and permanent ELR measures in agricultural landscapes. In an innovative approach, we combine real-world with mesocosm experiments and use remote sensing to up- and downscale identified patterns. Our research is conducted in the arid and partly strongly simplified agricultural landscape of Saxony-Anhalt, where we have selected restored and degraded sites along a landscape complexity gradient. Furthermore, we evaluate and synthesize the existing evidence base through meta-analyses and knowledge graphs and assess the benefits, risks and uncertainties of ELR measures to understand the underlying mechanisms better. We will present the first results regarding the efficiency of ELR measures for above- and below-ground biodiversity, as well as related ecosystem functions (incl. ecosystem services and disservices) and processes. Finally, we will give an outlook for the next five years, where we will gain an in-depth understanding of the relationships and processes related to ELR measures and derive key indicators for transitions towards more resilient ecosystems and landscapes across spatial and temporal scales.

Remote sensing for understanding sustainable land use across scales

Short title: Remote sensing across scales

Chairs: Cornelius Senf, Hanna Meyer, Martin Ehbrecht, Katja Kowalski

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Understanding how global land-use change and unsustainable land management impact biodiversity and ecosystem function requires consistent data across spatial and temporal scales. Remote sensing can help filling this data gap, but development of targeted methods applicable in ecology and ecosystem science are needed. We call for contributions that either develop new methodological approaches or apply existing approaches to current challenges in understanding sustainable land use, including agriculture, forestry, nature conservation and urban planning. Methods include both close-range and airborne/spaceborne sensors systems, ranging from local cameras over terrestrial laser scanning, uncrewed aerial vehicles to satellites. We encourage submissions integrating sensors across spatial and temporal scales.

RS2

01

Remote sensing and machine learning-based maps of the environment and the need to account for the area of applicability

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Spatial mapping is an important task in environmental science to reveal spatial (and spatio-temporal) patterns and changes in the environment. Predictive modelling is a common method in this context, where field data are used to train statistical models using spatially continuous predictor variables, many of them derived from remote sensing imagery. The resulting model is then used to make predictions for the entire area of interest, i.e. beyond the geographic locations of training data. Machine learning algorithms are frequently employed for this purpose, learning from local field observations to make spatial predictions for areas where direct measurements are unavailable, now ambitiously even on a global scale. This presentation aims to raise awareness of the challenges associated with applying machine learning to environmental spatial mapping and to provide ideas and suggestions to address them.

Branch biomass estimation for urban trees based on TLS data

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Urban trees provide a multitude of ecosystem services, many of which are closely linked to the total tree biomass in cities. Accurately quantifying above-ground biomass (AGB) is essential for evaluating their carbon storage potential. However, traditional methods often involve destructive sampling and are often based on allometric models developed for forest trees, which have different growing conditions and forms compared to urban trees. Moreover, the lack of urban tree-specific allometric models estimating branch biomass adds significant uncertainty. This study aimed to develop a non-destructive branch biomass model based on allometric relationships for six European abundant tree species (*Acer platanoides, Aesculus hippocastanum, Platanus x hispanica, Populus nigra var. Italica, Robinia pseudoacacia, and Tilia cordata*) using Terrestrial Laser Scanning (TLS) and Quantitative Structure Models (QSM) data. We scanned 3,156 trees across public green spaces in Munich, Germany, generating high-resolution 3D point clouds and processed it as TreeML-Data open source. Our aims are the estimation of the accuracy of TLS-derived branch volume and the development of species-specific allometric equations for predicting branch biomass for the selected tree species. We used the QSM data, which is integrated into the TreeML-Data, to incorporate the geometrical and topological characteristics of tree segments, offering insights into branching patterns and volumes. Initial analyses showed promising results in the allometric models developed for different species, yielded R^2 values ranging from 0.54 to 0.83. These findings highlight the potential of TLS data in accurately estimating branch biomass in urban tree species and developing species-specific allometric models for urban trees for better ecosystem service quantification and effective urban forestry management.

Leaf to landscape: deciphering vegetation's effect on rainfall erosivity by Lidar

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Rain splash, the initial process of soil erosion by water, is controlled by the erosivity of rainfall and the erodibility of soil surface. Rainfall erosivity, quantified as kinetic energy, is modified by vegetation, which can either act as a protective, dispersing layer or as an amplifying, drip aggregating layer. Research on the effect of vegetation on throughfall kinetic energy (TKE) has focussed on point-based vegetation records and erosivity measurements. There is a need for a spatially continuous, area-wide prediction of vegetation's effect on rainfall erosivity for erosion modelling and conservation. Recent studies have highlighted the importance of small-scale structures in tree structure leading to hotspots of erosivity known as drip points. To address these research needs, we have used lidar point clouds on different scales and explored the relationship between 3D vegetation structure and TKE. We used UAV lidar to derive vegetation cover and gap fraction in a voxel space to identify the layers contributing leaf drips falling to the ground without re-interception and to quantify the effect of vegetation. Additionally, we related field observations of active drip points to tree skeletons extracted from TLS point clouds to identify rules of drip formation. The effect of temperate forest vegetation on erosivity exceeded the values described in previous literature focussing on plantations. We achieved a significant correspondence between the predicted and measured effect of vegetation on TKE. We could demonstrate the potential of remote sensing in predicting vegetation's effect on rainfall erosivity in a wall-to-wall approach. When applied on tree scale lidar can improve our understanding of stemflow and re-interception processes on the vegetation surfaces. In turn, these detailed insights have potential to be transferred back to the landscape scale and improve the accuracy of predictions there. Lidar can help bridge the data gaps in traditional erosion studies.

RS2
04

Drone models to predict rangeland resources are transferable in space and time

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Drone-based monitoring offers a cost-effective approach for vast areas like rangelands. However, model transferability, that is, performance beyond training conditions, is rarely tested. This is crucial, as rangeland forage availability varies greatly in space and time. We evaluated drone models for estimating forage proxies (herbaceous biomass and land cover) across two land-use systems and two growing seasons in semi-arid rangelands. We compared case-specific models (trained on specific conditions) with a landscape model (trained on all data). As expected, the landscape model performed better, capturing the system's full variability. This highlights the importance of incorporating diverse conditions in model development. Our study advances the understanding of model transferability in dry rangelands, promoting the integration of drone technology for accurate monitoring and, ultimately, sustainable rangeland management.

RS2
05

A hybrid modelling approach to establish links between forest attributes and hyperspectral data

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Optical vegetation indices have become a key tool for monitoring forests' states and assessing their responses to disturbances and environmental change. Recent satellite missions provide high-resolution hyperspectral data, yielding novel opportunities for developing detailed quantitative models and indices for structural forest attributes. However, the sparsity of corresponding ground-based data makes it difficult to fit and validate such models for large-scale applications. We address this challenge via a hybrid modelling approach: we couple a forest model with a radiative transfer model to generate an extensive number of structurally different forests along with corresponding reflectance data. We apply statistical models to the resulting dataset, analysing the relationships between key forest attributes and different subsets of the reflectance spectrum. Thereby, we deduce which spectral frequencies are best suited to assess forest properties. The results of this systematic analysis may constitute a step towards a new generation of quantitative attribute-specific vegetation indices, providing new opportunities for forest research on large scales.

RS2
06

From pixels to birds: Remote sensing reveals habitat heterogeneity's role in Alpine bird communities

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Understanding the primary factors driving biodiversity loss in European agricultural landscapes has been a focal point of research in recent decades. Among these factors, habitat heterogeneity stands out as a key promoter of biodiversity, particularly crucial for avian species and their communities. Birds exhibit high sensitivity to environmental shifts and rely on a diverse array of ecological niches, rendering them exceptionally vulnerable to the decline of habitat diversity. Remote sensing techniques offer valuable tools for quantifying habitat heterogeneity across large geographical areas at fine scales. In this study, we utilized airborne LiDAR and satellite data to assess vegetation canopy height and primary productivity across 118 sites within complex agricultural landscapes in the Central Alps region. By employing various bird diversity indices and categorizing bird species into guilds based on specific traits (nest location, habitat specialization and level of threat), we examined the intricate relationship between avian communities and different aspects of habitat heterogeneity. Our findings underscored the critical role of habitat heterogeneity in shaping diverse bird communities, particularly within farmlands. Through an analysis comparing canopy height, primary productivity, and specific vegetation characteristics (e.g. grassland, shrub, and tree cover), we elucidated how various habitat features and landscape diversity influenced bird richness, diversity, functional diversity, and trait distributions. Notably, landscape and height heterogeneity, as estimated by NDVI (Normalized Difference Vegetation Index) and LiDAR Rao's Q indices, emerged as significant drivers impacting all response variables. For instance, high NDVI values were associated with increased species diversity and favoured ground-understory nesters, while the presence of a shrub layer was particularly important for ground-understory nesters and forest specialists. In conclusion, our study provides valuable insights for conservation efforts and suggests mitigation strategies to enhance bird diversity within agricultural landscapes. By emphasizing the importance of preserving habitat heterogeneity and implementing targeted measures, we can foster healthier and more resilient avian communities in these ecosystems.

RS2
07

Airborne assessment of evapotranspiration across tree islands in an oil palm landscape

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The conversion of tropical rainforest to oil palm plantations is impairing biodiversity and ecosystem functions. To study how mixtures of oil palms with native trees can alleviate some of the negative ecological consequences of crop cultivation, experimental tree islands varying in size and diversity were established in an oil palm landscape. Ten years after tree planting, we assessed energy partitioning and evapotranspiration across 56 tree islands. To do this, we used drone-based thermal imaging and subsequently applied an energy balance model. We found that increasing island size enhanced the conversion of energy to latent heat flux. Evapotranspiration around noon increased by 19% from an average of 0.67 mm/h from the smallest islands (25 m²) to 0.80 mm/h from the largest islands (1600 m²). These larger islands had a more forest-like structure which increased surface cooling due to evapotranspiration. Further, we found no statistically significant effect of planted tree diversity on evapotranspiration, probably because of high levels of actual tree diversity induced by abundant spontaneous wood plant regeneration. The direct and indirect effects of leaf area index, surface roughness, vegetation health and overall stand structural complexity will be discussed. Our findings highlight that establishing large diverse tree islands effectively cools land surfaces and enhances evapotranspiration on the plot scale. We therefore suggest that large diverse tree islands are cool.

RS2
08

Investigating post-disturbance forest recovery dynamics in the European Alps: What can be seen from Earth observation data?

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Natural disturbances and post-disturbance recovery are key drivers of forest ecosystem dynamics. While disturbances and their effects have been widely studied, there is a substantial lack of knowledge on post-disturbance recovery, which is crucial for forest resilience, carbon storage, and management strategies. This is particularly important in mountain landscapes like the Alps, where steep terrain and frequent climate extremes can hinder natural tree regeneration, yet closed canopy forests are needed to protect infrastructure from natural hazards. Our study addresses this gap using satellite-based Earth observation methods. By employing spectral unmixing based on dense time series from Landsat, we mapped land cover fractions annually from 1986–2023 across the Alps. This dataset allowed us to characterize post-disturbance recovery intervals across 1.76 million disturbance patches from both natural and human disturbances. Results show that disturbed sites achieve canopy closure on average after 10.6 years, with 60% reaching closed canopy within 10 years. Comparing recovery intervals derived from spectral unmixing to those based on simple vegetation indices, we found that traditional indicators overestimate canopy closure time by a factor of 1.5–2.0. We also tested whether post-disturbance bare land fractions and disturbance characteristics can predict long-term recovery success and found that long-term recovery success can be predicted with >80% accuracy. We conclude that (i) recovery indicators based on spectral indices are unsuitable for characterizing post-disturbance recovery in complex mountain landscapes, and (ii) long-term recovery trajectories can be projected from early post-disturbance signals. Our approach overcomes limitations of previous remote sensing-based recovery assessments, which require long time series to evaluate recovery, thereby enhancing our understanding of changes in forest recovery over time.

RS2
09

Mapping species-specific tree dieback across Germany using Sentinel-2 time series and regression based unmixing

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Temperate forests in Europe are increasingly affected by prolonged droughts linked to an increased likelihood of forest fires and insect infestations. Understanding forest dieback at various spatial and temporal scales is vital for carbon storage and biodiversity conservation. Satellite-based remote sensing (RS) can address gaps in spatial coverage left by field assessments. So far, most RS approaches rely on relative changes, changes in live cover or do not achieve the temporal resolution and continuity of freely available multispectral time series over large spatial scales. Fractional cover of non-photosynthetically active vegetation (NPV) can provide continuous, physically meaningful quantifications of vegetation condition across heterogenous ecosystems. Despite the possibility of reducing the impact of understory vegetation, the potential of directly estimating NPV from time series of multispectral data to quantify dieback has not been fully explored. Our study shows that regression-based unmixing of Sentinel-2 time series allows for monitoring species-specific (spruce, pine, beech and oak) dieback across the heterogeneity of forests in Germany. Using triangular feature space concepts, tree species maps, and high-resolution ortho-imagery, we created a comprehensive spectral library to generate synthetic data for training regression models through an ensemble approach. Our models achieve accuracies with MAEs of <14.5%. The fractional cover time series captures gradual processes like ephemeral defoliation, seasonal leaf shedding and dieback as well as abrupt disturbances such as windthrow and harvest. Annual aggregation of NPV predictions reveals reasonable species-specific dieback estimates aligning with the order of magnitude of mortality estimates of the German crown condition survey. Our spatially explicit quantifications unveil variations with forest structure and environmental conditions and pave the way for a more nuanced description of disturbance impacts.

RS2
O10

Evaluating machine learning techniques and data sources for dead trees detection

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In Central Europe, the extent of bark beetle infestation in spruce stands due to prolonged high temperatures and drought is currently under investigation. The research focuses on monitoring methods using three data sources: multispectral aerial imagery, multispectral PlanetScope satellite imagery and multispectral Sentinel-2 imagery. For the aerial imagery, the Vexcel UltraCam Eagle Mark3 camera was used. Planet satellite imagery was acquired using the PSB.SD sensor and tested on both 4-channel and 8-channel imagery. The classification results using Random Forest (RF) and Neural Network (NN) models were compared with two type of reference data the model accuracy on test data and vector format semi-automatic classification polygons done by human observer. The aerial imagery was found to have the highest accuracy, with the CNN model achieving up to 98% for object classification. Higher classification accuracy for satellite imagery was achieved by combining pixel classification and the RF model (87% accuracy for Sentinel-2). Comparison with the reference data showed a decrease in the classification accuracy of the aerial imagery to 79% and the classification accuracy of the satellite imagery to around 70%. In conclusion, aerial imagery is the most effective tool for monitoring bark beetle calamity in terms of precision and accuracy, but satellite imagery has the advantage of fast availability and shorter data processing time together with larger coverage areas.

RS2

011

From phreatophyte species to habitat probability for groundwater-dependent vegetation – A multiscale approach

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Groundwater-dependent vegetation (GDV) forms globally important biodiversity hotspots, which are threatened by climate and land-use change and require large-scale mapping efforts for their protection. Phreatophyte species are relevant local ecohydrological indicators of groundwater. However, there exists no approach to move from species to plot level to the final large-scale mapping of GDV. A novel mapping approach is presented that aims to identify both species and communities, indicative of GDV and high probability GDV habitats in the Mediterranean biome. The approach presented combines global plant community data from 'sPlot - The Global Vegetation Database' and satellite data in the Mediterranean. A list of ca. 1,080 phreatophyte species was compiled based on literature review. Additional species with high fidelity for groundwater-dependent EUNIS habitats were extracted within Europe. Based on the compiled lists, co-occurring species were extracted in an iterative process. Finally, the coverage of phreatophytes and associated species was calculated plot-wise to account for GDV. Remote sensing criteria included (i) vitality during dry periods, (ii) seasonal and (iii) interannual variation in vitality, (iv) high topographic potential for water accumulation, and (v) topography (elevation, slope). Finally, a regression analysis between the plots and the remote sensing criteria pinpoints areas with high phreatophyte cover and hence high probability GDV habitats in the Mediterranean biome. The resulting species list and composition indicative of GDV can support identification in the field. In addition, detailed maps of GDV for the Mediterranean biome will help to ensure sustainable groundwater management and thus protect GDV as biodiversity hotspots.

Assessing northern boreal forest migration and the extent of tundra losses in a warming climate

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Forest advance and colonization of tundra areas pushes their cold-adapted species to the limits or can drive them extinct as of no space for refugia in the north due to the adjacent Arctic Ocean. Determining timing and final extent of the forest expansion of the northern latitudinal tundra zone would help to map conservation regions to safeguard the different tundra types into a warming future. However, many processes are involved and leveraging on the fitness of the individuals in a changing environment. For example, uncertainty stems from life-cycle associated variables as the age to start producing seeds or general species parameters as seed dormancy, or also from adaptation of their traits such as seed size. Identifying importance of the difference factors in a changing environment and focusing on the interplay of the relevant interactions can help to understand the response of the advancing treeline that migrates currently only slow better. We combine data from observations with classical methods such as stem inventories with novel remote sensing methods to derive parameterization and validation data from Alaska, Canada and Siberian tundra-taiga transition regions. Application examples are introduced to show the different sources of data and derived metrics. The results are then plugged into our individual-based boreal forests vegetation model LAVESI to update and test with sensitivity analyses the importance of the different processes. Finally, with forward simulations of the forest advance using climate pathway scenarios we can project the forest cover and determine regions of interest for tundra species conversation.

Neural network models in standing dead trees detection: A comparative study of YOLO and Detectron approaches

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The tree mortality is a natural ecological phenomenon that gives significant information about the productivity and structural integrity of forest ecosystem. Mapping standing dead trees is essential for forest health estimation, its stability and vulnerability against disturbances like fire and windthrow. In this presentation we compare two major AI models for object detection in CIR aerial imagery Yolo8 and Detectron2 to estimate the presence of dead trees. Both models perform good in rasters with low objects per raster and both fails to detect all object with high number of dead trees. Interestingly we found that Yolo accuracy metrics appear to be better than those of Detectron, but the number of detected trees is very similar. Initial starting models and their weights may significantly influence the overall performance as well.

RS2
P2

A new approach towards mapping groundwater-dependent vegetation in the temperate biome using ECOSTRESS and Sentinel-2 data: A case study in Saxony-Anhalt

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Groundwater-dependent ecosystems (GDEs) are biodiversity hotspots and provide essential ecosystem services such as water purification, habitat for endangered species, and carbon sequestration. The European Union's water framework directive (WFD) stresses the importance of identifying and protecting GDEs. However, these ecosystems are still poorly analysed in the temperate biome, with most studies focusing on semi-arid or arid environments. To address this gap, a novel mapping approach is presented. The method combines Sentinel-2 remote sensing data and, for the first time, ECOSTRESS evapotranspiration data together with regional geodata and field observations to identify groundwater-dependent vegetation (GDV) in Saxony-Anhalt, Germany. Four criteria are introduced to identify GDV: (i) high evapotranspiration during dry spells, (ii) sustained vitality during dry spells, (iii) minimal fluctuations in vitality between dry and wet years, and (iv) presence in areas with high topographic potential for water accumulation. Several supervised classification algorithms were trained with 130 ground-truth vegetation plots to finally map GDV in the study region. The method presented offers a replicable solution for identifying GDV in the temperate biome. This is crucial for successfully implementing the WFD and can contribute to efficiently managing groundwater resources and preserving biodiversity hotspots. It is particularly valuable for regions facing high demand for groundwater extraction and experiencing biodiversity loss due to land use change and habitat fragmentation.

Society (SC)

Fostering collaboration between ecological sciences and the arts: opportunities and challenges

Short title: Arts and ecological sciences

Chairs: Florian D. Schneider, Monika Egerer, Oliver Szasz, Somidh Saha

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The session will showcase collaborations of ecologists with artist and illustrate the potentials of art-science collaborations for the ecological sciences. In recent years, art-science collaborations are being explored as a mode for science communication and to facilitate transformative change towards sustainability. Furthermore, this transdisciplinary approach has the potential to produce novel methodological and conceptual insights from the mutual exchange of perspectives with artistic research on nature and human-nature relationships. Time will be reserved for a panel discussion with the speakers, providing a platform for conceptual discussions on the potentials (e.g. for public outreach, science communication, and for informing the ecological research perspective) and challenges (e.g. time requirements, transdisciplinary communication, budget, logistics) for art-science collaborations in ecology. The panel discussion may be cast into a perspectives paper for Basic and Applied Ecology, to motivate a continued discussion in the GfÖ community. The session will include artistic visuals and auditory ‚soundscapes' within the speaker breaks. Actual art exhibitions and performances will emanate from the session into the conference program (submitted separately as lunchtime-sessions). With this session, we are building upon positive experiences with artistic interventions at the joint ecology conference in Metz 2022 and the GfÖ Annual Meeting in Leipzig, 2023, and pick up the thread from a session on art-science projects in Metz, 2022.

SC1
01

Connecting theater performance to science: on the creation of the play 'The Circus of the Trees – about the Future Role of Trees in the City'

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A splendid theater performance would allow the spectators to immerse themselves in the souls of the actors in front of them. The closeness of stage action and spectators can create an intense environment of emotions. We will present the lessons learned in the creation of a novel type of scientific theater performance to translate the research results of an urban ecology and urban forestry project into a play that can improve awareness of the challenges of solitary city trees and immerse spectators from all walk of life deep into the problems of climate change and biodiversity loss. We crafted the theater performance, an ensemble of different performances, such as drama, puppetry, singing, music, scientific contributions, and video clips. 'The Circus of Trees' is the first piece in the Karlsruhe trilogy that the Theater of the Anthropocene is currently developing together with the Institute for Technology Assessment and Systems Analysis (ITAS), a leading technology assessment (TA) and sustainability science institute within the research university Karlsruhe Institute of Technology. The theatre piece marks the beginning of a three-part series of ecological and techno-reflexive science theater at the interfaces of TA research, ecology, art, and society. The Theater of the Anthropocene (www.theaterdesanthropozaen.de) was founded in 2019 at the interface of art and science in the context of the Humboldt University of Berlin. Since then, this stage has played a variety of ecological topics with international actors, especially on stages in German-speaking countries. The Theater of the Anthropocene and KIT-ITAS have joined forces, harnessing the power of environmental and techno-reflective science theatre to bridge the gap between technological advancements and societal needs. Our collaboration aims to facilitate individual and collective learning processes about the intricate relationships between humans, nature, and our increasingly technological environment.

City soundscapes as an artistic way to understand links between people and nature

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Sound and soundscapes are an artistic medium through which people can emotionally engage with their natural and built environment. In our project 'CitySoundscapes' we focus on participatory processes, citizen science and art-science interfaces to share and evaluate people's thoughts and perceptions on soundscapes. In particular, we aim to increase the participation of city residents and communities in research and communication using creative science-art interfaces that provide an opportunity to monitor, reflect upon and evaluate soundscapes. To do so, we design participatory 'Sound Labs' and 'Sound Salons' with citizens to qualitatively evaluate the relationship between biodiversity and health via sound. In this talk, we will present on the different mobile and permanent formats that we utilize, as well as workshops and festivals that focus on sound currently in development. Specifically, as a case study, we will present the Dawn Chorus mobile platform and application in which we use citizen science to collect songbird biodiversity data from citizen science recordings as well as the restorative qualities of the soundscapes recorded. We will present an analysis of the different participatory formats, as well as a discussion on the novelty and benefits of sound and soundscapes as an engaging multisensory way to bridge ecology and art.

SC1
03

Ways of knowing – Potentials of a transdisciplinary integration of knowledge through art-science collaborations

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The ecological sciences seek to produce knowledge on the complexities of the natural world, on causes and consequences of biodiversity change, or on measures to restore or recover ecological functions for human well-being. In ecology, scientific objectivity and methodological standardisation are the means of making sense of the natural world. However, ecologists often struggle to see their findings take effect in real-life, and to contribute to the transformative societal change that is required to halt biodiversity loss. At the same time, artists often aim to intervene into the public discourse by developing new concepts or terminologies or by providing new perspectives for the target audiences. Topics of ecology and sustainability, of human-nature relations and coexistence in the Anthropocene become increasingly popular in contemporary art. Beyond the mere task of communicating these topics, artistic research deploys new modes of understanding the natural world and the human relationships with nature. Collaborations between ecology and the art thus not only promise to support transformative change in society, but also inform and advance the scientific approach to understand human-nature relations. This talk will present lessons learned of a series of art-science collaborations that were conducted in the context of a research project SLInBio, which explores interventions to increase valuation of urban insect biodiversity in the city of Frankfurt am Main. The project employs a conceptual framework for interventions to support behaviour change in urban everyday lifestiles, aiming for transformative change towards more insect friendly practices. From a transdisciplinary research perspective, I will discuss the potentials of art-science-collarborations in informing both the societal and the scientific discourse.

SC1
04

iDiv Artist Residency 2023. From the perspective of the safety net

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In spring 2023, the German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig and the Helmholtz Center for Environmental Research (UFZ) invited four transdisciplinary conceptual artists – Snow Paik, Steph Joyce, Nike Kühn, and Julie Hart – to delve deeper into their artistic exploration of biodiversity and ecological research during a three-month artist residency. The residency programme included workshops and excursions that promoted the transdisciplinary exchange between artists and scientists. The public exhibition 'From the Perspective of the Safety Net'' showcased the results of the collaborations between the residency artists and various iDiv scientists, contemplating human-nature-relationships in a range of ecological topics including biological invasions, species extinctions, experimental ecology and rewilding. With this talk, we want to share our experience in hosting and curating such a transdisciplinary project with the ecological community and hope to inspire similar initiatives in other places. For more information see our catalog documenting the residency and exhibition: https://doi.org/10.5281/zenodo.8335238

SC1
05

Szabadonbalaton: Methodology of a science–art collaboration around Lake Balaton, Hungary

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Szabadonbalaton (‘Free Balaton’), an ecological art initiative and cross-sectoral collaboration between artists and scientists, focuses on highlighting the ecological needs and risks of Lake Balaton, the largest lake in Central Eastern Europe. Advocating for adaptation to the lake's ecosystem rather than altering it to suit perceived human needs, Szabadonbalaton aims to establish research-based ecological art projects and science communication campaigns to foster public awareness and support decision-making for the long-term ecological, social, and economic sustainability of Lake Balaton. Since 2019, Szabadonbalaton has addressed key ecological challenges through various events and formats. Initiatives included raising awareness of the destruction of littoral vegetation and reed beds by showcasing a reed-designed sailing boat at the lake's regatta and participating in events like the Giro D’Italia cycling competition to spotlight issues surrounding infrastructural developments impacting wetlands and natural habitats. The initiative hosts various conceptual food and drink events in an alternative BAR format to deepen understanding of complex ecological issues for the broader audience. Szabadonbalaton also conceptualized and co-produced the cultural ecological program series BALATORIUM for the European Capital of Culture Veszprém-Balaton 2023, involving numerous institutions, artists, scientists, farmers, and experts, attracting thousands of visitors throughout 2022–2023. BALATORIUM encompassed professional talks, artist-in-residency programs, public art events, university courses, educational curriculum development, performative walks, and communication campaigns on key ecological themes, culminating in an ecological and cultural festival and art exhibition. Beyond regional challenges, Szabadonbalaton aims to explore interactions between fragile ecosystems and human landscape design and practices on an international scale, providing a toolkit for rethinking the balance between ecological needs and landscape shaping activities adaptable to other regions. The presentation offers insight into the concepts and formats of scientific and artistic collaborations based on the experiences of Szabadonbalaton.

On facilitating the imagination of regenerative futures

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All meaningful action is based on a convincing vision. Beginning with an exploration of the interconnectedness of sensory perception, cognition, and creativity, this presentation embarks on a journey to uncover the transformative potential of artistic methods in imagining diverse futures and catalysing proactive engagement. At the heart of the investigation is a thorough examination of the specific mechanisms of artistic approaches, their ability to challenge deeply rooted social norms and structures and to develop new ways of thinking. The presentation will be informed by a series of case studies that demonstrate the unique potential of artistic approaches to create sustainable visions and open new pathways towards a relational and regenerative paradigm.

Biodiversity and citizen science

Chairs: Birte Peters, Aletta Bonn

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Biodiversity change is happening at unprecedented rates, and reliable, large-scale data across space and time are needed for monitoring and to inform conservation and restoration planning and management. To address significant gaps in taxonomic and geographic coverage, biodiversity research has a long history of collaborating with volunteers in natural history societies and citizen science. In this session, we want to explore how innovative citizen science approaches, data integration of structured and opportunistic data, and the use of novel technologies as well as social media for citizen science recording can serve trend and attribution analysis as well as informing solutions for conservation and restoration in different ecosystems. In addition, we hope to gain insight into how citizen science could foster nature connectedness and ecological knowledge, skills, as well as social benefits and collective action to conserve biodiversity.

SC2
01

Counting butterflies – Are old-fashioned ways of recording data obsolete?

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Citizen Science projects aim to make data entry as easy as possible and often provide online data collection or data collection with an App. However, many participants cannot or do not want to use these possibilities and record their data the 'old-fashioned' way with pen on paper. We ask whether the quality of data recorded in the old-fashioned way (transect walkers record their data with pen on paper) is of the same, better or worse quality than data recorded 'online' (transect walkers enter their data via an online tool). We use the project 'Butterfly Monitoring Germany' as an example, where we identify three different types of volunteers: those who enter their data online, those who send their data to the project coordination via email in different formats and those who send their data to the project coordination via ordinary mail. We observed minor quantitative differences for transect walkers not entering their data online but significant qualitative differences. Transect walkers who send their data via email record significantly more data for some rare or difficult to determine species. This is essential to properly calculate these species' trends. In addition, the results of a questionnaire showed that old fashioned transect walkers did not use the online data entry because (i) data entry takes too long, (ii) is too cumbersome, (iii) they have bad or no internet connection or (iv) lack of technical capabilities. Accounting for different preferences of Citizen Scientists, different ways of data-submission should be made available (e.g. online, via app, or the old-fashioned way on paper). For the future, projects that collect large amounts of Citizen Science data should further develop low-threshold input data pipelines.

'Nature of the Year' organisms in Germany: Awarding does not make a flagship species

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Every year, species from various animal and plant groups are awarded the title 'Nature of the Year' in Germany and other countries. The annual nomination is intended not only to draw public attention to the species alone, but also to its habitat in order to communicate conservation messages. Nevertheless, it remains unclear whether this nomination truly enhances public awareness or translates into corresponding behavioural changes which has been shown for flagship species. Utilising citizen science occurrence records from iNaturalist and observation.org as well as Google Trends, we present a data-driven analysis of the association between public awareness and the various organisms awarded as 'Nature of the Year between 2018 and 2021. Of the 31 species studied, 17 showed a significant increase in either their occurrence records or Google search activity. Compared to previous years, citizen science records increased after nomination for the categories of insect, butterfly and amphibians or reptiles, while a higher Google search activity could be demonstrated for the categories animals, birds, trees and flowers. The results indicate, that awarding an insect, butterfly or amphibians or reptile of the year resonates with an already existing community of experts, who are specialized in specific groups, motivating them to upload observation records to citizen science platforms. Conversely, species nominated in the categories of higher hierarchy and familiarity, such as birds, animals, trees or flowers, receive more attention in the media but may not encourage people to contribute to iNaturalist or observation.org. To support the objectives of the 'Nature of the Year' campaign, it could be beneficial to resolve this dichotomy. Combining the communication efforts of the different organisations, such as a common date for the award announcements, or posters, flyers and videos, that feature the respective organisms together, could both draw the attention of the public to underrepresented groups and ensure more species-specific observations of the higher-level animal and plant categories.

SC2
03

Tracking the phenology of invasive hogweeds using citizen-science photo observations

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One crucial but understudied aspect in invasion ecology is the role of phenology in plant invasions. In the past, performing empirical phenological studies across large geographic scales has proven difficult. Photo observations provided by citizen-scientist (CS) have high potential to advance phenological research can help fill spatial, temporal, and taxonomic gaps in existing phenological data. Such observations can be used to study the role of phenology and its drivers in plant invasions. Among the non-native herbs found in Europe, several species of the genus *Heracleum* are considered invasive. These comprise Giant Hogweed (*H. mantegazzianum*) and Sosnowsky's hogweed (*H. sosnowskyi*), both of which are listed on the EU list of invasive alien species. These species reproduce exclusively via seeds and are monocarpic, i.e. they die after flowering and fruiting once, which makes having the right timing of flowering and fruiting vital for the species' success. Although there have been some local and regional studies on the phenology of *H. mantegazzianum*, large-scale studies comparing phenological patterns and drivers of different *Heracleum* species are still missing. Further, it remains unclear if similar cues drive the timing of phenological events between species, which is complicated by the species occupying different geographical niches in the invaded range. We investigate the phenology of several invasive *Heracleum* species based on >25,000 publicly available citizen-science photo observations between 2019 and 2023. To this end, we compared phenological patterns and drivers of these species. We show that citizen-science photos are highly suitable to track different phenological phases in invasive hogweeds. Additionally, we explore how phenological information of closely related species can be utilized to fill gaps in existing data. Our results show that similar cues drive the phenological cycle and reproduction of hogweeds, which can have important implications for management.

SC2
04

Butterfly assembly along space and season: The role of body size and colour

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Our understanding of the processes driving community assembly across taxa is key to predict biodiversity changes, but it is limited by the usually local nature of study systems in community ecology. Colour lightness and body size play a role in animal thermoregulation and contribute to driving variation in community assembly across space as described by the Thermal Melanism Hypothesis and Bergmann´s Rule. As seasonality replicates environmental variation along space, colour and body size may also contribute to determining optimal phenology. We use a functional approach based on colour and body size and hundreds of spatio-phenological high-resolution assemblages across Great Britain to analyse the role of environmental filtering and competitive processes driving butterfly assembly across space and their potential contribution to phenological patterns. Our functional diversity analyses suggested that different body regions of butterflies are subject to different ecological processes, whereby colour of the body was more strongly driven by environmental filtering and colour of the wings may mediate a possible role of competition. Large seasonal variation in both colour and body size stressed the relevance of phenology on insect diversity. Body size was large in early and late season, suggesting that Bergmann´s Rule may contribute to determining phenological patterns of butterflies. Seasonal variation in colour did not follow expectations from the Thermal Melanism Hypothesis, maybe due to butterflies' remarkable ability to fine-adjust radiation exposure. Our study shows that shifting towards using high-resolution community data along large spatial extents can greatly benefit our general understanding on animal community assembly.

SC2
05

Emerging technologies in citizen science — potential for monitoring, data integration and visibility

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Emerging technologies are increasingly employed in environmental citizen science projects, offering benefits and opportunities for entry level and specialist cittizen scientists. We show how technology can act as (i) a facilitator of current citizen science andmonitoring efforts, (ii) an enabler of new research opportunities, and (iii) a transformer of science, policy and public participation, but could also become (iv) an inhibitor of participation, equity and scientific rigour. Specifically we provide examples how citizen science — enhanced by emerging technologies — can foster large-scale monitoring, and complement agency monitoring, as well as unlock data types and aid conservation planning. We provide an outlook, how large data infrastructures, such as NFDI4Biodiversity and the Living Atlas - Nature Germany (https://land.gbif.de), can foster data mobilisation, curation and integration and visibility for citizen science data overall and what needs to happen to include data sources from novel technologies. We also discuss how technologies may easy entry hurdles for citizen science and enable learning, while noting limitations and challenges.

SC2
P1

How can citizen science support stream restoration? A scoping study

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Citizen science (CS) has great potential to advance ecological stream monitoring and restoration. In our scoping study, we aim to investigate how existing CS stream monitoring approaches can best be used and adapted to monitor and implement stream restoration projects together with engaged citizens as a part of inclusive governance. Effective freshwater monitoring and restoration requires not only scientific expertise and practical knowledge, but also the involvement of citizens and different stakeholders in freshwater protection measures. To foster knowledge and awareness about stream health and restoration benefits in local communities, we will establish CS monitoring activities at selected case studies of the EU freshwater restoration project MERLIN (https://project-merlin.eu/). These CS activities will be based on the German CS project FLOW (www.flow-projekt.de), which has mobilized and trained over 90 CS groups to assess the ecological status of small streams between 2021 and 2023. Results show that a large part of Germany's small streams are in poor ecological status. Many FLOW groups are now motivated to take action to improve the health of their streams. Our talk will outline current activities to mainstream the well-tested FLOW method to other European countries. We will also illustrate how CS stream monitoring data can be used as an evidence base to plan and implement low-threshold stream restoration measures (e.g. planting native plants along stream banks, introducing gravel or dead wood to improve flow and substrate diversity). Together with citizen scientists and various stakeholders, we will develop a hands-on guideline for freshwater practitioners on how to successfully establish CS stream monitoring and restoration activities. By involving different stakeholders and tracking the impacts of land use and restoration efforts on freshwater streams, the CS activities can support local decision-making for sustainable water management and stream protection.

SC2

P2

Detecting co-occurrences of an invasive local species through citizen science: the case of *Harmonia axyridis* in Argentina

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Species co-occurrences are frequent but difficult to detect, especially for small organisms like insects. Thus, citizen science emerges as a great tool, offering a broad spatial and temporal coverage to facilitate comprehensive observation of species co-occurrences. Our goal was to detect co-occurrences between the invasive Coccinellidae *Harmonia axyridis* and local biota (plants, fungi, and arthropods) in Argentina through citizen science records. We analysed three years of photographic records (December 2019 to December 2022) from a citizen science initiative aimed to map ladybirds distribution in Argentina (https://proyectovaquitas.com.ar). A total of 1538 photos were examined, of which 791 showed co-occurences between *Harmonia axyridis* and local biota (554 plants, 14 fungi and 223 arthropods records). We identified 13 classes, 45 orders, 99 families, 172 genera, and 148 species. Among the families, Aphididae stood out with 107 records. The most frequent co-occurrence between *H. axyridis* and plants was in association with the exotic genera *Rosa* sp. (70 records), followed by *Citrus* sp. (30); and between *H. axyridis* and arthropods, with the *Coccinellidae Cycloneda* (ten records) and *Hippodamia* (seven) genera. Co-occurrence with the fungi *Hesperomyces harmoniae* was detected 14 times. We also found co-occurrences and interactions not previously reported in Argentina. These include a new predator species for *Harmonia axyridis*: the hemipteran *Supputius cincticeps* (Asopinae) and the spiders *Trichonphila clavipes* (Nephilidae) and *Polybetes sp.* (Sparassidae). Furthermore, we observed an inter-specific copula event between *H. axyridis* and the coccinellid *Cycloneda sanguinea*, along with interspecific aggregations with two native species of coccinellids: *Adalia deficiens* and *C. sanguinea*. Citizen science shows promise in identifying co-occurrences with invasive insects, offering unique insights into the structure and dynamics of invaded communities.

Distribution of opportunistic plant observations on a local scale. Which habitats are sampled most?

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Identifying and recording geo-localized presences of plant species has become easy and popular, due to advances in AI image detection and social media apps like the German 'flora incognita', the Dutch 'ObsIdentify', or the German 'naturgucker'. The resulting crowd-sourced data is collected opportunistically by citizens and therefore differs from systematic field work sampling methods. However, it is available for research projects or even openly via the GBIF data platform, and the data volume and coverage of species and regions increases every year. Flora incognita data reproduces broad distribution patterns of systematic surveys, as well as phenological and some ecological properties. But little is known on the local distribution of observations, especially regarding the land use types surrounding the observations sampled by citizens or their distance to roads. I compared publicly available data of naturgucker (via GBIF portal) from Lower Saxony (Germany) to Open Street Map data, ATKIS land use classes, and publicly available data of land use as recorded by farmers for EU subsidy administration. Geostatistical analysis was carried out with the sf package in R. Preliminary results show that the number of observations declines sharply with increasing distance to roads or paths. In conclusion, using this data to gain insides on biodiversity on agricultural land is challenging, since species on borders are often very different from the adjacent arable fields and grasslands. Conversely, this data is uniquely suited to investigate species close to roads and paths, for example to compare biodiversity in plant communities along paths in agricultural landscapes in all of Germany. Only by classifying the plant locations according to their land-use type will it be possible to use the data for large-scale analyses on plant distributions. Possible applications are in detecting regions with well-managed field borders free from detrimental management practices.

Bridging the gap between knowledge and action: applying biodiversity knowledge in society, policy and economy

Short title: Bridging the gap between knowledge and action

Chairs: Arne Cierjacks, Leonie Fischer, Nico Beier

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Despite and numerous strategies and growing societal awareness, the loss of biodiversity continues unimpaired, underscoring the urgent need for taking real action for biodiversity in society, policy and economy. However, there often remains a clear gap between biodiversity knowledge and its transfer into practice, as this commonly exceeds the scope of scientific endeavors. This session aims at showcasing and discussing successful approaches of biodiversity management and governance. Mainstreaming biodiversity across different economic and societal sectors requires efficient conservation and restoration measures along with robust stakeholder involvement at various levels. In particular, scientists should interact with authorities, land users, corporations, and media for building strong networks based on scientific expertise and societal consensus. To address a wide range of biodiversity aspects, diverging environments such as natural, rural, and urban-industrial habitats should be taken into account. The compilation of best practice examples for mainstreaming biodiversity within this session may demonstrate how scientific knowledge can contribute to safeguard biodiversity and species conservation.

Is that normal? How to encourage farmers to stay calm when perennial wild flower strips go wild

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Perennial flower strips have become a popular agri-environmental measure in recent years. For their implementation, a part of a cropland field is taken out of management, wildflower mixes are sown and besides mowing parts of this flower strips once a year or less, the area remains untouched for five years. By this, perennial wildflower strips support many threatened species with habitat, shelter and food throughout the year. So much for the theory. But not every flower strip develops successfully. Dominant herbs, like thistles, and grasses can be perceived as problematic over time. Identifying problematic developments is non-trivial since the appearance of flower strips is highly variable. Among other things, it is this partial unpredictability in development that often makes it difficult for farmers to leave their flower strips untouched, except with minimal maintenance. Questions raise for applying specific herbicides or to plough and reseed when flower strip appearance is anticipated to be problematic. Together with biodiversity advisors from landscape conservation organisations, we develop a guideline for success control of perennial flower strips by farmers. In contrast to implementation checks to determine whether measures that have been invoiced have been implemented, this check serves the farmer himself and is not linked to sanctions in the event of failure. The aim of the success control is to enable the farmer to learn to assess the ecological potential of his flower strips and to deal more calmly with the less controllable plant growth compared to crops. The most important indicators for success that we used in the guideline are related to plant species richness, flower richness, and diversity and structural diversity. Here we present recent findings from (i) a survey on experience reports from biodiversity advisors on the implementation and maintenance of perennial flower strips, (ii) a collection of flower strip images for visualisation of variability, and (iii) a test of the guideline by farmers.

Tackling biodiversity decline within the agricultural landscape – Development of future pathways based on an expert-based scenario analysis in Germany

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Tackling the decline of biodiversity, especially in the agricultural landscape, is a major societal challenge. Broad scientific evidence exists on the impact of single drivers on biodiversity such as intensification of agriculture. However, the transition to halt biodiversity decline requires a systemic analysis and an understanding of the interactions between individual drivers, which has hardly been analysed. Hence, we aim to understand how different socio-economic indirect drivers of biodiversity in the German agricultural landscape interact and what are plausible scenarios and pathways that most likely lead to an improve of biodiversity in the agricultural landscape in Germany and to provide recommendations for political decision makers. We applied the expert-based Cross-Impact-Balance methodology to the German agri-food system (target year 2030). Within this system, we defined seven descriptors that represent the most relevant indirect drivers of biodiversity (here, we focus on species richness) in German agricultural and open landscapes. Within three workshops with different expert groups, we assessed all mutual interactions between these descriptors. Our analysis revealed complex interactions between the descriptors. Seven scenarios leading to enhancement of biodiversity in the German agricultural landscape were identified and were aggregated to four major future pathways, where we found that preserving biodiversity requires not only changes in individual indirect drivers such as reduction of land use pressures but rather a major system transformation. This change will be strongly dependent upon the evolution of social values, European and national nature conservation policies and agricultural policies, innovations in plant and protein production as well as global commodity markets.

From experience to action: the role of knowledge and nature-relatedness on pro-conservation behaviour intentions in adolescents and adults

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Addressing the global biodiversity crisis requires engagement from current and future generations, but the phenomena of generational amnesia and extinction of experience pose threats to conservation. Understanding how knowledge and nature exposure influence conservation behaviour is crucial, with a notable gap in intergenerational empirical research. In two German online surveys, we explored differences between adolescents (15–18 years) and adults (>18 years) in nature exposure (frequency of greenspace visits), knowledge (familiarity with species and identification skills), nature-relatedness, and pro-conservation intentions. Both generations reported similar species familiarity and nature exposure. Yet adults exhibited higher identification skills, nature-relatedness, and pro-conservation intentions. Generally, the identification skills decreased from plants to birds to butterflies. Visit frequency significantly influenced nature-relatedness and subsequently, pro-conservation intentions in both groups, while knowledge was not significantly related to pro-conservation behaviour intentions but moderately to nature-relatedness. These findings highlight the importance of counteracting generational amnesia by improving species knowledge among adolescents. Moreover, our results underscore the significance of nature exposure for fostering a strong connection with nature, irrespective of age. Urban areas can play a crucial role in engaging people in pro-conservation actions through integrated approaches that provide access to natural areas, opportunities to connect with nature and environmental education.

SC3
04

Can closer-to-nature forest management help maintain biodiversity and ecosystem services in European forests?

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Recognizing the need to halt biodiversity loss and adapt European forests to climate change, the new European Forest Strategy aims to promote "Closer-to-nature" forest management (CNFM). However, the implementation of this approach across Europe (e.g. through common incentives or certification schemes) faces substantial challenges due to the variability of forest types and forest management systems, where both the benefits and trade-offs of CNFM vary with environmental and socio-economic context. Here, we aim to synthesize the current knowledge about CNFM in Central Europe, including important context dependencies and knowledge gaps, and to identify good practices and barriers to the implementation of CNFM. We used a two-stage broadband Delphi approach (including a questionnaire and a workshop) with experts in forest ecology and management in the region to find a consensus about the impacts of specific CNFM measures (as proposed by the European Commission) on biodiversity and ecosystem services. We found a high level of agreement that CNFM measures tend to support biodiversity and help to maintain ecosystem services under climate change, especially if the landscape context is considered in forest management. The main tradeoff identified is between wood production on one side and other ecosystem services and biodiversity on the other, as wood production could be reduced by some of the proposed CNFM measures, especially setting areas aside. Incentives, such as payments for ecosystem services, may therefore be needed for forest owners whose income is currently strongly derived from wood production. Other barriers to implementing CNFM include sometimes conflicting regulations and beliefs. For example, prescribed sanitary logging and a negative perception of deadwood often limit deadwood retention. Nonetheless, we identified numerous examples of successful implementation of CNFM in Central Europe with clear benefits for biodiversity and ecosystem service provision.

SC3
05

Brazilian dry forests: from science to conservation actions

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Biodiversity conservation in tropical countries imposes scientific, social and political challenges. In order to design effective conservation strategies, one needs up to date information on the distribution of biodiversity and on the anthropogenic vectors that degrade natural ecosystems. Furthermore, we need to implement science-based political tools to promote real action. In this talk, I will focus on the Caatinga, a South American seasonally dry tropical forest which is one of the six terrestrial “biomes” legally recognized by the Brazilian government. I will discuss how science advanced in this last decades allowing us to understand (i) how diversity of amphibians, reptiles, birds, mammals and ants are distributed in space, (ii) how the landscape has been affected by habitat loss and fragmentation, and (iii) how the remaining fragments have been affected by chronic anthropogenic disturbances. Furthermore, I will show how such knowledge was used (iv) determine priority areas for conservation, by the Brazilian Ministry of Environment (MMA), and (v) to determine priority areas for restoration based on threatened plants and ecosystem resilience. Finally, we will discuss (vi) the importance of scientists to participate in the political arena to push environmental policies and promote human welfare.

Implementing a bottom-up stepping stone program in Austria

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Austria is one of the most heavily forested countries in Central Europe, with 48% of its land (4.0 million ha) covered by forests, of which 84% (3.4 million ha) are managed. The country hosts a rich biodiversity, with around 68,000 species, including 2,900 plant species and 54,000 animal species. However, climate change and habitat fragmentation threaten this biodiversity. Enhancing habitat amount and connectivity to allow species migration is crucial for combating both of these threats. To address this, a national stepping stone program aimed at improving forest connectivity and conserving forest biodiversity was initiated. Around 750 stepping stones ranging from 0.5 to 25 ha in size are to be excluded from regular forest management. Priority is given to areas with significant amount of deadwood, habitat trees, rare species, and special sites. Since 82% of Austrian forests are privately owned, with 54% being small-scale properties of less than 200 ha close collaboration with forest owners is essential. The program involves stakeholders from forestry, nature conservation, research, and government, ensuring transparent implementation and support through funding schemes. A GIS-based approach supports site selection featuring four indicators: Protect Value, Connect Value, Species Value, and Habitat Value. Evaluation follows a systematic method, gathering insights and identifying strengths and weaknesses. A steering group oversees the program, while a scientific board advises on research design, data collection, and analysis. Data collection includes both habitat and biodiversity surveys. Through this collaboration and systematic approach, the program aims to safeguard biodiversity-rich forest ecosystems and ensure their long-term conservation.

SC3

P1

The TUM Green Office Weihenstephan presents its work transforming the campus, educating, and building a community, concentrating on the results of the first 'Biodiversity week Weihenstephan'

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The TUM Green Office Weihenstephan is a completely student led organisation and serves as a central contact point for sustainability on campus. We help realise projects and events, that educate about current issues and solutions, transform the campus and connect students, professors and employees who are working toward the same goal. This spring we oraganised the first 'Biodiversity Week Weihenstephan', where TUM students, employees and citizens of Freising had the opportunity to learn about biodiversity trhough excursions, talks and workshops. Our goal was to bring people closer to biodiversity and show how science can look firsthand. Our further projects include: (i) TUM Bee Paradise, together with the research groups Plant-Insect Interaction, Biodiversity of Plants and Urban Productive Ecosystems, we try to upkeep the local wildbee population on campus and educate students about the problems of the degrading pollinator populations as well as about action, that can be taken; (ii) waste management: Promoting waste separation; (iii) raised beds on campus: building a community around urban gardening and planning pollinator friendly beds; (iv) swap events: clothes, books and plants swap; (v) sustainable dinner: raising awareness about food waste and the climate impact of food we consume; and (vi) sustainability network.

Residual areas in the intensive agricultural landscape – a chance for biodiversity?

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The aim of the research project was to find out more about the importance of residual areas in the intensive agricultural landscape for biodiversity and the biotope network. The subject of the study was 15 power mast base areas in Central Saxony. Analyses of the current status were carried out using species and biotope mapping as well as GIS analyses. The calculation of the connectivity index according to Jaeger (2000) was carried out using the Zonal Metrics Toolbox. The results showed an increase in the index when taking into account the mast base areas, and thus a higher connectivity, for five different umbrella species. These included badger, stoat, tree shrew, common whitethroat and copper-coloured sandpiper. However, a significant difference could not be clearly confirmed. The calculation of optimal regional connections provided a visual result. The most cost-effective connection network was analysed for all five species with and without the use of the masts. In three out of 15 landscape sections around the masts, more cost-effective pathways were found for all species except the common sandpiper using the masts as stepping stones. The investigations provided evidence of the positive ecological value of mast bases in the agricultural landscape.

Soil (SL)

Illuminating the black box of soil food webs across ecosystems, scales, and approaches

Short title: Solid food webs

Chairs: Olga Ferlian, Anton Potapov, Andrei Zuev

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Soils food webs process most of the organic matter and channel most of the energy in terrestrial ecosystems, supporting numerous functions and services vital to our society. Soil food webs encompass tens of thousands of morphologically and functionally diverse species, living in a highly heterogeneous environment, small-sized and cryptic. Thus, the study of the 'black box' underneath our feet is especially difficult compared to other habitats. This leads to a limited knowledge on feeding interactions in soil and, consequently, the structure of soil food webs. In this session, we try to summarize recent advances in this field by answering the following questions: How to predict who feeds on whom in soil food webs? What are the basal resources in soil food webs and how do they differ across ecosystems? How are soil food webs structured by land-use and other (global change) drivers? How do soil food webs regulate soil functioning? To answer these questions, this session will host contributions reporting novel knowledge on the trophic interactions between resources and consumers, predators and prey, and across entire food webs in soil. Our focus topic is to understand how soil food webs vary in space and time across ecosystems and scales. We welcome a wide range of approaches, such as molecular and isotopic tools, energy flux, food-web modelling, and functional traits in laboratory and field experiments as well as in observational studies. We look at the entire spectrum of soil organisms, including microorganisms, animals, and plants, from single species to soil communities. We would like to show how we can build on current findings to advance the field in the future, and how we can apply the knowledge to understand the consequences of global change.

SL1
01

Sustainable land use strengthens microbial and herbivore controls in soil food webs in current and future climates

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Climate change and land-use intensification are threatening soil communities and ecosystem functions. Understanding the combined effects of climate change and land use is crucial for predicting future impacts on soil biodiversity and ecosystem functioning in agroecosystems. Here, we used a field experiment to quantify the combined effects of climate change (warming and altered precipitation patterns) and land use (agricultural type and management intensity) on soil food webs across nematodes, micro-, and macroarthropods. We focused on assessing the functioning of soil food webs by investigating changes in energy flux to consumers in the main trophic groups: decomposers, microbivores, herbivores, and predators. While the total energy flux and detritivory, herbivory and predation in the soil food web remained unchanged across treatments, low-intensity land use led to higher microbivory and microbial control under future-climate conditions (i.e. warming and summer drought). At the same time, microbial and herbivore control were higher under low-intensity land use in croplands and grasslands. Overall, our results underscore the potential benefits of less intensive, more sustainable management practices for soil food-web functioning under current and future climate scenarios.

SL1

02

Decreasing trophic transfer efficiency in soil food webs along an altitudinal gradient

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Soil food webs capture the feeding relationships between soil organisms, which are key to ecosystem functioning such as energy flow and material cycling. Recent studies have revealed the network structure and energetic dynamics of soil food webs in certain ecosystems, but how they vary along environmental gradients are rarely investigated. To fill this gap, we sampled soil fauna along an elevation gradient from 1350 m to 2750 m in the Ailao Mountains. In order to calculate the energy flux of soil food webs, we used individual body mass to estimate the metabolism of different trophic guilds and applied energy flow models to determine the energy flux within the soil food web. Our results shows that the total energy fluxes of soil animal communities decrease with increasing altitude, but the energy transfer efficiency between trophic levels increases with altitude. These patterns are primarily due to the reduction in the biomass of large decomposers, particularly earthworms, at high altitude, which are the major contributor to community energy flux. Our study reveals altitudinal patterns of energetic processes of soil food webs, which aligns with the metabolic theory of ecology.

SL1
03

Energetic and functional development of soil micro- and macro-food webs along a secondary succession

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As the ecosystem develops, aboveground biomass and belowground organic matter accumulates, while energy turnover goes down. Evidence supporting this general ecological pattern come mainly from vegetation, while over 90% of energy is channelled to soil food webs. We have very little empirical data on how soil food web biomass, energy fluxes and related functioning develop along ecosystem succession. To fill this gap, we assessed changes in soil micro- and macro-food webs along a secondary subalpine succession in southwestern China including grassland, shrubland, secondary and primary forests. Our results showed that animal biomass-to-energy flux ratio in soil food webs increases towards late successional stages, confirming theoretical expectations of lower energy turnover rates in mature ecosystems. Soil food web functioning changed from a strong herbivory-based channel 'green state' in early successional stages to a more detritivory-based channel in late successional stages 'brown state'. Macro-food webs had higher bacterial/fungal flux ratios, while micro food webs had higher trophic hierarchy in the late successional stage. Energetic and functional changes were closely linked to the litter quantity and quality, microbial biomass, and animal diversity. Our study pushes forward general ecological theory on functional development of soils highlighting the link among environmental changes, community succession and ecosystem functioning, which can improve efforts on restoration and understanding of ecosystems assembly.

SL1
04

Soil food web states across successional stages, climates, and land-use types

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Soil biogeochemical cycles are regulated by soil food webs. However, variation of soil food web structure and functioning across major environmental gradients remains unknown, hampering generalisations of links between soil fauna and biogeochemistry. Here, I summarise our several recent projects applying energy flux approach to explore successional development of soil animal food webs and responses of their structure and functioning to climate type and land use. Aligned with the classical ecosystem development theory, we show that along a secondary succession in China, soil food webs develop from fast turnover systems with high herbivory and predation ('green' state) to low turnover systems based on detritus consumption ('brown' state). We further found a similar trend while comparing energy distribution across micro-, meso- and macrofauna in temperate (Germany, Russia) and tropical forest soil food webs (Vietnam, Indonesia). We showed that tropical soil food webs have high energy flux, predation rates and herbivory, while temperate food webs have high bacterivory and litter feeding. Finally, comparison of forests versus agricultural systems in Indonesia and Argentina showed that land use does not result in reduction of energy flux in soil food webs, but with a strong restructuring of energy pathways depending on particular land-use type. In intensively managed systems a drop in predation and an increase in basal consumption is observed, mainly explained by earthworm dominance. Our studies show how the functioning of soil animal food webs changes across ecosystem stages and types, summarising functional roles animals play in different biomes.

SL1

05

Niche dimensions in soil oribatid mite community assembly under native and introduced tree species

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Forest soils are a critical component of terrestrial ecosystems and host a large number of animal decomposer species. One diverse and abundant decomposer taxon is oribatid mites (Acari: Oribatida), whose species composition varies with forest type and tree species composition. We used functional traits that indicate different niche dimensions, to infer assembly processes of oribatid mite communities in monocultures and mixed forests of native and introduced tree species. We found that coexisting species differed more in the resource-related niche dimension, i.e. reproductive mode and trophic guild, than in the morphological dimension, e.g. body length and width, sclerotization and concealability. These results suggest that both filtering and partitioning processes structure oribatid mite communities. In native European beech forests, but not in non-native Douglas fir forests, oribatid mites were mainly structured by filtering processes acting via traits related both to environmental tolerance and to resources. Furthermore, oribatid mite trait diversity, but not phylogenetic diversity, differed significantly between monocultures and mixed forests, demonstrating that multidimensional diversity indices provide additional information on soil biodiversity. Overall, the study provides evidence that traits representing different niche dimensions need to be considered for understanding assembly processes in soil animal communities and thereby soil biodiversity.

SL1
06

Broader trophic niches of soil animals under land use and in warmer climate

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Soil animals are remarkably diverse and regulate a wide range of ecosystem functions via their feeding activities. Unravelling factors affecting the trophic diversity of soil animals is essential for comprehending soil functioning and its stability. However, information on how trophic diversity of soil animals vary across functional groups and major environmental gradients is lacking. Here, we approach this question using stable isotope composition ($^{13}C/^{12}C$ and $^{15}N/^{14}N$ ratios) of 28 high-rank taxa of soil animals representing herbivores, microbivores, detritivores, predators and omnivores from 343 sites across temperate and tropical ecosystems and different land-use types. We found that across functional groups, microbivores and omnivores have higher trophic diversity, i.e. larger isotopic niche area, than detritivores and predators. Further, trophic diversity of functional groups was on average 36% larger in agricultural ecosystems than in woodlands and was 47% larger in tropical than in temperate regions. The higher trophic diversity was related to both exploration of more diverse basal resources (variation in $^{13}C/^{12}C$ ratios) and longer trophic chains (variation in $^{15}N/^{14}N$ ratios). Annual precipitation and temperature indirectly increased trophic diversity of functional groups via increasing trophic (isotopic) dissimilarity both within and among soil taxa. The results provide evidence that trophic niche diversity is lower in functional groups that couple multiple energy channels (i.e. detritivores feeding on leaf litter mixed with microbes or predators feeding on various prey). The high trophic diversity in agricultural systems and in the tropics may be associated with resource limitation forcing soil animals to exploit a wider range of resources and alternative prey. Overall, our first comprehensive assessment of soil animal trophic diversity provides insight into how soil animals and entire food webs respond to environmental changes, with significant implications for ecosystem functioning, resilience and the impacts of human land use.

SL1

07

Introducing the circum-arctic present and future ecology of the soil food web group

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Arctic soil systems are exceptional, and have received much recent attention, due to their enormous stocks of carbon and nitrogen, which in a warming climate could have long term effects on the earth system. Despite tremendous progress in quantifying future changes in arctic soils, large uncertainties remain, which may be partly explained by soil food web dynamics. Unlike most ecosystems at lower latitudes, most plant biomass resides belowground in large parts of the Arctic, making belowground consumers disproportionately important. Strong seasonal variations and the presence of permafrost imply that freezing and thawing dynamics severely constrain the activity and habitats of soil taxa. Further, soil food webs structures in the Arctic reflect not only climatic constraints but also glaciation history and associated biogeographical patterns. Despite commendable research efforts at a few isolated sites, even the coarse structure of arctic soil food webs remains unknown across immense areas: if soil food webs are often presented as a black box, then soil food webs in the Arctic should be seen as a black box in a coal mine. Illuminating this black box by understanding the current functioning of arctic soil food webs is a required step to predict their future behaviour and impacts on biogeochemical cycles in this important region. However, the different fields of research that together form the soil food web, from molecular microbial ecologists to ecosystem ecologists, from permafrost specialists to plant and soil fauna ecologists, need to work together more tightly to address this pressing issue. We gathered such experts together as the Circum-Arctic Present and Future Ecology of the Soil Food Web group in Tromsø in May 2024, aiming to draft an agenda for the future of arctic soil food web research. Here we showcase some of the ideas that emerged from this collaborative approach.

SL1
08

High litter and root- derived resources quality enhance plant energy channelling by earthworms

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Plant litter and root-derived resources constitute the two main resources in soil food web. Due to their high biomass, earthworms play a central role in soil food web, influencing nutrient cycling and belowground energy flux. Yet, the influence of litter- and root-derived resources quality on earthworm nutrition, and consequently on soil food web dynamics, has remained largely underexplored. Here, we combined bulk and compound-specific stable isotope analysis of amino acids to investigate the dietary contribution of litter and root resources of differing quality to earthworm species of different ecological groups. Our findings show that earthworms acquired most essential amino acids from bacterial (~60%) and plant (~30%) resources, with the latter increasing in importance with higher resources quality. The high bacterial contribution to earthworms corresponds to the dominance of bacteria in the experimental soil, suggesting that bacteria served as important intermediate link in the acquisition of food resources. Bacterial contributions were notably higher in the soil-feeding earthworm species than in the litter-feeding earthworm species. This suggests that the spatial and dietary niche is linked, likely due to more pronounced ingestion of soil by soil-feeding earthworms. Overall, our study indicates that a major group of soil macro-detritivores, earthworms, play a key functional role in linking brown and green energy, i.e. litter- and root-derived resources, with these resources being assimilated mainly via the bacteria energy channel. Further, it underscores the important role of plant-based resources quality in shaping the trophic niches of detritivores, thereby influencing the overall structure of soil food webs.

SL1
09

Macro-decomposers can rapidly transfer litter carbon and nitrogen into soil mineral-associated organic matter: direct evidence from a novel microcosm experiment of tropical forest

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Recent frameworks proposed that dividing soil organic matter (SOM) into particulate and mineral-associated organic matter (POM vs. MAOM) is a promising method to understand SOM functions. Macrofauna (i.e. earthworms and millipedes) in tropical forests constitute the majority of the total soil animal biomass and substantially contribute to soil food-web functioning. However, how the two co-existing macrofaunae directly affect the formation of POM and MAOM via the litter decomposition process remains unclear. Here, we set up a microcosm experiment with four treatments: earthworm and litter addition, millipedes and litter addition, earthworm-millipede-litter addition (E+M), and control (only litter addition) in five replicates. To test our idea, we sterilized all microbes in the soil and litter before our experiment. After 42 days of incubation, litter mass, C and N significantly reduced especially under the E+M treatments. The life activities of soil macrofauna can shape the structure of soil micro-food webs, and macrofaunal activities (e.g. burrowing, feeding, and excretion) can spread microorganisms and nematode communities in their habitat to rebuild the micro-food web in the sterilized microcosm. The feeding and digestion of litter and SOM by macrofauna promoted the enrichment of soil nutrients, and the processes significantly increased the microbial biomass and nematode abundances and promoted the greenhouse gas emission of the whole microcosm. It is worth noting that the presence of earthworms promoted the emission of N_2O, but millipedes promoted the emission of CH_4. Notably, all macrofauna additional treatments increased the organic carbon (OC) and total nitrogen (TN) content in MAOM fractions and decreased the C^{13} abundance. The distribution of OC and TN in two fractions in all soil depths can be explained by the physicochemical and microbial processes. For instance, changes in the OC distribution in the 0–5 cm soil layer are probably caused by the decrease in soil pH and the increase in arbuscular mycorrhizal fungi. Our results indicated that the coexistence of earthworms and millipedes could accelerate the litter decomposition process and store more C in the MAOM fractions. This novel finding helps to unlock complex SOM systems as carbon sinks in tropical forests under global climate changes.

O10

Widespread occurrence of plant cell wall degrading enzymes (PCWDEs) in Oribatida: Revisiting their role in soil food webs

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Oribatida are among the most abundant soil microarthropods, playing a crucial role in decomposing plant material. Traditionally, this degradation ability has been attributed solely to their gut and external microorganisms. However, emerging evidence suggests that Oribatida may themselves encode Plant Cell Wall Degrading Enzymes (PCWDEs). Here, we investigated 53 oribatid mite genomes for 29 different PCWDEs. Using 55 protein sequences from 27 organisms (12 bacterial and 15 fungal) as seed sequences, we identified numerous orthologs potentially encoding PCWDEs, suggesting that oribatid mites encode enzymes capable of degrading plant cell walls themselves. In addition to this, the presence of PCWDEs aligns with their feeding habits, i.e. primary/secondary decomposers show a higher number of PCWDEs than their predatory counterparts. Phylogenetic analysis suggests that PCWDEs were acquired early in the natural history of Oribatida, likely through frequent horizontal gene transfer from bacteria and fungi. Apparently, some PCWDEs were gradually lost in derived taxa due to subsequent radiations. Altogether, the occurrence of PCWDEs in oribatid mites suggests a greater impact on plant material degradation than previously understood, reshaping our view of their role in soil food webs and nutrient cycling.

SL1
O11

Root–nematode economics space drives the carbon cycle

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An important aim of ecology is to understand the multidimensional ecological strategies of species and their linkages with ecosystem functions. The root economics space describes two key dimensions of plant ecological strategies belowground, but little is known about the correlation between these dimensions and soil nematode ecological strategies, as well as how the coordination of plant and nematode traits shapes the carbon cycle. Here we identify the leading dimensions of nematode ecological strategies and their coordinated relationships with root economics space based on a large trait collection spanning three vegetation types in six regions of China. The results confirm the trade-offs underlying a two-dimensional nematode economics space. One major dimension is defined as the reproduction dimension, representing fecundity strategies along a high–low continuum and aligning with the root collaboration dimension. The other dimension reflects the nematode economics spectrum, which balances body construction costs against growth potential, coordinating with the root conservation dimension. Furthermore, both dimensions of the root–nematode economics space contribute differently to trait dimensions involved in the soil carbon cycle. The collaboration–reproduction dimension is primarily related to carbon fluxes, while the conservation–conservation dimension correlates with carbon pools. The integrated root and nematode economics space provides a more holistic understanding of belowground responses to environmental change and the multidimensional influences on the carbon cycle.

Do nitrogen- or phosphorus-rich nutrient patches in soil attract specific ectomycorrhizal communities?

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Ectomycorrhizal (ECM) fungi play a crucial role in the biogeochemical cycles of boreal and temperate ecosystems. Also, ECM fungi are essential for tree nutrient uptake, as their extraradical mycelium extends into the soil, effectively expanding the mycorrhizosphere and enhancing the volume of soil exploited by tree roots. Different ECM fungal groups exhibit varying abilities to access soil nutrients. However, we do not know whether hot spots of distinct mineral or organic nutrients result in the accumulation of distinct fungal communities or whether they reflect the fungal composition of the surrounding soil environment. In our study, we tested the influence of organic or mineral N- or P-rich nutrient patches on the assembly of fungal communities in three regions, characterized by differences in soil and climatic conditions. We supplemented sand/hydrogel-filled mesh bags, accessible to fungal hyphae but not to roots, with organic nitrogen (N_{org}), inorganic nitrogen (N_i), organic phosphorus (P_{org}), inorganic phosphorus (P_i) or no addition. We collected the mesh bags and soil samples after 6 and 18 months of exposure. As part of the Biodiversity Exploratories project, our experiment was established in the VIP plots in three regions: Schorfheide-Chorin (SCH), Hainich-Dün (HAI) and Schwäbische Alb (ALB) in May 2021. We measured the pH, soil moisture, carbon (C), nitrogen (N), phosphorus (P), available P, hyphae colonization, enzyme activities of the C, N and P cycle, and fungal communities by DNA barcoding. Our findings revealed that pH, soil moisture, soil C, and N concentrations exhibited significant differences among three regions and hardly any significant variations between two harvests, whereas those variables showed significant differences between harvest time points and different types of nutrient patches. We observed significantly higher activities of C- and N-cycle enzymes in organic N patches compared to other treatments across different regions at both harvests. In contrast, the activities of P-cycle enzymes remained relatively consistent across all treatments. Soil and nutrient patch chemistry and potential enzyme activities will be linked with shifts in fungal community composition and with functional traits of specific ECM taxa.

SL1
P2

Influence of increasing proportion of Douglas fir and silver fir in mixed stands with beech on oribatid mite communities

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Temperate forests are challenged by the consequences of climate change and associated drought events. Introducing drought resistant tree species like Douglas fir in ecological friendly practices in mixed stands represent promising future perspectives. However, the consequences of planting non-native Douglas fir on soil fauna are sparsely investigated, especially regarding different proportions of Douglas fir in beech stands. As soil animals such as oribatid mites play an important role in forest soils, understanding their response to planting non-native tree species is needed. We investigated the abundance, distribution and species richness of oribatid mite communities in mixed beech – conifer stands with different proportions of non-native Douglas fir and native silver fir. The results indicate decreased abundance and species richness with increasing proportion for both conifer species. Consequently, the response of soil animal communities to the plantation of mixed forests depends on the proportions of tree species in mixed stands and this needs to be considered in future forest management.

SL1

P3

Higher trophic levels and reduced direct plant resource uptake for microbes in response to lower litter quality

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Saprotrophic microorganisms are in the central of soil food web and global carbon cycling, however, understanding their trophic niches is lacking due to their small size and technical reasons. Here, by combining bulk and amino acid stable isotope analyses in a microcosm experiment, we for the first time quantify the trophic level and resources usage of microbes under different litter qualities. We find that the trophic level of microbes was above two and decreased with litter qualities. AAs -TP related with $\delta^{15}N$ but not $\Delta^{15}N$, while related with $\Delta^{13}C$ but not $\delta^{13}C$. Besides, microbes grow on higher quality litter are more directly get essential amino acids from plant. Unlike commonly assumed, the microbial CSIA patterns of carbon in individual amino acids (fingerprinting) varies with litter types, indicating more information were needed for future studies using fingerprinting method.

Influence of trees on earthworm abundance and soil properties in wood pastures of Southern Transylvania, Romania

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Earthworms, attributed as ecosystem engineers, contribute to various soil ecological processes and functions. Wood pastures, one of the traditional agroforestry systems, exhibit complex interplays among pasturelands, mature trees, and animal presence influencing soil dynamics and plant biodiversity. The focal point of this research is to investigate the intricate relationships between tree canopy cover of oak-based wood pastures, proximity to oak (*Quercus robur*) stems with earthworm abundance, and various soil properties in southern Transylvania, Romania. The study methodology involved sampling of soils and earthworms across 30 oak-based wood pastures at three different elevations. Within each wood pasture, the sampling was carried out along a transect on the southern slope at four distances from a tree stem: 1 m, 3 m (under tree canopy), 7 m (at the edge), and 24 m (control plot). Earthworm species were collected along these transects using hand-sorting techniques from the top 25 cm of soil in blocks. Additionally, 120 soil pits were dug to evaluate soil characteristics, with samples collected from three depths: 0–5 cm, 5–25 cm, and 25–40 cm. Soil properties such as pH, texture, gravimetric water content, organic matter content and bulk density were analysed. The analysis revealed distinct patterns in both earthworm abundance and soil properties across the sampled distances. The highest earthworm abundance was observed under the canopy (at 1 m and 3 m from the tree stem), which gradually declined towards the canopy edge. Sites under the tree canopy and in proximity to the stem exhibited higher soil organic matter content compared to those at greater distances. Soil pH displayed no significant gradients, consistently showing slightly acidic conditions across all sites. Soil moisture levels were notably higher under the canopy and closer to the tree roots. These findings stress the multidimensional impacts of tree canopy cover and stem proximity on soil ecosystems of wood pastures, enhancing the necessity of considering spatial dynamics in agroforestry management practices. Such insights could be crucial for nurturing sustainable land utilization and biodiversity conservation in wood pasture systems.

SL1

P5

Shared community history strengthens plant diversity effects on belowground multitrophic functioning

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The relationship of plant diversity and several ecosystem functions strengthens over time. This suggests that the restructuring of biotic interactions in the process of a community's assembly and the associated changes in function differ between species-rich and species-poor communities. An important component of these changes is the feedback between plant and soil community history. In this study, we examined the interactive effects of plant richness and community history on the trophic functions of the soil fauna community. We hypothesized that experimental removal of either soil or plant community history would diminish the positive effects of plant richness on the multitrophic functions of the soil food web, compared to mature communities. We tested this hypothesis in a long-term grassland biodiversity experiment by comparing plots across three treatments (without plant history, without plant and soil history, controls with ca. 20 years of plot-specific community history). We found that the relationship between plant richness and belowground multitrophic functionality is indeed stronger in communities with shared plant and soil community history. Our findings indicate that anthropogenic disturbance can impact the functioning of the soil community through the loss of plant species but also by preventing feedbacks that develop in the process of community assembly.

SL1

P6

How do different organic and mineral fertilizers affect abundance of Collembola?

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The ability of agricultural systems to provide food, feed, fuel, and fiber is heavily dependent on soil fertility, which, given worldwide soil degradation trends, is critical to maintain and restore. Many soil-dwelling organisms, including insects, play important roles in humus production and nutrient cycling. Despite their significance, currently little is known which of the many organic or mineral fertilizing methods may assist soil-dwelling insects and their functions. Our research focuses on springtails (Collembola), which are functionally significant groups of soil fauna. It employs two large static field trials, located at Wiesengut (organic farm) and Klein-Altendorf (managed conventionally), both situated in North Rhine-Westphalia, that have been running for three years to investigate the response of soil organisms to a variety of organic and mineral fertilizers. Specifically, utilizing Berlese traps, the impacts of four different fertilization regimes (straw, compost, mineral NPK, and unfertilized control with a cover crop) on the abundance, species richness, and species diversity of Collembola is being studied and evaluated, using samples collected starting from spring 2021 until autumn 2023. Preliminary results indicate that the Collembola are among the most abundant arthropods in the Berlese trap soil fauna samples, with mites and flies being less abundant. There was a trend for the unfertilized control to show lower abundance of Collembola than the fertilized treatments, but differences between fertilized treatments were highly variable. The poster will present the analysis of the collected data to evaluate the comparative effects of different organic and mineral fertilizers on Collembola.

Urban Ecology
(UE)

Urban biodiversity: how to assess the social-ecological value of urban environments

Short title: Social-ecological value of urban environments

Chairs: Marco Moretti, Monika Egerer, Joan Casanelles-Abella

Contact: marco.moretti@wsl.ch

Urbanization has been identified as a significant contributor to global biodiversity loss and biotic homogenization. However, urban environments also present an opportunity to support biodiversity, ecological processes, and human well-being through the implementation of green and blue infrastructure. The Global Biodiversity Framework (GBF) urges cities to 'enhance green spaces and urban planning for the benefit of both biodiversity and residents' by 2030. Despite these recommendations, there is a lack of comprehensive assessment tools, analytical frameworks, and indicators of urban biodiversity to estimate the social-ecological values and qualities of different urban environments. Although such tools exist for natural ecosystems, they are still lacking in urban ecosystems. This gap hinders our ability to set goals for specific interventions and assess their success in countering biodiversity loss and related services. The main goal of the session is to foster discussions that will contribute to the development and implementation of effective indicators to evaluate and enhance urban biodiversity. By defining clear goals for ecological interventions in urban environments and establishing effective monitoring systems, we can ensure that cities play a crucial role in countering biodiversity loss and promoting the well-being of both nature and humans. The session will also foster discussion on creating collaborative systematic efforts to e.g. monitor biodiversity in cities worldwide.

UE1
01

Urban biodiversity: how to assess the social-ecological value of urban environments

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Urbanization has been identified as a significant contributor to global biodiversity loss and biotic homogenization. However, urban environments also present an opportunity to support biodiversity, ecological processes, and human well-being through the implementation of green and blue infrastructure. The Global Biodiversity Framework (GBF) urges cities to 'enhance green spaces and urban planning for the benefit of both biodiversity and residents' by 2030. Despite these recommendations, there is a lack of comprehensive assessment tools, analytical frameworks, and indicators of urban biodiversity to estimate the social-ecological values and qualities of different urban environments. Although such tools exist for natural ecosystems, they are still lacking in urban ecosystems. This gap hinders our ability to set goals for specific interventions and assess their success in countering biodiversity loss and related services. The main goal of the session is to foster discussions that will contribute to the development and implementation of effective indicators to evaluate and enhance urban biodiversity. By defining clear goals for ecological interventions in urban environments and establishing effective monitoring systems, we can ensure that cities play a crucial role in countering biodiversity loss and promoting the well-being of both nature and humans. The session will also foster discussion on creating collaborative systematic efforts to e.g. monitor biodiversity in cities worldwide.

Urbanization affects freshwater macroinvertebrate richness in tropical reservoirs

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Benthic macroinvertebrates are important contributors to the biodiversity, structure, and functioning of freshwater ecosystems as well as indicators of water quality, socio-economic important pest and flagship species for conservation. In the tropical island city state of Singapore, artificial substrate samplers were used to sample and quantify the macroinvertebrate composition across 13 reservoirs and two quarry lakes, enabling computation of an urban biotic index as an indicator of reservoir water quality. Based on replicated sampling, methodological sampling effects, species-area and species-habitat relationships of major benthic macroinvertebrate taxa were characterized. Accumulation curves and regression modelling were used to verify if the used method ensured representative sampling of the lentic macroinvertebrate community, and to elucidate the major drivers affecting macroinvertebrate occurrence and distribution. More than 50,000 macroinvertebrate specimens from 35 families representing all major freshwater invertebrate classes were collected. The macroinvertebrate community was dominated by non-biting midges (Chironomidae), followed by mayfly species and viviparid freshwater snails. Sampling sufficiently captured the overall macroinvertebrate family richness across the city state, whereas macroinvertebrate communities of some restricted areas and of both unmanaged reference sites did not reach saturation. Multiple regression models further indicated weak or no support for the species-area relationship and time hypothesis, i.e. the oldest and largest reservoirs not necessarily harboured the highest macroinvertebrate family richness. Instead, habitat features such as the degree of urbanization most strongly governed the macroinvertebrate distribution patterns, with the most urbanized reservoirs harbouring the lowest macroinvertebrate diversity, even if age, size and geographic origin of the reservoirs is accounted for.

UE1
03

Quantifying functional contrasts between native and commercial plant species in Swiss urban green spaces

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As the world's population is increasingly concentrated in urban areas, the expansion of these environments has led to several challenges, including biodiversity loss and the formation of urban heat islands. Urban vegetation provides critical ecosystem services such as air purification and temperature regulation, making it essential for urban sustainability and public well-being. However, the introduction of non-native, commercial plants into urban landscapes could threaten the functioning and resilience of urban green spaces (UGS) and thus the provision of these services. This study investigates the functional differences between native and commercial plant species in Swiss UGS to understand the potential impact of commercial plant selection in UGS. Using Principal Component Analysis, we analyse a range of morphological, physiological and life-history traits to explore the overlap between native and commercial plants at both national and city-specific levels for trees, shrubs, herbs and lianas. Preliminary results show that native herbs and lianas cover a larger area of trait space than their commercial counterparts, and that for both groups the trait space of commercial individuals is nested within that of native individuals, whereas trees show the opposite trend. Commercial herbs, shrubs and trees have smaller plant heights and lower seed dry mass than their native counterparts. Commercial herbs are dominated by multi-coloured, bilaterally symmetrical flowers, which generally begin flowering earlier in the year than native counterparts. These differences in functional composition may influence urban plant community dynamics by increasing competition with native species and altering biotic interactions such as pollination or herbivory. This research highlights the importance of informed plant selection in urban planning to maintain plant diversity and maximise the ecosystem services provided by UGS.

UE1
O4

Hierarchical filtering of plant traits in urban ecosystems

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Cities host an important diversity of native and cultivated plant species, typically higher than in their surrounding landscape. To survive in urban environments, plants must exhibit traits that allow them to cope with the socio-ecological context of cities. Urban plant community composition results from hierarchical filtering of species from a regional pool by climate, biogeography, anthropogenic facilitation, land use, socio-economic and cultural factors, and species interactions. However, these processes remain understudied limiting our understanding of urban plant community assembly. In this study of the PAPPUS project, we address this gap by quantifying the filtering of plant traits from a regional pool of native and cultivated species to three Swiss cities (Lugano, Zürich, Geneva). Urban plant species composition was surveyed in 180 UGS of five different types (gardens, allotments, real estate green space, parks, and ruderal areas). Community-weighted mean, standardized effect sizes, and functional diversity were calculated. The filtering effects of the cities and the UGS types were assessed using null models on the different hierarchical levels. We found cities to exert strong filtering towards more generalist species with earlier and longer flowering periods, as well as yellow, multi-colored, and bilaterally symmetrical flowers. Traits such as seed mass and winter hardiness showed no clear trends. The filtering effects of UGS types exhibited similar patterns in the aforementioned traits, and no major differences were observed among the cities. Aesthetic traits and traits related to phenology emerge as the main drivers of urban plant assembly, highlighting the combined role of anthropogenic facilitation, urban micro-climate, and urban landscape heterogeneity. Our study gives valuable insights into the complex socio-ecological mechanisms driving plant community assembly in cities and UGS, with implications for future urban planning and management.

The seasonal influence of vegetation structure on the cooling potential of urban greenspaces in Munich, Germany

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Urban greenspaces provide valuable ecosystem services throughout all seasons. One of the most important ecosystem services is the regulation of the urban microclimate. Especially during summer, greenspaces can significantly reduce the urban heat island effect by increasing humidity and lowering air temperature. The cooling potential of urban greenspaces is spatially heterogeneous and depends on several park characteristics such as size and design, as well as the greenspace structural composition of the vegetation. To investigate the influence of different vegetation structures and greenspace size on the cooling effect of urban greenspaces, we measured air temperature and humidity on 61 plots with differing structural complexity, located in 36 differently sized greenspaces across Munich, Germany. The same meteorological variables were recorded in the non-green surroundings to determine the greenspaces' local cooling potential. The structural complexity of the vegetation was quantified using mobile terrestrial laser scanning. We found that in 2023, temperature differences between greenspaces and their non-green surroundings were up to 4 °C on hot days. While most of the greenspaces showed a distinct cooling effect in summer, some parks were on average warmer than the non-green environment. While size has a strong influence on the cooling potential of urban greenspaces, a complex vegetation structure can partially compensate for differences due to size. Small greenspaces that are structurally diverse can have a higher cooling potential than large greenspaces with a low structural complexity. Thus, even small greenspaces contribute to the regulation of the urban microclimate — if the vegetation arrangement is designed accordingly. Stakeholders responsible for future greenspace planning and management might need to prioritize increasing the structural complexity of the vegetation to ensure the best possible urban heat island mitigation.

UE1
O6

Plant communities and their management practices in park green space affect pollinator diversity – A case study of Chongqing city, China

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In-depth analysis of the effects of different vegetation types and their management practices on pollinator community traits is important for scientific and practical pollinator-friendly plant community establishment and management practices. Five vegetation types (lawns, perennial meadows, shrubs, sparse forests, woodlands) in ten large comprehensive parks in Chongqing were surveyed to analyse their differences in pollinator community traits and their responses to plant variables and management practices. Results show that the dominant species of pollinators are *Apis cerana, Episyrphus balteatus*, and *Melanostoma orientale*. Significant differences were found in the pollinator diversity among different vegetation types. Shrubs and sparse forests have the highest diversity of pollinator species, followed by perennial meadows and woodlands while lawns have the lowest diversity. There was a significant positive correlation between species richness of plant and pollinator communities. Flowering plant abundance and herbicide use frequency had significant positive and negative effects on pollinator diversity and composition, respectively. Although *Humulus scandens* and *Erigeron annuus* significantly affected the species composition of some pollinators, they have strong invasiveness and attract only species that are widely distributed around the world by sacrificing pollination of native plant species. *Serissa japonica* and *Cyperus alternifolius* significantly increased the number of flower visits by *A. cerana, Eristalis cerealis* and *Lasioglossum subopacum* because of their flower traits. Therefore, in the future design and management of green spaces, the proportion of shrubs and sparse forests and plant species diversity of perennial meadows should be increased to provide nectar and pollen resources for different groups of pollinating insects; the use of herbicides should be prohibited to reduce the negative effects on local pollinators.

Night shift in the city: Temporal and spatial patterns of wildlife in relation to residents' perceptions

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Urban areas offer a unique setting for interactions between wildlife and humans, with each group typically active at different times, i.e. wildlife at night and humans during the day. This study explores the spatial and temporal intersections between these groups to understand how often their paths cross and how humans perceive various species. We analysed camera trap data from 24 locations within Freiburg, Germany, combined with an online survey of residents (n = 750) regarding wildlife encounter and perception. The camera trap data revealed that species such as hedgehogs, stone martens, badgers, and foxes are present across a wide range of urban environments, from densely sealed areas to more open spaces. Wild boar, hare and roe deer, however, were generally found in less-developed regions near human settlements. The survey results indicated a preference among residents for species like hedgehogs, hares, and roe deer, while wild boar, foxes, martens, and badgers were less favoured. These findings suggest a disparity between the wildlife species commonly seen and liked by humans and those that are often present but less appreciated. This gap could influence public support for conservation efforts and urban planning decisions. Emphasizing the conservation needs of less preferred species, while capitalizing on the positive perceptions of more popular ones, could lead to more effective strategies for promoting urban biodiversity and humans-wildlife coexistence.

Multi-functional solar parks promoting biodiversity – an ecological-industrial perspective

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To reduce the reliance on fossil fuels, the development of renewable energies needs to be accelerated. Agriphotovoltaic systems (APV) offer a promising approach, integrating agricultural and energy production to promote biodiversity and soil health through tailored methods. This makes APV with biodiversity measures an interesting solution for multi-functional land use, and potentially attractive to stakeholders from society. However, there are uncertainties about how solar parks affect multiple animal taxa and plants, and whether measures to promote biodiversity can offset their potential negative impacts. This uncertainty is particularly pronounced in the context of APV that are often constructed in areas with intensive farming practices. Starting a new research initiative, our project aims to illustrate that solar parks on agricultural fields can successfully promote biodiversity, potentially overcompensating for any negative effects. We will sample plants, birds, wild bees and butterflies at solar parks and at nearby agricultural control sites without solar parks. Comparing biodiversity at solar park sites with control plots will help determine if solar parks, especially APV, can serve as biodiversity promotion hubs in agricultural fields. The results of our first field season will be presented, and measures to promote biodiversity at solar parks discussed.

UE1
09

Opportunities for nature conservation in heavily utilised recreational areas in the city – the success story of the former Tempelhof airfield, Berlin

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The former Tempelhof Airport in Berlin was closed in 2008 and the airfield was made available to the public as a landscape park from 2010 with only minimal changes. Following a referendum, both the structural use of the site and any additional park design were ruled out by law. With between one and two million visitors a year, Tempelhofer Feld is now a major attraction for tourism and local recreation. At the same time, the former airfield represents a unique open landscape in the centre of the city — with an abundance of endangered species and biotopes. From the outset, the question for nature conservation was therefore how and whether the unique biodiversity could be preserved in the context of the often intensive recreational use. A detailed biotic monitoring scheme was therefore developed in order to recognise even small shifts in species diversity and species composition at an early stage. In this contribution we present the results of the first twelve years of vegetation monitoring on Tempelhofer Feld. By including socio-ecological data on user density, we show that (i) vegetation composition and species diversity remain surprisingly stable over 12 years, regardless of the intensity of recreational use; and (ii) endangered species and species-rich grassland can be preserved and further developed through adapted biotope management. Similar successes can also be observed for almost all the animal species groups analysed. Finally, we discuss favourable factors and proven strategies for successful nature conservation in heavily used urban landscapes.

UE1

O10

NDVI and green volume as proxies for urban bird diversity

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Research continues to show the importance of urban green for human health and well-being, for example, through exposure to natural sounds such as bird songs. Beyond positively impacting humans, birds provide insights into ecosystem services and the diversity of other taxa. Monitoring birds at a city scale can be complex, time-consuming and data-intensive. Therefore, alternative methods to rapidly predict bird diversity, like remote sensing, could give urban planners the ability to estimate the impacts of projects quickly. While the effectiveness of NDVI for predicting urban bird diversity has been demonstrated by others, this is based on low-resolution data. Further, NDVI only considers the ratio between visible light and near-infrared spectra, providing only a description of vegetated area. Much higher resolution (VHR) data (e.g. <1 m) and other products, such as LiDAR, are now readily available. Thus, new products, such as VHR vegetation volume, can be derived, which may be a better proxy for urban bird diversity. We aim to a) determine which spatial scale best describes local bird diversity from 25 m to 800 m buffers around each monitoring point, b) test if vegetation volume is a better predictor of bird diversity than NDVI, and c) investigate the impact resolution has on predictive power. We recorded birds at sites selected by their NDVI and distance to Marienplatz across Munich and used BirdNET to derive species richness, vocal activity, diversity, and community composition. We produced linear models and NMDS for community composition, compared how well VHR NDVI and vegetation volume described bird diversity, and compared the effects resolution has on model fit. We found that a ca. 100 m buffer best predicted local bird diversity and that NDVI and vegetation volume are good predictors of bird diversity in Munich; however, NDVI outperformed vegetation volume. Further, we found that VHR products performed better, although only minimally so. We, therefore, conclude that for rapidly estimating bird diversity in cities, readily available NDVI products work well and that data resolution does not have a great impact. Our results add to the body of evidence that NDVI can be a valuable tool for rapidly predicting bird diversity in urban areas.

UE1

O11

Rethinking urban co-habitats through the lens of a novel agnostic four-level classification

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In green urbanism, urban planners seek to reduce the impact of urbanization by catering for the liveability of the city habitat has a whole. Usually, decision-making is based around species-specific tools, that condense large heterogeneous information into manageable formats. Although common, these portrayal and classifications focus on humans' perspective, or fall short in acquiring a comprehensive view necessary for managing inter-species interaction across different cities and regions. We argue that by taking an agnostic perspective, an innovative classification could characterize urban habitats overstepping anthropocentrism, meaningfully describing the diversified living inhabitants within co-habitative landscapes. Our approach yields four fine resolution sub-classifications (10-m scale), each delineating different facets of urban metabolisms: urban morphology at both local and landscape scales (land covers, classes aggregation etc.), anthropic imprint (demographics, land-use policies etc.), and biophysical conditions (topography, climate etc.). Our workflow leverages open data sources with global validity, resampling at a 10-m resolution using a 100-m moving window algorithm. To illustrate this methodology, we present three distinct urban case studies: Vienna, Munich, and Genoa. The output layers are designed to be paired with models and frameworks by themselves or combined, empowering researchers to different perspectives for questioning urban sites. The classification's general purpose and large reach enables it to bridge different fields around a common understanding of urban habitats: nature conservation, adaptation to climate change, nature-based solutions design. This can be achieved by site comparison, by extracting meaningful local information, building-up knowledge from a specific site or through an array of different regions. This work sets the ground for a following application, comparing all mayor European cities.

UE1

P1

PAPPUS – How human and biophysical factors jointly shape biodiversity and nature's contributions to people in cities

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Cities are facing major challenges, such as urban intensification and climate change. Measures are therefore required to guarantee and restore biodiversity and quality of life. Urban green spaces (UGS), which contain a variety of vegetation types, can help to achieve these multiple goals (evaporative cooling, insect habitat, recreational areas, etc.) in various ways. For decision makers to be able to make well-informed decisions about what to plant in UGS, we must first understand how plants are currently selected by stakeholders and based on what criteria. Additionally, it is important to first know how these different plant assemblages can benefit existing species, humans, and local climate. In this poster, we present the PAPPUS project, whose goal is to evaluate how decision-makers influence plant assemblages across UGS in Switzerland and how these plants impact the ecological and human benefits in the context of changing climate. We will identify the type (species) of plants and their characteristics (traits) in 180 urban green spaces across three Swiss cities (Geneva, Zurich, Lugano). Combining social, ecological, and climatic approaches, we will investigate how decisions related to plant choice and management, insect associated to plants, microclimate and human well-being is interlinked. The originality of the PAPPUS project lies in the strong integration of social, ecological, and climatological theories and methods. Together, we combine field sampling with a detailed modelling approach that uses plants traits to quantify effects on biodiversity, microclimate, and human benefits. Ultimately, we will gain social, ecological, and microclimatic knowledge needed to ensure that urban green spaces continue to provide crucial co-benefits in the face of climate change, biodiversity loss, urban densification, and differing needs of plants, insect species and humans.

UE1

P2

The fitness of wild bees in urban community gardens

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Urban environments hold potential for biodiversity conservation. Although urbanization may negatively affect plants and animals, various forms of urban green spaces can be relatively biodiverse compared to rural areas. Community gardens are a common green space in cities where people come together to grow food and flowers, which can contribute to biodiversity conservation through horticultural activities and education. Wild bees play an important role in the pollination of many garden crops and are therefore important for gardeners. Although some studies have investigated which garden characteristics support wild bee abundance and richness, we know less about what drives the reproductive fitness of wild bees in gardens. Our research examines how wild bees and their interaction with plants are affected by urbanization and variation in floral resource availability and diversity in community gardens. As part of the project, we aim to understand the effects of urban heat and imperviousness on the nesting behaviour of cavity-nesting bees. We installed trap nests in 32 community gardens in Munich and Berlin, located along a gradient of low-high urbanization. We collected all occupied nests every 6—8 weeks between April and September, counted the number of brood cells per nest and documented the developmental stage of the bee in each cell. In addition, we documented the floral abundance in each garden to study how floral resource availability predicts the diversity and fitness of wild bees. We found a high variation in the number of occupied nests per urban garden, likely driven by a combination of urbanization parameters, floral resource availability and floral resource diversity. The results of our study can be used to guide gardeners in their attempts to conserve wild bees by specifically focusing on how to promote bee fitness.

Exploring plant assembly in urban green spaces: A trait-based modelling approach

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With most of the global population now residing in urban areas, the rapid expansion of these environments has led to adverse effects such as biodiversity loss, air pollution and urban heat islands. Urban green spaces (UGS) are increasingly recognized as effective countermeasures against the negative impacts of urbanization. Although plants play a key role in UGS, the mechanisms guiding plant community assembly remain unclear. Using a trait-based approach, we test the potential of various machine learning algorithms to model plant community assembly in UGS and predict the ecological and human benefits that can be realized from UGS. Unlike existing trait-based community assembly models, our model integrates both environmental and human filters to account for the importance of human preferences and decision-making on plant assembly in cities. Trained on species presence data from five different UGS types across three Swiss cities, our model considers traits ranging from commonly used ecological traits, such as plant height, to those more pertinent from a social perspective, such as cultural importance. By acknowledging human filters as crucial determinants of plant assembly, this novel approach will enhance our understanding of the dynamics between humans, the environment and plant communities in urban settings. We explore the potential of our model as a tool for UGS stakeholders to advise on sustainable planning amid rapid anthropogenic change and the biodiversity crisis.

A new self-test to assess garden biodiversity

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Private gardens have a high potential to harbour a rich biodiversity but differ considerably in their actual species richness. One major obstacle is the lack of knowledge among garden owners concerning biodiversity-friendly garden management practices. Furthermore, research has shown that many garden owners have false perceptions of how biodiversity-friendly their own garden is or which actions promote biodiversity; i.e. the majority of respondents in a survey mistakenly think that a lawn is better for biodiversity than a clayey sandy area. In the gARTENreich project, we address the question of how garden biodiversity can be increased in harmony with the needs of garden owners. One goal was to create a self-assessment tool that would enable interested garden owners to find out the current state of biodiversity in their garden while, at the same time, learning about possible actions. To do that, we mapped the vascular plants in 55 gardens and created a list with biodiversity-enhancing garden elements (such as deadwood, berry-bearing plants, a wildflower meadow). For each element, we split the gardens into two groups, according to element presence or absence, and calculated the change in plant species richness between these groups. Point scores were assigned to the elements according to these effect sizes. To do the self-test, garden owners tick which elements their garden has, sum up the points and read the evaluation. Compared to existing garden biodiversity indices, our self-test has the advantage that different elements score different numbers of points, giving garden owners a better sense for the effect of the elements. In our data set, the correlation between point scores and the plant species richness was rho = 0.88. As the self-test will be part of a set of communication materials resulting from the gARTENreich project, we hope many garden owners will fill out the test and be inspired to more biodiversity-promoting actions in their gardens.

Collaborative insights: A transdisciplinary perspective on urban biodiversity projects and lessons learnt

Short title: Diverse perspectives on urban biodiversity

Chairs: Valentin Klaus, Tanja Straka

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In this session, we want to collect and discuss insights and experiences from urban biodiversity projects. Presentations can refer to any type of habitat (gardens, green spaces, forests or others) that are located in an urban context or include a comparison with peri-urban or rural areas. The session is meant to provide a platform where practitioners and researchers can present and discuss transdisciplinary projects on urban biodiversity. The focus will be on challenges and effective strategies, as well as on the approaches and methods that were decisive for the success of the projects. This may include encounters and lessons learned from transdisciplinary collaboration with different partners or organisations, the acquisition of funding, the implementation of new approaches or the communication with the general public. In relation to the conference theme, we would like to highlight innovative ideas and solutions for sustainable urban land use. As sustainability encompasses many dimensions, from environmental to economic to social, we invite presenters to include such different perspectives on sustainability in their contributions.

Designing and implementing evidence-based insect conservation interventions with and for city neighbourhoods

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The ecological transformation of the city requires evidence-based interventions to support biodiversity, as well as coordinated efforts among relevant city actors. In our project 'BioDivHubs' in Munich, Germany, we collaborate with gardeners, neighbourhood residents, organizations, and government agencies to develop, implement and evaluate insect conservation interventions. Urban community gardens and their surroundings are our 'living laboratory' to co-create, test and collectively implement these biodiversity conservation strategies with residents. In this talk, we will present on our current activities including a citizen science balcony greening project, a mobile educational demonstration garden, and a seed mixture in part based upon conservation gardening principles to implement in different gardening and neighbourhood contexts. These various activities represent different interventions for biodiversity conservation, but also different ways in which people and ecological research interact. We will discuss the opportunities, challenges and successes in transdisciplinary urban ecological engagement.

UE2
O2

Co-creation of pollinator conservation interventions: Experiences from working with urban community gardeners

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Urban community gardens are socio-ecological systems that support biodiversity, ecosystem services and diverse human-nature interactions in the same place. They are therefore an ideal ‘living lab’ for developing, testing and implementing biodiversity conservation strategies together with gardeners. In our transdisciplinary approach in Munich and Berlin, we combine urban ecology research on pollinators in community gardens with the knowledge and experiences of gardeners in order to co-create interventions for pollinator conservation. One challenge of the co-creation process is to link these different bodies of knowledge. In the first phase, we held workshops with gardeners in Berlin to discuss the empirical findings of our research, as well as to identify barriers, previous experiences and open questions regarding the implementation of pollinator-friendly interventions. In the second phase, we then spoke with gardeners in Munich about the practical applicability of specific guidelines and the recommendations for choosing the right intervention. In our presentation, we will provide insights into the experiences from these workshops and take a closer look at the results and their implications for the development of a catalogue of evidence-based and practice-oriented interventions. We will use this example to illustrate the potential and challenges of transdisciplinary and collaborative development of nature conservation interventions. At the same time, we will critically reflect on what the collaboration with gardeners means for our own scientific work in terms of translating research into practice.

UE2

03

'GrüneLunge' (green lung) project in the city of Karlsruhe – map applications showing urban biodiversity

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Urban biodiversity, especially about city trees, is often difficult to grasp for the broad public. To simplify the access to research results of the project 'GrüneLunge' for citizens, interactive maps were created for a public geoportal. Sample-based inventory data of the trees and their ecosystem services as well as survey results on the perceive value of urban green are represented. The existing geoportal of the city of Karlsruhe has therewith been expanded. Citizens can thus find current research data in a known site, alongside other thematic maps. Expanding the existing tree cadaster of the city of Karlsruhe with detailed, regularly updated data about ecosystem services and their trade-offs, may also become interesting for the city's tree management. The city of Karlsruhe was involved in the project 'GrüneLunge' as a practice partner from the beginning. This cooperation has lowered some bureaucratic and legal hurdles. The remaining challenges offer lessons for other projects in this field. The effective communication with various relevant departments is one such challenge. The question, which data can be shared with the public in detail, has also proven not to be trivial.

Bon appetit! Using citizen science and deep learning to study the foraging activity of ants

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What drives foraging activity in ants and how adept are they at locating optimal resources? Here, we report on a citizen science experiment, the Ant Picnic ('Ameisenpicknick'), conducted mostly by children in Berlin, Leipzig and Halle from 2022–2024. Together, we conducted over 160 2-h baiting experiments in school yards, gardens and parks across an urbanisation gradient to investigate how changes in environmental and temporal variables such as urbanisation, vegetation, temperature, soil moisture, time of day and Julian date affect ant activity. Five sugar-water baits of increasing concentration from 0–40% sugar were laid out and ants were observed and counted at regular intervals (after 5, 10, 20, 40, 80 and 120 min) throughout the 2 h, after which they were collected for identification. We present the first results to the questions (i) how is ant foraging activity influenced by prevailing environmental conditions, and (ii) are ants capable of discerning and exploiting high reward resources. In addition to our empirical findings, we reflect on the merits and complexities associated with engaging children in scientific endeavors. Moreover, we report on the development of an adapted 'Insect Detect' DIY camera, which will enable continuous monitoring and tracking of ants at bait stations throughout the day and across longer time periods. Coupled with citizen science, this camera trap, the development of which was funded by the GfÖ, could help shed more light on the behaviour of these important ecosystem engineers.

UE2
05

InsectMobil: Impacts of landscape on insect diversity and composition through the use of citizen science and DNA metabarcoding

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Urbanisation and agricultural practices are some of the most drastic changes to natural habitats as a result of anthropogenic land cover change. However, the relative importance of different land cover types in shaping insect communities remains unclear. In this study, we combine large spatial scale sampling using citizen scientist car net data collection (nets installed on vehicle roofs) and DNA metabarcoding to investigate the influence of landscape patterns on insect community composition and richness, as well as land cover heterogeneity. In June and July 2018 and 2019, volunteers collected 334 car net samples on 67 roads in seven German federal states. A DNA metabarcoding protocol was used to estimate the taxonomic composition of the insect bulk samples, and the results were compared with known data on flying insect richness and occurrence. Flying insect richness and diversity were examined across the main land cover types. Our results indicate a strong negative association between urban land cover and insect abundance, suggesting that urbanisation may be a main driver of insect decline. As a consequence, the conservation and expansion of protected natural and semi-natural habitats should be a top priority for the conservation of insect diversity in temperate regions. Using a simple, standardised citizen science initiative, we were able to sample flying insects over a wide geographical area within a month, with a response rate of over 86% of samples returned. Therefore, citizen science carnet sampling may be a promising approach for monitoring flying insects at the landscape scale.

UE2
O6

FLOW — Citizen science shows that Germany's small streams are in poor ecological status

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Freshwater streams are affected by pesticide and nutrient inputs and severe alterations of the natural water course and riparian vegetation. The goal of the European Water Framework Directive (WFD) to achieve a good ecological status for all surface waters by 2015 has been missed in a large part of German rivers and streams. In the BMBF-funded citizen science project FLOW, over 900 volunteers have assessed the ecological status of small streams between 2021 and 2023. More than 90 groups from NGOs, schools and angling clubs have collected data on the hydromorphology and macroinvertebrate community of 137 streams across Germany according to WFD monitoring standards. For this purpose, we developed citizen science learning materials (e.g. identification booklet and video tutorials) and organized citizen science training sessions. A biological indicator ($SPEAR_{pesticides}$) was used to assess the pesticide contamination of the stream sample sites based on the macroinvertebrate data. Results showed that 58% of the sample sites in agricultural catchments failed to achieve a good ecological status in terms of macroinvertebrate community composition, indicating high pesticide exposure. These streams were classified as 'moderate', 'poor' or 'bad' using the $SPEAR_{pesticides}$ index. In terms of hydromorphology, 65% of the agricultural streams studied failed to achieve good ecological status. Rigorous testing showed that the citizen science monitoring achieved a high degree of accuracy, with results from citizen scientists and professionals highly correlated. We could also show that the citizen scientists' ecological knowledge and collective action to protect streams increased through learning-by-doing in the FLOW project. As a next step, the citizen scientists would like to work on restoring stream ecosystems and monitoring the ecological effects.

Urban ecology meets urban planning — using ecological insight to increase people-nature interactions

Short title: Urban ecology meets urban planning

Chairs: Wolfgang Weisser, Thomas Hauck

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Cities are the place where most humans work and live. Cities are therefore also the place where humans can experience nature in their day-to-day life. While greening cities and allowing for more human-nature interactions is now a major aim of governments worldwide, there is a lack of tangible solutions that can be integrated into established urban planning procedures. This is because ecology has only recently started to understand what species can live in a city under what circumstances, and because urban planning has traditionally focused on planning for humans only. This session will start with an introductory 30 min talk by Thomas Hauck (TU Vienna) on 'What urban planners need from urban ecologists'. The session welcomes talks focusing on one or more of the following topics: a) integration of ecological knowledge into urban planning and design (both conceptual approaches as well as practical examples), b) the role of urban form for the occurrence of species in the city, c) the role of urban form and urban greening for people-nature interactions. In addition to the session, there will be a workshop on how ecology could contribute better to the planning of green cities.

UE3
01

What urban planners need from urban ecologists

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Cities are the place where most humans work and live. Cities are therefore also the place where humans can experience nature in their day-to-day life. While greening cities and allowing for more human-nature interactions is now a major aim of governments worldwide, there is a lack of tangible solutions to make the city more wildlife-inclusive. What is needed is ecological knowledge that can be integrated into established urban planning procedures. In this talk I first outline how urban planning proceeds at the level of individual objects, such as buildings, and at the level of urban precincts or cities as a hole. I will show that in the current practice ecological insights are not entering the planning processes at the right time, or in the right form. I will then outline the type of knowledge that urban planners would need from ecologists, to plan in a way that developments are wildlife-inclusive. A key insight is that quantitative information is needed on resource requirement of species, because it is not sufficient to know e.g. what species eat, but also how much of it and how this can be provided. A second requirement is that ecological planning tools need to become digital and aligned with existing digital planning tools, e.g. of traffic planning. Thirdly, I will present possible models of collaboration between urban planners and ecologists to achieve wildlife-inclusive design. I conclude with a list of applied research topics and of possibilities how ecologist can engage to bring more nature back to cities.

UE3
02

Planning cities for a nature positive future for people and biodiversity conservation

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Accelerated urbanization leads to city expansion, emphasizing the need for strategies that minimize ecological impacts. The current debate centres on two approaches: land sharing, which promotes larger, greener cities, and land sparing, focusing on dense development to potentially free land for nature outside cities. Here, we assessed the impact of urban growth on biodiversity in the Tel-Aviv region, Israel, using simulated scenarios of land sharing and land sparing. The region (>300 km²) includes 12 cities, rural and natural landscapes. We conducted an extensive systematic bird survey with over 2,000 points across this area and simulated 2050 urban growth using densification and sprawl strategies. Using MAXENT, we modelled the distributions of 77 bird species and applied them to these scenarios. Results show that land sharing significantly alters regional bird distributions more than land sparing, leading to an 80% increase in building cover and predicting over a 30% decrease in non-synanthropic species' occupancy and a 50% increase for synanthropic species. Conversely, land sparing results in only a mild 2% decrease for non-synanthropes but reduces opportunities for people to experience nature. We explored additional 'nature positive' planning scenarios, restoring habitats on 15—30% of low-density residential areas either at city peripheries or within cities to enhance nature experience. Our findings indicate that even full restoration of 30% of urban residential areas at city edges provides only a mild improvement (11% increase in non-synanthropic species' occupancy). In contrast, such an approach diminishes nature interaction opportunities more than other sparing scenarios, while restoration within cities boosts these opportunities with minimal biodiversity cost. Our results underscore the importance of promoting dense and green urban development as a sustainable strategy for a nature-positive future that benefits both people and biodiversity conservation.

UE3
03

Ecological objectives for the built-up area of a city

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In the last decade, efforts to conserve and augment biodiversity in the urban environment have increased, following the realization that many species can live in the city and that human-nature interactions are beneficial for humans. An open question is whether target setting for urban conservation efforts need to be different from conservation targets outside the city. This question is particularly important for the built-up area of the city where human made structures such as buildings are intermingled with generally small greenspaces. We argue that ecological objectives for the built environment must take into account the fact that a species in these areas both use, and are threatened by, structures built for human stakeholders, such as buildings or roads. This makes it often impossible to retrofit ecosystems that occur outside the city into the urban environment. Extending published considerations of why humans conserve nature, we then review and assess different ecological objectives for the urban environment. We also consider the practicability for the different objectives, with respect to financial effort needed, biological feasibility, and acceptance by city dwellers. We argue that different target-setting is possible, and that there is no simple or obvious solution. Ecological objectives should be decomposed into those that mainly benefit the human stakeholder, such as ecosystem services, and those that mainly benefit plants or animals as non-human stakeholders. To increase acceptance by society, ecological objectives can be integrated with other objectives targeting the various human needs in the city. We conclude that while target setting for the urban environment is not fundamentally different from target setting in the natural environment, the choice that humans have in choosing conservation objectives becomes more apparent in the city context and requires intensive discussions among stakeholders including, but not entirely restricted to, ecologists.

Assessing functional connectivity in 3-D and the importance of green roofs as stepping-stones in urban areas

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Green roofs are important components of urban green infrastructure, offering cooling, recreation, and habitat benefits. Previous studies suggest that a wide network of green roofs can facilitate species movement for mobile species across the landscape and connect isolated ground level habitats. While it is known that green roofs experience both horizontal and vertical isolation from nearby ground-level habitat, their role in connecting habitat across the city by serving as ecological stepping stones is not sufficiently assessed. This study aimed to quantify the contribution of green roofs to functional connectivity for native bees across two spatial scales (municipality and neighbourhood) in Melbourne, Australia. Using a habitat suitability model to incorporate the three-dimensional aspect of building heights into the functional connectivity analysis, identified that green roofs located lower than 14 m above ground had the same likelihood of native bee presence as ground-level greenspaces, whereas green roofs above 27 m were more likely to have absences than presences. Our connectivity model estimated that, depending on the spatial extent considered and dispersal range of the native bees, 0—5% of the ground-level greenspace were functionally connected for native bees. The addition of green roofs into the landscape enabled movement across sites for all bees but the effect was greatest in long dispersal species, reaching 14–21% of all green spaces, depending on the spatial extent. However, most gains in functional connectivity were across green roofs which reached a high level of inter-connectedness. This study highlights that although green roofs can indeed increase functional connectivity of larger ground-level greenspaces, they are more likely to offer a greater benefit as expanded areas of habitat, rather than acting as vital stepping stones for movement across the existing landscape.

Urban biogeography to enhance city ecosystems for people and nature

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Cities represent a system made of complex interactions between human and natural processes, resulting in a spatially heterogeneous mosaic of social and ecological conditions. While the expansion of cities often destroys habitats for many taxa and exacerbates existing social and environmental injustices, cities can also offer areas to preserve wildlife and support people's well-being as acknowledged by the COP15 biodiversity agreement. Particularly in the face of global change, accurate spatial information describing changes in species-, biodiversity distribution and its contributions to people across urban areas is needed. Here, we discuss future prospects on the integration in urban ecology of modelling frameworks vastly employed in biogeography to study biodiversity changes. Thanks to the exponential availability of urban georeferenced ecological data and environmental information, achieving biodiversity modelling in cities is increasingly feasible. Biodiversity modelling represents a promising tool to better understand urban ecological patterns, and their outputs could help improve wildlife management, city planning, climate change mitigation, and promote social and environmental justice.

The spatial distribution inequity and relationship between green surface area and green volume: a perspective from public and private green

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Equity in the distribution of green space and ecosystem services is vital for environmentally just urban development. Numerous studies on green space inequity were limited to 2-dimensional green. Also, green space standards mostly relate to the per capita provision of green area in meters square but do not consider further targets of green space quality. A further perspective is opened up by green volume. It is important for biodiversity and ecosystem services such as carbon sequestration and air cooling. Moreover, for distributional justice, attention needs to be given to the ownership of green and, hence, who can benefit from it. To close this gap, we integrated high-resolution spatial data of green surface area and green volume derived from remote sensing to examine their spatial distribution and their relationship by Gini coefficient and Spearman's rank correlation. The city of Munich, (Germany) was chosen as a case study due to its size and data availability. Our results showed that: (i) Green space, both surface area and volume, was distributed unevenly over Munich. (ii) For surface area, there was more private (74%) than public green (26%), whereas for green volume, private and public make up about half of the total green. (iii) Generally, green volume was less equally distributed in space than green surface area. Private green surface area was more equally distributed than private green volume ($Gini_{\text{private green surface area}} = 0.38$, $Gini_{\text{private green volume}} = 0.50$), but public green surface area and public green volume were similarly unequally distributed ($Gini_{\text{public green surface area}} = 0.79$, $Gini_{\text{public green volume}} = 0.85$). (iv) Green surface area and green volume had a significantly positive relationship, and their correlation was much stronger for public green ($r = 0.98$) than private green ($r = 0.42$). We also analyse accessibility to public and private green based on socioeconomic data. Our study shows that considering the volume of vegetation rather than only the surface area provided new insights into the green space provisioning for residents.

Demographic and experience-based correlates of attitudes towards and preferred proximity of 32 different animals among the population of Munich

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Animals are a constant presence in urban environments. While there is a handful of studies that have addressed which urban animals people like, there is little knowledge on where in the city people want them to be. A preceding study by the authors indicated that the preferred proximity that residents of Munich want different animals on is influenced by their attitudes towards these animals. While it was established that the people that liked a certain animal more would also place them closer to their homes, it is unclear how demographic parameters and experiences with animals influence the decisions of people on where to place animals. We used data on demographics, experiences, and attitudes from the survey to test how these factors influence how close to their home people wanted the different animals – in the form of the closest acceptable relational scale chosen for the animals. A multigroup structural equation model with attitudes towards the animals as a mediator and the animals as grouping variables was done for the analysis: variable selection and path constraint were done using PiecewiseSEM, and the final estimates were produced with Lavaan. We found that it differs between animals if, how much, and in what way different demographic aspects or experiences are associated with accepting the animals closer to home. In general, people who liked the animals more, had higher levels of education, stated that they enjoy spending time in nature more, or help animals in their environment, generally accepted most animals closer to their home; conversely, people who live in a house instead of an apartment generally wanted most animals further away from their house. Our results emphasize that people have a differentiated view of animals that is influenced by a number of internal and external factors. Taking this into account can help identify reasons for the acceptance or rejection of an animal in an urban environment, and can help to guide urban conservation projects and mediate human-wildlife conflicts.

UE3

08

Roadsides as novel ecosystems and potential ecological traps: reviewing the state of knowledge

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Roadside habitats have abiotic and biotic conditions that deviate from natural habitats and thus constitute ‘novel ecosystems’ with insufficient adaptation of native biota. In roadsides, the net effect of positive and negative impacts determines population viability. This situation constitutes an ‘ecological trap’, when attractive habitats become demographic sinks due to locally reduced reproduction or increased mortality. The impact could be exacerbated by novel ecological factors. To investigate to what extent, for which species and under which conditions ecological traps are actually occurring, we reviewed the effects of roadsides on plant and animal performance and population dynamics. We identified 390 relevant publications with 470 different effect cases based on a standardized literature review (2008–2018). Overall, 30% of these cases reported positive effects of roadsides on plant and animal populations, 31% of cases reported negative effects, and 39% showed no effects at all. In only 18 cases, negative effects were combined with positive ones, most often due to attractive but unsuitable habitats that constituted ecological traps. Ecological novelty was not used to interpret these effects. We conclude that there is abundant literature on ecological effects of roadsides, while specific research is needed on ecological traps, including potential effects of ecological novelty.

The effect of optimizing a building envelope for plants and humans: a case study using simulated green roof communities

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Conserving and enhancing biodiversity in the urban environment requires finding greening solutions for the built-up part of the city, where architecture is responsible for building design. Many suggestions have been made to improve biodiversity by greening buildings. However, most of these approaches do not follow clear ecological objectives or do not analyse the interaction between architectural design and the ecological communities living around the building. In addition, ecological and architectural objectives are often considered separately rather than together, which is essential to systematically create buildings in the future that both meet the high standards for human living while also being able to promote biodiversity in our cities. Here, we combined objectives for human inhabitants and plants living on the building and investigate how different designs of residential buildings affect the assembly of plant communities on and around the building envelope. We couple a plant community model, which models competition and facilitation interactions, with an architectural design generation algorithm, to investigate how the building envelope form and the depth of soil placed on the building affect the diversity and distribution of plants that can be expected to live on the design. Our results emphasize that ecological benefits are higher when ecological objectives are included along with architectural objectives in computational building design while keeping the standards for human inhabitants. They also emphasize that it is possible to increase the value of building greening in ecological terms with simple adjustments of environmental conditions, here soil depth and shading heterogeneity.

UE3
O10

Biologische Vielfalt in der Städtebauförderung berücksichtigen – Ergebnisse und Empfehlungen

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Die Klimakrise wird zwischen als wichtige Herausforderung in der Stadtplanung wahrgenommen. Klimabelange haben auch in der Städtebauförderung durch die Verpflichtung, in Fördergebieten Maßnahmen zu Klimaschutz und -anpassung vorzusehen, eine prominente Position erhalten. Erhöhung der biologische Vielfalt wird als eine Maßnahmen-Option in der aktuellen Verwaltungsvereinbarung Städtebauförderung 2023/2024 erwähnt. Im Rahmen des Forschungsprojekts „Biologische Vielfalt berücksichtigen in der Städtebauförderung" (BioVibeS, 2022–2024) ging es um die Frage, wie Schutz und Entwicklung der biologischen Vielfalt in Vorhaben der Städtebauförderung integriert werden können. Ausgehend von Expert:innen-Interviews mit Verteter:innen aus den Fachverbänden und der kommunalen Praxis sowie Verantwortlichen für Städtebauförderung auf Bundes- und Landesebene wurden Herausforderungen und Chancen herausgearbeitet. Es wurde ein Katalog mit zwölf Maßnahmen entwickelt, die in rund 40 Varianten Möglichkeiten zur Förderung der biologischen Vielfalt in Gebieten der Städtebauförderung aufzeigen und Verantwortlichen in Kommunen als Inspiration dienen sollen. In unserem Vortrag stellen wir Erkenntnisse aus dem Vorhaben vor und diskutieren Ansätze, mehr Bewusstsein für biologische Vielfalt in Vorhaben der Stadtentwicklung einzubringen, z.B. indem Synergien zwischen Klimaschutz und -anpassung und einer vielfältigen Stadtnatur deutlich gemacht werden.

UE3

P1

CURT: the international network of Comparative Urban Ecology Research Training

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Comparative urban ecology is crucial for understanding the shared patterns but also differences among cities. While the comparative approach in urban ecology research has provided invaluable insights, for instance into functional traits of organisms in urban areas across geographies, comparing social-ecological systems among cities remains a challenge. While the urban ecology literature is rich with papers outlining this complexity, there is a lack of methods and approaches that offer solutions to untangle it and identify the most effective ways forward. Social-ecological networks (SENs) are an approach to clearly define and unpack actors, their relationships with each other and feedback loops within social-ecological systems. They offer a promising approach to untangling the interconnections among animals, plants, humans, and institutions in urban and other habitats, and can facilitate interdisciplinary collaboration between the social and ecological sciences, a crucial goal in urban ecology research. Against this background, we established an interdisciplinary network with scientists in urban ecology (terrestrial, freshwater, marine) and experts in SEN research. Our network involves experienced researchers and early-career scholars from diverse cultural backgrounds (e.g. Australia, Europe, South Africa, North America). The aim is to provide a platform to foster collaborations and train future urban ecologists in comparative urban SENs, but also to further develop SEN methods and approaches to untangle social-ecological systems in urban areas. Developing SEN approaches within the framework of comparative urban ecology will not only better equip the research toolbox of urban ecologists, but also facilitate comparisons of complex social-ecological interactions across diverse cities. This will reveal how these dynamics shape emergent properties irrespective of geographical location and contribute to our understanding and visions of socially, ecologically, and technologically resilient cities.

Exploring the role of urban green spaces as Nature-based Solutions in Korea and Germany

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Urban green spaces (UGS) play a critical role as Nature-based Solutions (NbS), providing diverse cultural ecosystem services (CES) that contribute to urban biodiversity, physical and psychological health, and overall urban sustainability. While international agreements and conceptual frameworks emphasize the importance of NbS, integrating local populations into the research, policy, and management of UGS remains a challenge. Additionally, the abstract nature of CES means they are often underrepresented in co-benefit quantification and policy considerations. Based on insights from questionnaires and expert interviews conducted in both Korea and Germany, this study evaluates the integration of public perspectives into UGS and NbS management and policy decisions. Relevant policies and frameworks are analysed to identify key policy drivers, potential areas of improvement, and barriers in NbS and UGS management in both countries. By bridging research, policy, and community engagement, this study contributes to a more holistic approach in harnessing the potential of UGS as Nature-Based Solutions. It underscores the need for collaborative efforts to create resilient and sustainable urban environments.

UE3

P3

Understanding the role of structural and environmental factors in green roof biodiversity

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Roof greening has been advocated to increase biodiversity in cities, but there is still limited knowledge on which taxa inhabit these green roofs (GR) and what environmental and structural factors affect plant and animal communities. Green roofs differ in several parameters, including substrate type and thickness, as well as the height and size of the roof. Additionally, community assembly takes time, so GR age may also influence the community living on the roof. To address this knowledge gap, we studied 73 green roofs in the city of Ingolstadt in Bavaria, Germany, selected along gradients of roof height, size, age, and substrate thickness. All roofs were visited in the summer of 2023 (July—August), and plant and bryophyte communities, as well as arthropods both below- and above-ground, were sampled using a variety of methods. Additionally, we took soil samples, measured plant biomass, recorded environmental variables (e.g. air temperature and rainfall), and finally, contacted owners to obtain information on roof age and management practices. In total, we identified 106 plant taxa, and community composition was strongly influenced by substrate depth, age, and management practices such as mowing or weeding. Plant diversity increased with increasing soil depth and roof height, while bryophyte cover decreased with increasing substrate depth. Increasing substrate depth also increased plant biomass, which, in turn, was one of the main drivers positively affecting the abundance and richness of arthropods inhabiting the GR both below and above-ground. We counted 81,595 individual arthropods (below: 46,156; and above: 35,439) representing 20 taxa, with Collembola being the most abundant taxon. Roof age, as well as plant richness, also increased total arthropod abundance, with individual insect groups positively affected (e.g. Nematocera, Brachycera, Apocrita, and ants). Our study shows that the structural variables of the roofs affected plant communities developing on the GRs, and the mature vegetation simultaneously supported arthropod communities. Our results may provide useful insights for more environmentally and financially sustainable design and management of GRs, and clear targets for roof biodiversity are needed if GRs are to compensate for communities lost due to impervious surfaces.

Urban trees: hydraulics of *Platanus acerifolia* under stress

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In urban environments, trees have to cope with various and often intense stresses, such as drought, heat and (in regions with winter frost) freezing and salt stress. We monitored hydraulics and growth of trees in several sites of different stress intensities in Innsbruck, Austria and performed experiments on winter and salt stress with a focus on the role of photosynthesis in green stem tissues. Monitoring on adult trees was based on automated dendrometer and sap flow measurements combined with micro-meteorological and phenological analyses. Experiments were performed on potted plants exposed to artificial winter drought and freezing as well as to salt stress. In experiments, trees with inhibited stem photosynthesis (covered, light-excluded stems) and control plants were compared. Trees growing on traffic islands showed high variability in growth and hydraulic parameters. Based on sapwood areas calculated from electric resistivity tomograms, annual transpiration of monitored trees was estimated between 5.750 and 14.210 l. Experimental winter and salt stress induced hydraulic impairments but trees were able to recover during spring. No differences between light-excluded and control trees were observed. Stem growth and hydraulic data indicated high variability under stress exposure within the city of Innsbruck. Some trees probably profited from access to additional water sources, such as wastewater channels, others suffered from damages, such fungi attacks. *Platanus acerifolia* seems to be relatively resistant to winter drought and salt stress, though, its vitality at extreme urban sites might be considerably limited.

Interactions between tree species identity, development stage, and growing habitat (park vs. street) influenced soil respiration near urban trees of *Quercus robur* and *Quercus rubra*

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The differences in soil respiration (R_s) among tree stands of different species and ages are known. However, there is little research on how tree age, species, and growing habitat of urban trees influence R_s. In this study, we examined R_s under urban trees in two of the most common urban ecosystems (park and street) and how Rs varies between growing habitats, species, and tree development stages (DS). We hypothesized that R_s values would differ between growing habitats but not between the native *Quercus robur* and *Quercus rubra*. Additionally, we expected a decrease in R_s with with advancing DS. The study involved 60 trees, evenly distributed across three DSs, in the city area of Karlsruhe. Rs was measured using a LI-COR Smart Chamber in combination with the LI-COR LI-870 CO2/H2O Analyser. Alongside R_s, environmental (site and soil attributes), and dendrometric data were collected. Regression model analysis revealed a significant interaction between habitat and DS. Park trees in the latest DS had higher R_s. Additionally, *Q. rubra* exhibited higher R_s values. PPFD, soil water content, pH, and impervious surface cover explained significant amount of variance in R_s, with park locations having higher soil water content and pH and street locations more impervious cover. These findings suggest a complex interplay between growing habitat, tree species, DS, and environmental factors in shaping urban R_s. Future studies can build on these findings and focus on how growing habitat, tree species and DS influence R_s in urban areas.

Urban waterfronts as areas where social-ecological systems meet: A blue-green infrastructure connectivity perspective

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Waterfronts are the primary contact between the water and land. Their artificialization prevents interactions between aquatic and terrestrial ecosystems. A reduced lateral (transversal) connectivity in lotic and floodplain lentic systems is proven to seriously affect the ecological balances of a healthy habitat along the aquatic and terrestrial gradient and the effectiveness of blue-green infrastructure. Especially in urban areas, the consequences of direct human interventions on the waterfront are evident. Through a simple, rapid, and effective method, the 'Waterfront Development Index' (WDI), we characterized the relative waterfront usage by comparing waterfront land use and land cover change across 91 German functional urban areas. Our results show remarkable disparities between metropolitan waterfront land use along running and standing waters. Transportation was the most pressing human land use on the urban waterfronts, especially along the riverbanks leading to severe drawbacks on urban aquatic ecosystems. Between 2012 and 2018, 237 km of waterfront outlined by natural, water, or agricultural surfaces have been altered to urban, industrial, or transportation land use across German metropolitan areas. Even though the national level average transformation is relatively low (0.4%), the change ratio in some FUAs like Flensburg is alarming (2%). Nonetheless, we also report promising transformations the other way around as a consequence of the ongoing river restoration projects. Our findings have remarkable social and ecological implications regarding human well-being and the terrestrial and aquatic ecosystems that tightly depend on the freshwater waterfronts. We advocate for sensitive urban planning and landscape management on the urban waterfronts in Germany and beyond, as altering the natural waterfronts will have unrepairable consequences on the respective ecosystems and degrade their servicing capacities for enhancing human well-being.

Urban land fragmentation and climate change adaptation in Ghana

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Climate change and variability are delaying the achievement of global food security. This is especially the case in Africa because African countries have not been able to increase productivity while decreasing greenhouse gas emissions and the changing climate affects all components of food security. Household food security among smallholder farmers are sensitive to a variable and changing climate, requiring farmers in Ghana to adopt new land management practices to improve food security. Although progress has been made, in the years 2014–2016 the majority of the people still undernourished were in sub-Saharan Africa. It is difficult to overcome the impacts of climate change and variability on agriculture, especially in less developed countries like Ghana. Farmers in Ghana are unable to produce sufficient food for consumption, even during good rainfall years. This makes Ghana particularly vulnerable to climate change impacts and famine. Sustainable land management increases resilience to climate change and variation, reduces socioecological vulnerability, and, as a result, increases food security. The objective of the study is to analyse the food security consequences of the interactions and relationship between land fragmentation and sustainable land management practices using Probit and Poisson models. The study found that food insecurity was severe during the food shortfall season. Land fragmentation improved different food security dimensions by reinforcing farmers' efforts to achieve food security. Also increasing the quality and quantity of sustainable land management practices proved to be very important in coping with the adverse impacts of climate change and variability on food security. It is therefore recommended that the availability, variety, and quality of inputs like fertilizer and seeds should be improved to enhance adaptation. Farmers should be supported with credit both in kind and cash for their farming activities. Extension workers, experts, and farmers could collaborate to plan and implement short and long-term maintenance services of their farmlands. Reducing severe land fragmentation through the assembly of small parcels into larger heterogeneous plot clusters could enhance food security by exploiting synergies between adaptation practices and land fragmentation.

Utilizing the Transversal Connectivity Index (TCI) to assess the existing and potential transversal connectivity among terrestrial and aquatic habitats across pan-European functional urban areas

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The effectiveness of the blue-green infrastructure (BGI) depends on the connectivity condition between terrestrial and aquatic systems. The fragmentation of BGI is primarily caused by human activities including the network of transportation infrastructure. Yet, identifying and mitigating this fragmentation via innovative models is vital for fostering sustainable land use and urban landscape management. The Transversal Connectivity Index (TCI) is developed as GIS-based method to assess the transversally (laterally) connected natural landscape mosaics (TCNLM) at metropolitan level, relying on the available LULC data. Freshwaters are of central importance within TCI methodology and – combined with TCNLM – may intermediate the identification of an effective BGI at metropolitan level. In this study we aim to assess the current situation regarding BGI connectivity across European functional urban areas (FUA). Using Urban Atlas data we were able to screen the existing and potential BGI networks of more than 500 inland metropolitan areas from thirty five countries. According to our results the average share of natural land patches that have a connection to a freshwater surface is 33%. Norway records the highest share of 91%, while Luxemburg has the lowest record of 9%. Nevertheless, our scenario building steps via TCI show that the BGI connectivity share is improvable to 79%, where more than one third of states increase above 90%.

Potential and challenges of urban restoration

Short title: Urban restoration

Chairs: Leonie K. Fischer, Somidh Saha, Brenda Maria Zoderer, Valentin Klaus

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Urban habitats for flora and fauna are found within all European countries, with differences and commonalities in each specific local context. Yet, urbanization is one of the most severe threats to biodiversity, and by 2030 about 80% of the European population will live in urban areas. Therefore, many people will rely on urban greenspaces as places for their cultural values, including health benefits. Greenspace planning in cities could thus follow a dual strategy, which counteracts biodiversity loss (as much as possible) and facilitates human wellbeing. Up to now, many concepts and projects on improving the ecological quality of urban habitats have been developed. Yet, urban areas are highly dynamic environments, and approaches assessing and enhancing biodiversity and ecosystem functions/services must be adapted to the specific anthropogenic context. Moreover, it is crucial to take the urban population and their specific needs and plural values into account, when developing or changing urban green spaces. Thus, considering urban site conditions (e.g. parks, streets, meadows, cemeteries, woodlands), ecological processes, habitat connectivity, land use, and meeting the requirements of urban residents and other stakeholders represents a special challenge for approaches such as ecological restoration projects in cities. The aim of the special session is to present research on urban habitat restoration, including practical approaches such as biodiversity management, the restoration of natural processes through rewilding, or the inclusion of species of special conservation concern within urban greenspaces. In particular, we want to discuss challenges and opportunities in reducing potential trade-offs and promoting ecological values of urban green infrastructure for the benefit of both people and nature in cities. Bringing together these aspects will make the session a place for interdisciplinary discussions within a framework of ideas and projects to create biodiverse and socially-inclusive environments in cities.

UE4
01

The potential of tree-related microhabitats (TreMs) and other ecosystem services among cemetery trees in Karlsruhe city

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Solitary trees near streets and inside city parks have been widely studied in urban ecology research, but cemeteries remain understudied green spaces. We investigated tree-related microhabitats (TreMs) and other ecosystem services supplied by trees in three cemeteries in Karlsruhe in southwestern Germany. For this purpose, 200 cemetery trees with a diameter at breast height (DBH) >40 cm of five deciduous tree species commonly found in cemeteries (*Acer platanoides, Carpinus betulus, Fagus sylvatica, Platanus x acerifolia, Quercus robur*) were inventoried during the vegetation period, and TreMs were recorded after leaf fall in a second field data collection. Provisioning and regulating ecosystem services were estimated using i-Tree Eco from the United States Department of Agriculture (USDA) Forest Service. Regression results showed that tree species, size, and vitality were crucial factors influencing microhabitats in urban trees. According to our measurements and modelling results, more big trees positively impacted microhabitat richness, abundance, and ecosystem service provision. Crown dieback, an indicator of tree vitality, negatively affected ecosystem services by reducing growth and productivity but increased microhabitat abundance. Pruning intensity and light availability were not decisive influencing factors. Comparing the occurrences of individual microhabitat groups between tree species revealed significant variation in their microhabitat compositions, suggesting that a high tree species diversity promotes the provision of a wide range of microhabitat types through a complementary effect. Moreover, the findings emphasize the need to preserve large old trees in urban environments to ensure their significant contribution to urban ecosystem services. Overall, this study shows the complex interplay of influences on ecosystem services of cemetery trees and provides implications for urban green space management.

The role of roadsides for urban rehabilitation: Trait–environment and trophic interactions in cavity-nesting bees, wasps, and their antagonists

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Urbanization is accompanied by high densities of roads, contributing to degradation or destruction of habitats. Nevertheless, recent studies report overall positive effects of diverse roadside vegetation on insects. Roadsides cover significant proportions of urban green space, which highlights their untapped potential for conservation and rehabilitation. In a three-year experiment, we established 75 wildflower patches along five major roads in Munich. To analyse functional and trophic interactions of beneficial insects, we sampled cavity-nesting bees, wasps, and their antagonists with trap nests. Additionally, we investigated the role of the local roadside vegetation, and the urban landscape for the cavity-nesting communities. We found 50 species in the trap nests and counted more than 10.000 brood cells. The number of intact brood cells, taxonomic and functional diversity, as well as antagonistic interactions were positively affected by roadside rehabilitation. Increasing urbanization intensity, however, affected the insect communities negatively. We conclude that urban roadside rehabilitation holds great potential to conserve urban insect communities and their trophic networks, and city-wide implementation can increase local habitat quality and landscape connectivity.

UE4
03

Maintenance effects on the biodiversity of floodplain grasslands: vegetation, ground beetles and general arthropod fauna

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Dykes and green spaces near urban waterbodies offer great potential for biodiversity conservation, as they represent contiguous habitats for animals and plants. To ensure flood protection, these areas are mostly maintained by frequent mowing, albeit extensive mowing with removal of the cutting material is supposed to be more beneficial for biodiversity. We investigated the long-term and short-terms effects of different maintenance schemes, i.e. intensive vs. extensive mowing and sowing a regional seed mixture on vegetation, ground beetles and the general arthropod fauna. We surveyed a total of 32 areas, each with four sampling plots, with vegetation surveys, sweep net sampling and pitfall traps. A change in the plant species community could be observed in the extensively maintained sites compared to the intensively maintained sites. While no increase in the number of plant species was observed when extensive mowing was implemented, the plant species richness on the sites that were additionally sown increased by a factor of 1.4 compared to the intensively managed sites. The effects on the fauna varied. Our study sheds light on the differential effects of maintenance on urban floodplain grasslands.

The acceptability of urban rewilding among local communities

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The restoration of wild nature in cities is increasingly recognised as an important agenda in urban greenspace planning and management for safeguarding urban biodiversity and reconnecting urban residents with nature. Yet, little is known about the acceptability of urban rewilding among local communities and how acceptability is related to existing opportunities for experiencing wild nature. This contribution presents key findings of the research project SUCCESS, which set out to (i) explore the conditions under which urban rewilding is accepted by local communities in Vienna (Austria), (ii) the spatial distribution of wild nature areas across the city, and (iii) the opportunities for in-situ experiences of wild nature across different urban environments. Based on a survey of urban residents (N = 800), we find that urban rewilding meets high levels of acceptability across different scenarios, which vary in terms of ecological (i.e. site conditions, natural succession processes, preliminary rewilding output) and social processes (i.e. actors involved, restoration practices, and facilitated human-nature interactions). Acceptability is positively linked to previous wild nature experiences and particularly high among residents that visit wild nature areas frequently and use them for multiple purposes. Opportunities to experience wild nature are unevenly spread across the city, however, being particularly scarce in more densely built areas, as WNAs are not only poorly available, but also disproportionately exposed to barriers to use. In sum, the findings suggest that improving the accessibility and multifunctionality of existing wild nature areas in densely built areas is a key enabler for urban rewilding at other sites.

Blooming beauty or withered weeds? Empirical study of public perception and acceptance of insect-friendly urban meadows over the course of the year

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Establishing insect-friendly meadows in urban areas can foster urban biodiversity. These meadows differ from ordinary lawns in their ecological value, and also in their appearance, which changes notably throughout the year. Feedback from the public to the city administration suggests that there is a connection between these different states of appearance and the acceptance of the meadows. However, if the meadows are not accepted by the public, conflicts may arise. To respond adequately to the public concerns and to create attractive urban areas for people and insects alike, it is necessary to understand acceptance patterns and what exactly influences acceptance of insect friendly meadows. To systematically investigate the public perception of urban meadows, an empirical online survey (n=225) was conducted in which participants were asked to rate different states of the meadow (growing, flowering, withered, mowed) according to different criteria (e.g. overall acceptance, perceived ecological value, aesthetic appearance). To complement these theoretical evaluations, >400 standardized interviews were conducted with passers-by of urban meadows in early summer (flowering meadow) and late summer (withered meadow) in Aachen, Germany. The empirical studies confirm the hypothesis that urban meadows are perceived significantly differently in the different seasons. A flowing meadow is the most accepted and scores highest in terms of aesthetic appearance and perceived ecological value, which are also the most important predictors of overall acceptance. The interviews provide more detailed account of the perceptions, e.g. the trade-offs people make between ecological value and aesthetic appearance. As insect-friendly meadows inevitably pass through all four states during the year, including the less accepted ones, seasonal communication strategies are needed to inform the public about the value of the different meadow states for biodiversity in general and insects in particular.

What hinders the restoration of urban ecosystems? Results from a pan-European survey

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Urban ecosystems are often in an ecologically degraded state, either due to intensive maintenance or neglect. Many successful examples have proven ecological restoration to be able to significantly increase the biodiversity and general ecological quality of degraded urban ecosystems. Such approaches, however, require cities to take initiative and act for urban ecological restoration. A lack of such initiative still exists in many places, considerably restricting the vast potential of urban ecosystems to contribute to biodiversity conservation. With partners across Europe, we conducted a questionnaire survey asking more than 350 city administrations about their measures taken to enhance the ecological quality of the greenspaces within their boundaries. We also inquired the underlying motivations for creating and maintaining urban green and assessed the obstacles to further increasing ecologically oriented greenspace management. The countries we surveyed cover all climatic regions of Europe, from Scandinavia and the Baltic states to the Mediterranean climate as well as the Alps. Results reveal many cities to already implement a range of restoration approaches such as converting lawns into meadows or reducing pesticide use to enhance urban biodiversity. The main obstacles to more restoration actions differed between cities and countries. Major issues included preserving a well-kept appearance of green spaces and limited financial and time resources that city administrations can invest in optimising greenspace planning and management. We thus conclude that, although urban ecological restoration is already being done across Europe, supporting cities in planning and managing greenspaces for biodiversity could significantly advance the ecological state of urban areas. One approach to improve the current situation would be to strengthen the engagement with city populations to stimulate concerted public and private action to ecologically optimise urban habitats.

Green roofs: habitats facing climate change and biodiversity crisis

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Green roofs have many advantages including water retention, temperature regulation and a pleasant visual appearance. In addition, they are often promoted as valuable secondary habitats that can counteract the negative effects of urbanisation on biodiversity. Conditions on green roofs can be extreme regarding temperature and water availability. Higher temperatures and longer drought periods caused by climate change further increase the challenge of surviving on the roofs for plant and insect species. In the Sparkling Science project 'Green roof habitats' we work together with middle- and high-school students to investigate how green roofs support biodiversity and how they are affected by droughts and heat events. We want to gain a better understanding of the complex interactions between climate and substrate conditions, vegetation, and insect biodiversity on green roofs using multiple methods. Weather stations and soil sensors constantly measure the conditions on the roofs, while cameras capture changes in the state of the vegetation. Malaise-traps in combination with metabarcoding are used to sample flying insects. We compare the insect diversity on green roofs with nearby meadows and sealed areas. The comparison with these sites allows an assessment of the specificities of the insect communities on green roofs and hence their contribution as secondary habitats in urban environments. The involved students take part in several steps of the research process from data collection to analysis and communication. In direct exchange with scientists, they gain insights into research and deal with topics of high relevance for our society. During the first half of the three-year project, we gained valuable experience with applying both new and innovative as well as state-of-the-art methods on green roof habitats. In addition, we developed approaches for a meaningful integration of students aged 12–17 in the research process.

Optimizing biodiversity support of solar parks implemented in open landscape

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Agriculture negatively impacts biodiversity through habitat destruction, chemical use, and monoculture practices. Loss of biodiversity in agriculture can lead to reduced ecosystem resilience, increased vulnerability to pests and diseases, and diminished soil fertility. Addressing the diversity crisis in agriculture requires a holistic approach considering ecological, social, and economic dimensions. This includes promoting sustainable farming practices, supporting small-scale and diversified agriculture including restoration of the rich mosaic of non-production habitats. The motivation for setting up solar parks in the Czech Republic was economic benefits. Inadequate regulations led to the fact that solar parks were often created spontaneously and fundamentally negatively affected the aesthetic and functional quality of the environment. Over time, perspectives on solar parks have evolved considerably, influencing the development of strategies for integrating solar parks harmoniously within the surrounding landscape. Unfortunately, due to the intensive maintenance, the habitat diversity of solar parks' environment is relatively uniform. Our project focuses on existing solar parks (n = 24) and their biodiversity of model groups of organisms — vascular plants, birds, and selected groups of pollinators (butterflies, solitary bees, hoverflies) and ground-dwelling invertebrates (spiders, ground beetles). The main objective of our project is to exploit the still neglected potential of existing solar parks as suitable areas for biodiversity support. Based on our preliminary results, it is evident that the diversity of solar parks is influenced by both the diversity of the surrounding environment and the type of environment on which the solar park was founded (brownfields, ruderals, agricultural land). Based on these results, it is clear, that there is no universal optimal measure to support biodiversity. It is necessary to consider both spatial limitations and the context of the surrounding landscape. We aim to optimize management measures given spatial constraints and surrounding landscapes within existing solar parks.

UE4

P3

UrbanPArt – Phenology of arthropods in urban green spaces and implications for urban grassland restoration

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Within highly modified urban environments, green spaces can serve as important refugia for arthropods. The quality of these habitats for arthropods is influenced by interactions of habitat and landscape parameters, which is reflected in variable responses of different taxonomic and functional groups to urbanization. As urban case studies often cover short sampling periods, they are not well suited to depict shifts in arthropod community composition over phenological cycles. This is of particular concern, as distinct characteristics of cities such as habitat fragmentation, the urban heat island effect and intensive habitat management, are likely to affect phenological cycles and the behaviour of arthropods. Generally, little is known about the phenology of lesser-studied arthropod groups in cities such as Heteroptera and Auchenorrhyncha. It is currently unclear when arthropods are recolonizing habitat patches after management events and which habitat and vegetation structures are commonly used for overwintering. To address these knowledge gaps, we selected 36 urban grassland sites in the city of Würzburg, Germany. The grassland sites are categorized according to their management intensity (semi-natural grassland / extensive urban grassland / intensive urban grassland) and location (city center / suburb). Arthropods will be sampled monthly between May and September 2024 using suction sampling. An additional suction sampling session will take place in winter 2025 accompanied by innovative methods, such as the dissection of dead standing vegetation. Habitat and landscape parameters will be assessed in the field and using a geographic information system. Based on our results, we aim to develop suitable management and restoration techniques for urban grasslands to maintain habitat networks in which arthropods can complete their life cycles. In this session we would like to present our project aims, applied methods and first results of the current field season.

Workshops

Research data management for advancing sustainable land use practices

Short title: Better manage your data!

Organizers: Daniel Tschink, German Federation for Biological Data (GFBio e.V.), dtschink@gfbio.org, Jimena Linares, German Federation for Biological Data (GFBio e.V.), jlinares@gfbio.org

Location: Forestry science building, Hans Carl-von-Carlowitz-Platz 2

Description: In the context of the GfÖ24 conference, dedicated to exploring the future of sustainable land use across ecosystems, landscapes, and biomes, our workshop aims to address the critical role of research data management in advancing innovative land use and management strategies. As global land-use change and unsustainable practices continue to drive biodiversity and ecosystem function loss, the workshop focuses on empowering ecologists with the skills and knowledge needed to harness the full potential of research data. The escalating volume, complexity, and creation speed of research data pose challenges to their long-term value and accessibility. Recognizing the importance of transparent and collaborative data practices, this workshop emphasizes the need for 'good' research data management. Drawing inspiration from the FAIR principles (Findable, Accessible, Interoperable, and Reusable), the workshop aligns with the increasing demand for transparency from research institutions, funders, and publishers. The workshop begins with an exploration of the basics of research data management across the entire data life cycle. The second section delves into the initial stages of the data life cycle, focusing on the planning of research projects and the subsequent publication of heterogeneous data. Practical examples illustrate the significance of a robust data management plan and guide participants in preparing data for publication and archival. In the final section, the workshop offers a firsthand account of experiences within the consortium NFDI4Biodiversity, providing valuable insights into tools and services that support effective research data management. Through this workshop, we aim to equip participants with the skills and knowledge necessary to enhance the transparency, accessibility, and interoperability of research data. By fostering collaborative efforts and leveraging the vast resources of ecological data, the workshop contributes to the overarching goal of advancing ecological knowledge for the development of sustainable land use and management strategies.
Workshop combining theoretical and practical aspects of Research Data Management. A hands-on session spotlights one of the NFDI4Biodiversity Services.

Effective digital note taking: How to organize your knowledge and streamline your workflow with Obsidian

Short title: Effective digital note taking

Organizers: Anne Lewerentz, Karlsruhe Institute of Technology, anne.lewerentz@kit.edu; Selina Baldauf, Freie Universität Berlin, selina.baldauf@fu-berlin.de; Max Luttermann, UFZ Leipzig, max.luttermann@uni-goettingen.de

Location: Forestry Science Building, Hans Carl-von-Carlowitz-Platz 2

Description: Effective note-taking is an important skill for any scientist, as it allows you to keep track of the tasks you need to complete, key learnings from papers you've read, the design of your research, and any new ideas that come up while you're working. There are many different ways to take notes, including using pen and paper, post-its, digital documents, and even printed out papers with notes written on them. This often results in scattered notes on different media that are difficult to extend, connect, search or archive. Having all of your different notes in one place allows you to keep your thoughts organized and interconnected and helps you to always find your notes again and to streamline your workflow. The goal of this interactive workshop is to explore the various methods of note-taking, discuss what we require good notes to look like and introduce a powerful tool called Obsidian. Obsidian is a markdown-based note-taking tool that can help modelers stay organized and on track with their work. It provides an easy-to-use interface for creating and organizing notes, as well as a system for linking notes with each other to create a web of interconnected thoughts and ideas. Obsidian is very flexible and can be customized and optimized for your specific workflow and thought process. This flexibility and adaptability make it a valuable tool for any modeler looking to improve their note-taking and stay organized. To get started, we will provide a Demo-Notebook for academic note-taking with a lot of useful functionality (e.g. daily notes, literature notes connected to Zotero, organizing to-dos and projects) on Github.
Interactive pre-conference workshop with hands-on sessions. We would like to offer the workshop as a pre-conference format to allow participants to train on note-taking during the conference and to answer any further questions that may arise. Equipment needed: Every participant should bring his / her laptop.

Improving the contribution of ecology to the planning of green cities

Short title: Bringing ecology into urban planning

Organizers: Wolfgang W. Weisser, Technical University of Munich, wolfgang.weisser@tum.de; Sarah Bekessy, Royal Melbourne Institute of Technology RMIT, Australia, sarah.bekessy@rmit.edu.au; Thomas Hauck, Technical University of Vienna, thomas.hauck@tuwien.ac.at

Location: Forestry Science Building, Hans Carl-von-Carlowitz-Platz 2

Description: Cities are the place where most humans work and live. Cities are therefore also the place where humans can experience nature in their day-to-day life. While greening cities and allowing for more human-nature interactions is now a major aim of governments worldwide, there is a lack of tangible solutions that can be integrated into established urban planning procedures. This is because ecology has only recently started to understand what species can live in a city under what circumstances, and because urban planning has traditionally focused on planning for humans only. The aim of the session is to discuss how ecology can contribute to a better planning of cities where positive human-nature interactions are made possible while conflicts are minimized. Discussion questions include: What type of research is needed to better understand the conditions under which species can live in the city? How can ecology contribute to setting objectives in the planning of urban green infrastructure, but also in planning of the built environment? What are hallmarks of applied urban ecology? Can ecology integrate better with the disciplines shaping the city – urban planning, architecture, landscape architecture, transport planning and how can this be achieved? How can ecology contribute to sociological research on human-nature interactions, e.g. human-animal studies? Participants of the workshop will decide if the results of the workshop should be summarized in a perspective paper and agree on follow-on activities.
This will be a half-day workshop. There will be three short inputs by workshop organizers then discussions, first in the plenary, then in groups and again in the plenary.

Exploration, analysis and cloud processing of free Sentinel imagery for ecological monitoring with Copernicus Data Space Ecosystem

Short title: Copernicus Data Space Ecosystem

Organizers: András Zlinszky, Sinergise (andras.zlinszky@dataspace.copernicus.eu)

Location: Forestry Science Building, Hans Carl-von-Carlowitz-Platz 2

Description: Satellite imagery offers many ways to monitor ecosystems and bridge gaps in space and time. However, processing large image datasets used to demand complex software, large data storage and processing capacities. However, Copernicus Data Space Ecosystem changes the paradigm for satellite data analysis: imagery can now be accessed in code through a set of API-s, data can be visualized directly in a web browser, and regional-scale data processing on virtual machines is available free of charge. In this workshop, we will start from the basics of satellite earth observation, explore various ways of visualization (Copernicus Browser, QGIS Plugin), look into new ways to make code development for earth observation easy (Request Builder, openEO), and learn to use the on-board Jupyter Lab that allows online processing without setting up an environment. After this course, you will be able to make the most of the official data infrastructure for Sentinel Data by understanding the technical details of satellite data access and analysis.
This will be a half-day workshop, starting with an introductory presentation and continuing with hands-on exercises. Participants should use their own laptops, but no software installation is necessary.

Social Events

Recharge, Reflect, Revive rooms

People - Nature - Future: A digital exhibition

Organizers: Ingrid Rügemer, Symbio(s)cene e.V., i.ruegemer@symbioscene.com; Oliver Szasz, Macromedia University of Applied Sciences and Symbio(s)cene e.V., o.szasz@symbioscene.com; Tina Heger, TU Munich and Symbio(s)cene e.V., t.heger@tum.de

Location: Relaxation rooms on both ZHG and Forestry Science Building

Description: The digital exhibition »People – Nature – Future« presents the internationally awarded works by the Scandinavian artist duo Karoline Hjorth and Riitta Ikonen. In their remarkable art project »Eyes as Big as Plates«, which has been ongoing since 2011, the artists explore the relationship between people and nature. To this end, they have travelled the world and portrayed people in a wide variety of landscapes. The photo portrait series shows individuals wrapped in artistic sculptures made from elements of the environment. The artists play with symbiotic narratives and new aesthetic worlds - nature serves here both as content and context.

The digital exhibition will be curated by the NGO Symbio(s)cene. The artworks will be prepared as slides to be shown repeatedly during the conference on the presentation screens in the lecture halls. The digital exhibition will be complemented with a documentation of the making-off. Conference visitors are invited to experience the inspiring photographic works of art during breaks. The impressive series of portraits will create a unique atmosphere and will enrich the conference experience by offering sources of inspiration, demonstrating the significance of emotional human-nature connections, and stimulating informal conversations.

A disco in city soundscapes

Organizers: Monika Egerer, Technical University of Munich, monika.egerer@tum.de;
Susanne Schmitt, Ludwig-Maximilians-Universität München, schmitt@biotopia.net;
Stefanie Burger, Technical University of Munich, stefanie.burger@tum.de

Location: IGZW rooftop, Gregor-Mendel-Straße 4, 85354 Freising

Description: Join the 'CitySoundscapes' team as we immerse ourselves in an auditory exploration of urban soundscapes. Our aim is to heighten the awareness of the diverse auditory tapestry in cities, showcasing both the biological features (birds chirping) and anthropogenic elements (cars honking) that contribute to the sonic identity of urban environments. In this interactive session, participants will groove to the eclectic blend of biophonic, geophonic, and anthrophonic sounds derived from acoustic ecological research in Munich based on the Dawn Chorus Art&Science Project. The international sound making collective Alligator Gozaimasu have created an album based on those soundscapes recordings and will share a playlist they specifically created for the GfÖ conference.

Participants will gain insight into the ecological diversity of city green spaces but also the profound impact of natural soundscapes on human health and well-being. As we synchronize our movements to the rhythms of urban life and the melodies of nature, we invite attendees to ponder the therapeutic benefits of immersing oneself in natural sounds amidst the hustle and bustle of the city. Moreover, the disco serves as a platform for the convergence of art and science, illustrating how soundscapes can become a dynamic multisensory interface of sound, environment, and human experience.

What is the role of ecologists in the climate and environmental crisis? – A case for public action

Organizers: Matthias Grotkopp, Freie Universität Berlin, m.grotkopp@fu-berlin.de; Elodie Duyck, Universität Hamburg, elodie.duyck@uni-hamburg.de

Location: Forestry Science Building, Hans Carl-von-Carlowitz-Platz 2

Description: Despite repeated warnings from the scientific community, global greenhouse gas emissions are still on the rise. Records after records are being broken, the extinction rate is rising and many eco-systems are on the verge of breakdown, but instead of taking the necessary urgent action to slow down the climate and ecological emergencies, governments continue subsidizing and approving new fossil infrastructure, and pursuing policies that undermine biodiversity. When confronted with "a rapidly closing window of opportunity to secure a liveable and sustainable future for all", as stated in the last IPCC report, what is our role as scientists? In this lunchtime event, we want to discuss the role of scientists, particularly ecologists, and the scientific community, in the face of the climate and environmental crisis. What is the relationship between scientists, the scientific community, the general public and politics? Should we limit ourselves to the production of knowledge or do we have a responsibility to engage with that knowledge and with society? Can research be completely neutral and value free, in particular when it has direct implications for the lives and livelihoods of human and more-that-human beings? What other forms of public engagement are suitable for scientists apart from informing about the crisis? As an open discussion forum, we want to invite participants to reflect on their position and exchange ideas about the many different modes of activism available to scientists, the kind of roles can we envision for ourselves, and the support and network do we need to translate research into public action?

Publishing tips and tricks from the other side

Organizers: Andrea Stephens, Editor in Chief, Trends in Ecology and Evolution, Cell Press, Elsevier, Oxford, a.stephens@elsevier.com; Valeria Rinaudo, Ecology Publisher, Elsevier, Amsterdam, v.rinaudo@elsevier.com; Oscar Brusa, Scientific Editor, iScience, Cell Press, Elsevier, Munich, o.brusa@cell.com

Location: Forestry Science Building, Hans Carl-von-Carlowitz-Platz 2

Description: Publishing ecological results is important for myriad reasons. However, the prospect can be daunting as the process seems opaque and littered with unwritten rules. This is a session aimed primarily at early career researchers, although all are invited to attend. The three presenters are all professional staff at ecological journals with slightly different roles. We will outline the general process of publishing from our perspective and discuss common pitfalls. We plan to focus on the initial part of the process – selecting a journal, parts of the submission and how to minimise the probability of desk rejection. We will explain how editor's make the decision to send a paper out for peer review and what article transfer means for the authors. The workshop will be kept light, and participants will be encouraged to ask questions and engage in discussion.

We would like to offer participants the opportunity to submit questions in advance to tree@cell.com. All speakers will be around for the duration of the conference and will be available for further questions.

Open data publishing in biodiversity science and ecology: The viewpoint of a scholarly publisher

Organizer: Iva Boyadzhieva, Head of Journal development, PR and Marketing (Pensoft), i.boyadzhieva@pensoft.net

Location: Forestry Science Building, Hans Carl-von-Carlowitz-Platz 2

Description: The main goal of the session is to address existing challenges and issues experienced by ecology and biodiversity researchers in data publishing and discuss innovative tools, platforms and solutions that facilitate the sharing of open research data and results while fostering the best scientific practices aligning with the FAIR data principles.

We plan to run a preliminary survey and compile a short video presentation, in order to identify some of the most common struggles the community currently faces.

During the session, we will present and discuss common struggles and obstacles related to open and efficient communication of research results and data, including increasing AI use in scholarly publishing. We will suggest solutions to address those issues, ranging from publishing technology to workflows and best practices. We will also invite feedback and further ideas.

As an academic publisher and research project partner, Pensoft will share experience and evaluate together with the participants some of the existing innovative solutions that can be used to overcome the identified constraints.

As an outcome of the session, we will not only identify additional challenges the ecologists are currently facing but will also raise awareness about some of the existing innovative tools and encourage further cooperation on the subject.

Theatre: The Circus of the Trees - about the future role of trees in the city

Venue: HS14, ZHG, TUM Campus Weihenstephan

Technical Information: Directed by Frank M. Raddatz, text by Frank M. Raddatz and Somidh Saha.

A performance of the Theater of the Anthropocene

Urban trees play a crucial role in the future development of cities. Only a sufficient number of healthy trees can regulate the rising temperatures in cities, with differences of up to four degrees. However, only trees that have reached a certain age and are supplied with sufficient water can protect the health and quality of life of human and non-human city dwellers. City trees play a key role in urban future planning as they provide cooling, moisture and shade, provide numerous ecosystem services and are also hotspots of biodiversity. They form an indispensable habitat for countless creatures, microorganisms, insects and birds.
With drama, puppeteers, singing and music, scientific contributions and video clips, The Circus of Trees presents a multifaceted program about the actors who hold the key to the future of cities in their hands or branches. The Theater of the Anthropocene (www.theaterdesanthropozaen.de) was founded in 2019 at the interface of art and science in the context of the Humboldt University of Berlin. Since then, this stage has played a variety of ecological topics with international actors, especially on stages in German-speaking countries. The Circus of Trees is the first piece in the Karlsruhe trilogy that the Theater of the Anthropocene is currently developing together with the Institute for Technology Assessment and Systems Analysis (ITAS), a world-leading technology assessment (TA) facility within the research university Karlsruhe Institute of Technology (https://www.itas.kit.edu/english/index.php). The piece marks the start of a three-part series of ecological and techno-reflexive science theater at the interfaces of TA research, art and society. KIT-ITAS research arises from dialogues at eye level with society. At the same time, KIT-ITAS advises and conducts research on behalf of the German Bundestag and other political institutions. KIT-ITAS' research is problem-oriented and takes into account the perceptions, wishes and concerns of numerous social actors, for example with regard to environmental problems or the effects of digitalization on society. The orientation towards the goal of sustainable development is crucial for all the institute's activities.
With their cooperation, the Theater of the Anthropocene and KIT-ITAS want to use ecological and techno-reflective science theater as a means to better harmonize technological developments with social needs and to enable individual and collective learning processes about the relationships between people, other living beings and our increasingly technological environment.

Excursions

01

Upper Isar: 1-day excursion with Thomas Wagner

Date: Sunday, 08.09.2024

Time: Departure from Freising railway station in front of the 'Freisinger Tagblatt' at 8:00, return ca. 19:00

Price: 50 EUR per person (food and drinks not included)

Max. 24 participants

Description: Once an untamed Alpine river with a braidplain up to 2 km wide, stretching into the Alpine forelands as far as Freising, the Isar has been heavily modified for flood protection and hydropower generation over two centuries. Today, only the Upper Isar between Wallgau and Sylvensteinspeicher is still in a largely natural state. On our excursion, we first visit the Isar near Vorderriss with its still natural riverscape, then a degraded section downstream of the Sylvenstein dam, and conclude with a visit to the Mühltal restoration section, one of the largest restored continuous Alpine river sections in Europe.

02

Vegetation and management of calcareous grasslands in the Munich gravel plain – 1-day excursion with Johannes Kollmann

Date: Sunday 08.09.2024

Time: Departure from Freising railway station in front of the 'Freisinger Tagblatt' at 9:00, return around 16:00

Price: 50 EUR per person (food and drinks not included)

Max. 24 participants

Description: Lowland hike in three sections, with both parts of the hike lead along unpaved paths through flat terrain, each approx. 4 km long. The first excursion destination is the Garching Heath. It is a relict of the historical heathland in the intensively utilised Munich gravel plain. In terms of plant sociology, the vegetation is a mosaic of semi-dry and fully dry grasslands. In addition to the typical plants of the nutrient-poor grasslands, dealpine and continental flora elements contribute to the biodiversity of the area. The area currently harbours 61 species on the Red List of endangered vascular plants in Germany or Bavaria. Representatives of the variegated ground lichen community can be found on the tarmac, an 80-year-old topsoil removal site. Although the Garching Heath has been maintained for over 100 years in the interests of nature conservation, many target species have declined. Possible causes include eutrophication, fragmentation, lack of pollinators, seed removal, rabbit predation and the maintenance regime. A new maintenance and development plan was adopted in 2021, which aims to curb this negative trend through, among other things, a differentiated mowing regime and harrowing of pleurocarp mosses. In order to increase this habitat, extension areas have been created since 1993, where some of the target species have successfully established themselves. The second excursion destination is the Dietersheimer Brenne in the degraded Isarauwald forest. The area has a somewhat lower floristic biodiversity, but is an important FFH biotope and, with its mosaic of calcareous grassland and successional woodland, is an important habitat for butterflies and wild bees in particular. The species composition, conflicts between hunting and nature conservation, habitat fragmentation and corresponding solutions are the topics discussed there. The last excursion point is the Krimmer organic seed propagation farm. Some of the species planted on the expansion areas of the Garching Heath were temporarily propagated there. The production and application of organic seed will be demonstrated and discussed.

03

Kranzberg Forest Roof Experiment (KROOF) – Half-day excursion with Karl-Heinz Häberle and Thorsten Grams

Date: Friday, 13.09.2024 in the morning, about 3,5 h

Time: Departure from Freising railway station in front of the 'Freisinger Tagblatt' at 9:00 , return around 13:00

Price: 25 EUR per person (food and drinks not included)

Max. 50 participants

Description: Ongoing climate change and the associated increase in the frequency and intensity of droughts pose a significant threat to trees and forests worldwide. The death of large forest areas in 2018/2019 has brought this home to us in Germany to an alarming way. The half-day excursion takes us to the Kranzberg Forest Roof Experiment (KROOF), the largest drought experiment on a mature forest in Germany. After a 10-min bus ride and an equally long walk on forest paths, we arrive at the forest laboratory of the Technical University of Munich. In 2013, a drought experiment was started here on about 100 mature trees in a mixed beech-spruce forest. In the first phase of the experiment (4/2014 to 7/2019), successive summer droughts were simulated with the help of throughfall exclusion roofs. Since then, the trees have been in the second phase (2020-2024), in which recovery and legacy effects are monitored before the third phase of the experiment begins in 2025 with an extreme drought until the trees die. We will have the opportunity to discuss the above and below ground drought stress responses and acclimation of the trees growing in mono and mixed situations.

04

Murnauer Moos: 1-day excursion with Hanno Schaefer

Date: Friday, 13.09.2024

Time: Departure from Freising railway station in front of the 'Freisinger Tagblatt' at 8:00, return ca. 19:00

Price: 50 EUR per person (food and drinks not included)

Max. 20 participants

Description: The Murnauer Moos is with an area of 32 km^2 the largest still relatively well-preserved bogland ecosystem in Bavaria and Germany. During 10-km hike, we will see the most important vegetation types, characteristic flora and fauna, and some of the challenges for nature conservation in this nature reserve.

05

Exploring City Oases in Munich: 1-day excursion with Monika Egerer

Date: Friday, 13.09.2024

Time: 9:30 at Marienplatz, Munich (meet at 'Mariensäule'), to end ca. 16:00; use S train S1 from Freising until station 'Marienplatz'

Price: Free (food and drinks not included;-)

Max. 25 participants

Description: Urban green spaces are important habitats in the city for people and nature – becoming what we consider 'urban oases' in the built environment. Under climate change, elements such as trees, park areas and forests will gain importance for contributing to urban heat mitigation and thus climate resilience. Furthermore, vegetatively diverse and structurally complex urban green spaces are linked to biodiversity conservation, as well as to the health of people in the city, who demand recreation and socializing in urban green spaces. In response, the City of Munich has many ambitious plans around urban greening for climate adaptation, biodiversity conservation, and public health. Although great strides have been made in recent years, many challenges remain. In this full-day excursion led by our interdisciplinary research groups, we will visit different green spaces in the city of Munich, including city parks, street trees and gardens. We will discuss developments in urban greening in the inner city, as well as new research in transdisciplinary engagements with city administration in urban labs for the monitoring and assessment of biodiversity. The walk will also be accompanied by a 'climate walk' in which we will use new methods to assess thermal comfort with a 'climate backpack' designed by TUM entrepreneurs.

06

Weltacker Landshut: Half-day excursion with Theresia Endriß

Date: Friday, 13.09.2024 in the morning

Time: Departure from Freising Bahnhof, RE to Landshut at 8:28

Price: 5 EUR per person (food, drinks and public transport not included)

Max. 20 participants

Description: If we divide the global arable land area of 1.5 billion hectares by the number of the world's population, this results in slightly less than 2000 m² per person. A 'Weltacker' is an example of this area. The currently most important crops are grown on this area in proportion to their global acreage. The Weltacker thus makes it clear to us how small this area actually is on which everything is supposed to grow: Food, feed for livestock, cotton for clothing, bio-gas and bio-diesel, renewable raw materials for industry and also luxury foods such as tea, coffee, cocoa and tobacco. There are already 21 Weltäcker worldwide. On our excursion we will visit Bavaria's first Weltacker in Landshut.

07

Berchtesgaden National Park: Two-day field trip on science and conservation in an iconic mountain landscape with Rupert Seidl

Date: Friday 13.09.2024 – Saturday 14.09.2024

Time: Departure from Freising railway station in front of the 'Freisinger Tagblatt' at 8:30 on Friday; return to Freising on Saturday at ca. 17:00

Price: 160 EUR (food, drinks and hotel not included)

Description: Berchtesgaden Nationalpark is Germany's only national park in the Alps. It is a unique landscape characterized by strong environmental gradients and very high biological diversity, that is strongly affected by the ongoing environmental changes. Since 2019, research and monitoring at Berchtesgaden Nationalpark is managed in cooperation with Technical University of Munich, utilizing opportunities for improved insights into the dynamics of mountain landscapes, and providing suport for evidence-based management of protected areas. The field trip will allow participants to experience the diverse ecosystems of Berchtesgaden National Park first hand. We will discuss ongoing research at Berchtesgaden National Park, including topics such as biodiversity across gradients of elevation and land cover, vegetation changes at the tree line, dynamics of mountain ungulates and forest change. We will also address current issues of managing protected areas, including visitors management, the regulation of ungulates, high mountain pastures, and the management of spreading forest disturbances such as bark beetles. The field trip will be guided by the teams at TU Munich and Berchtesgaden National Park (Rupert Seidl, Sebastian König, Michael Maroschek, Rudolf Reiner) with a focus on providing diverse inputs and perspectives for participants.

Hotel Booking: We have reserved a block of rooms for the participants of the excursion for the night 13.09.–14.09.2024 at Hotel Vier Jahreszeiten Berchtesgaden; info@hotel-vierjahreszeiten-berchtesgaden.de; +49(0)8652 9520. To book your room please contact the hotel directly and ask for a room reserved under 'GfÖ' until 10.06.2024; after this date the room block will be returned to the hotel.

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2024

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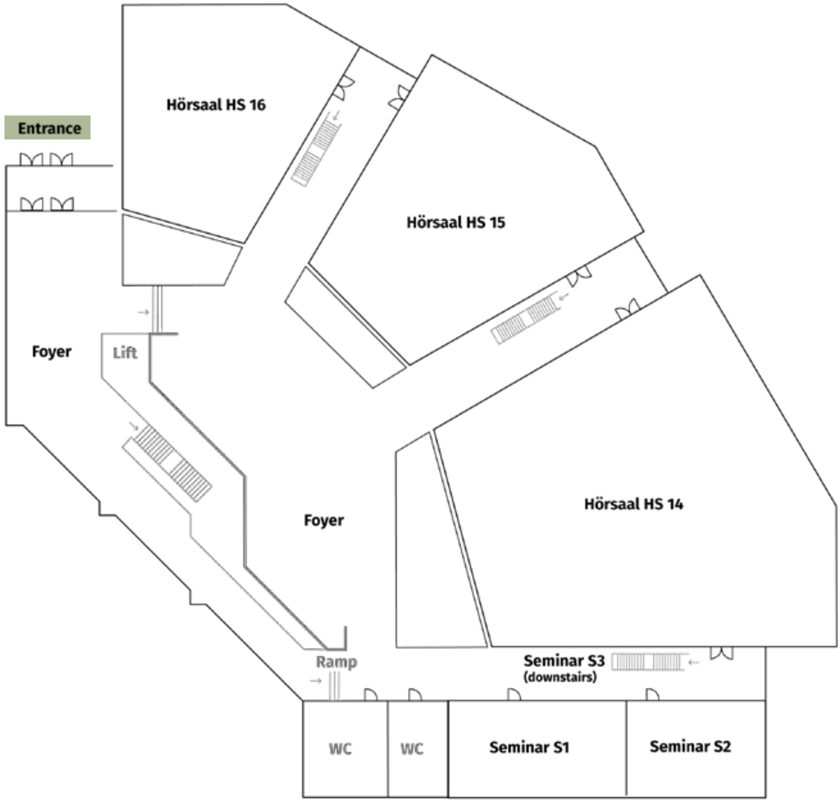
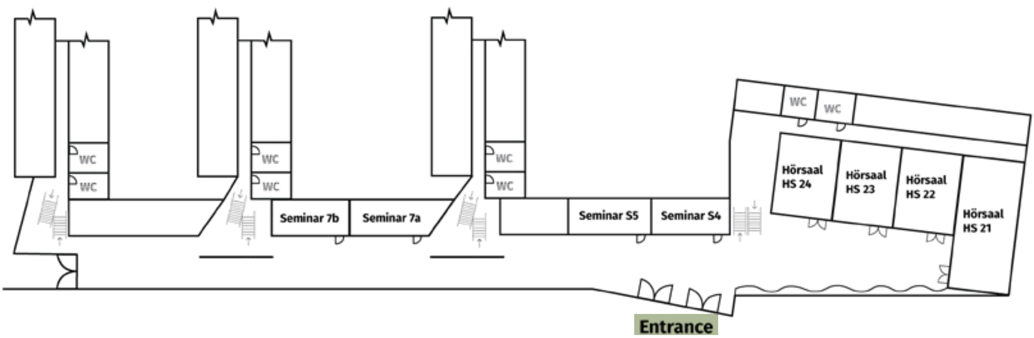
Maps

Map ZHG Building



Map Forestry Building



Schedule

Sunday 08.09.2024

Time	Event
08:00–19:00	**Upper Isar: 1-day excursion with Thomas Wagner** *Location: Freising*
09:00–16:00	**Vegetation and management of calcareous grasslands in the Munich gravel plain - 1-day excursion with Johannes Kollmann** *Location: Freisinger Tagblatt*

Monday 09.09.2024

Time	Event
08:30–18:00	**Registration** *Location: ZHG, foyer*
08:30–20:20	**Recharge, Reflect, Revive pt 1** *Location: ZHG, S3*
08:30–20:20	**Recharge, Reflect, Revive pt 2** *Location: Forestry, S4*
13:00–13:45	**Opening ceremony** *Location: ZHG, HS14*
14:00–15:30	**PE1: Plant responses to the environment across scales** *Location: ZHG, HS15* PE1-O1 - Dryland Mechanisms - do temperate ecosystems copy deserts when adjusting to a warming and drying climate? Speaker: José Grünzweig PE1-O2 - Plant functional composition buffers productivity loss in semi-arid rangelands under drought and high grazing intensity Speaker: Lisa-Maricia Schwarz PE1-O3 - Drought resistance and seed dormancy drive population temporal stability Speaker: Johanne Gresse PE1-O4 - Relevance of osmotic adjustment during drought in mature temperate trees Speaker: Tobias Zhorzel PE1-O5 - Effects of climate, stand structure, soil characteristics and topography on leaf unfolding in Switzerland Speaker: Isabella Ostovary

Time	Event
14:00–15:30	**FE1: Reconciling forest conservation, forest protection and forest management in the climate crisis** *Location: ZHG, HS16* FE1-O1 - Forests in the climate crisis – are we protecting forests from themselves? Speaker: Henrik Hartmann FE1-O2 - Bark beetles in mountain forests: Challenges and opportunities Speaker: Concetta Lisella FE1-O3 - Drought resilience and legacy of a mixed beech-spruce forest – results from a 10-year throughfall exclusion experiment Speaker: Thorsten Grams FE1-O4 - Investigating novel disturbance interactions among 33 tree species with simulated late-frost and drought events Speaker: Vincent Wilkens FE1-O5 - European beech in times of climate change – Insights on tree growth, wood anatomy and leaf morphology from a provenance study along a north-south gradient in Germany Speaker: Juliane Stolz
14:00–15:30	**NC1: Perspectives on biodiversity monitoring are diverse** *Location: Forestry, HS21* NC1-O1 - Results from the first five years of Biodiversity Monitoring South Tyrol (Province of Bolzano/Bozen, Italy) Speaker: Andreas Hilpold NC1-O2 - Benefits of an advanced sampling design for national vegetation monitoring of protected biotopes Speaker: Klaus Ecker NC1-O3 - Human-Computer interaction - reflections on the impact of design and development of a smartphone-app for citizen science and nature experience Speaker: Ulrike Sturm NC1-O4 - Measuring aquatic environments: upscaling the resolution of a biotic index Speaker: Rosetta Blackman NC1-O5 - Rapid Biodiversity Assessment survey for efficient forest biodiversity evaluation in central European forests Speaker: Owen Bradley NC1-O6 - Systematic changes in diversity and composition of tree-related microhabitats across climate and human impact gradients on a tropical mountain Speaker: Giovanni Bianco

Time	Event
14:00–15:30	**NC2: Trends in grassland conservation and restoration** ***Location: Forestry, HS22*** NC2-01 - Is trait-based restoration able to achieve European habitat types? Speaker: Markus Bauer NC2-02 - Spatial patterns of taxonomic, phylogenetic, and functional diversity in plant communities across grassland habitat types Speaker: Selina Baldauf NC2-03 - Estimating grassland restoration success across environmental conditions using beta diversity and metanetworks Speaker: Frank Jauker NC2-04 - Evaluating the impact of grassland management on wild bee communities along an elevational gradient Speaker: Lisa Obwegs NC2-05 - Does the protection of Swiss dry grasslands of national importance work? Speaker: Steffen Boch
14:00–15:30	**CM1: Bringing together theory and data to understand ecological communities** ***Location: Forestry, HS23*** CM1-01 - Do we have the right data? Which ecosystem properties matter? Speaker: Yuval Zelnik CM1-02 - Ecological resilience: Inconsistencies, challenges, and new empirical approaches Speaker: Martina Sánchez-Pinillos CM1-03 - Disentangling metacommunity assembly mechanisms from eDNA using joint species distribution models Speaker: Maximilian Pichler CM1-04 - The multiple advantages of bridging theory and data in the study of interaction networks Speaker: Marco Mello CM1-05 - Dynamics of a plant-pollinator network: Extending the Bianconi-Barabási model Speaker: William J. Castillo CM1-06 - Species diversity, food web structure and the temporal stability of ecosystems: bridging the gap between theory and data? Speaker: Elisa Thebault

Time	Event
14:00–15:30	**SL1: Illuminating the black box of soil food webs across ecosystems, scales, and approaches** *Location: Forestry, HS24* SL1-O1 - Sustainable land use strengthens microbial and herbivore controls in soil food webs in current and future climates Speaker: Marie Sünnemann SL1-O2 - Decreasing trophic transfer efficiency in soil food webs along an altitudinal gradient Speaker: Chen Haozhen SL1-O3 - Energetic and functional development of soil micro- and macro-food webs along a secondary succession Speaker: Ajuan Zhang SL1-O4 - Soil food web states across successional stages, climates, and land use types Speaker: Anton Potapov SL1-O5 - Niche dimensions in soil oribatid mite community assembly under native and introduced tree species Speaker: Johanna Noske SL1-O6 - Broader trophic niches of soil animals under land use and in warmer climate Speaker: Zheng Zhou
15:30–16:00	**Coffee break** *Location: Foyers*
16:00–17:30	**PE1: Plant responses to the environment across scales** *Location: ZHG, HS15* PE1-O6 - Smoothing out the misconceptions of the role of bark roughness in vascular epiphyte attachment Speaker: Jessica Tay PE1-O7 - Arctic tundra ecosystems under fire – potential trajectories for stable state shifts Speaker: Ramona Heim PE1-O8 - Quantifying the changes along the shrub encroachment gradient in sub-alpine grasslands Speaker: Lucia Laorden PE1-O9 - The role of functional plant traits in grassland recovery from drought Speaker: Marie-Louise Schärer PE1-O10 - Bryophyte functional traits are highly responsive to small-scale environmental changes in temperate forest ecosystems Speaker: Till Deilmann PE1-O11 - Physiological response of a mixed forest stand to stress conditions assessed by a novel cuvette system Speaker: Clara Stock

Time	Event
16:00–17:30	**FE1: Reconciling forest conservation, forest protection and forest management in the climate crisis** ***Location: ZHG, HS16*** FE1-O6 - Tree species classification for monitoring ecological succession and assessing forest resilience Speaker: Sebastian Preidl FE1-O7 - Intraspecific variation in phenology of *Fagus sylvatica* - causes and implications for forestry Speaker: Ilka Beil FE1-O8 - Exploring Barriers to Silvicultural Adaptation for Resilient Forests: Insights from a European Survey Speaker: Julius Willig FE1-O9 - Temperature buffering capacity of deadwood Speaker: Orsi Decker FE1-O10 - Influence of forest structure on above- and belowground microclimate Speaker: Barbara Brunschweiger FE1-O11 - Forest temperature buffering in thinned stands and forest gaps Speaker: Kerstin Pierick
16:00–17:30	**NC1: Perspectives on biodiversity monitoring are diverse** ***Location: Forestry, HS21*** NC1-O7 - High throughput digital processing of bulk insect samples for biodiversity monitoring Speaker: Harald Meimberg NC1-O8 - Wild bee monitoring in agricultural landscapes – A conceptual approach incorporating DNA analyses in biodiversity monitoring Speaker: Wiebke Sickel NC1-O9 - Butterfly monitoring – survey methods and their applications Speaker: Friederike Barkmann NC1-O10 - Evaluation of non-destructive lysis for insect DNA metabarcoding Speaker: Lisa Wolany NC1-O11 - CRISPR-Dx assays detect more elusive and endangered amphibians in environmental DNA samples compared to traditional monitoring Speaker: Flurin Leugger NC1-O12 - Metatranscriptomics of soil eRNA: a test study analysing soil animal communties along two elevation gradients in the Alps Speaker: Ina Schaefer

Time	Event
16:00–17:30	**NC2: Trends in grassland conservation and restoration** ***Location: Forestry, HS22*** NC2-O6 - Nitrogen limitation promotes the competitive strength of invasive plants in temperate grasslands Speaker: Leonardo H. Teixeira NC2-O7 - Alien plant invasions in a temperate grassland biome: a case study from northern Kazakhstan Speaker: Tatyana Vakhlamova NC2-O8 - Grazing effects on insect communities and insect-plant networks in mountain pastures Speaker: Bernd Panassiti NC2-O9 - Productivity, moisture, competition - Habitat conditions affecting population viability of the wet grassland orchid Dactylorhiza majalis under conservation-oriented management Speaker: Laura Josephin Hartmann NC2-O10 - Sowing functional grasslands: Effects of forb- and legume-rich seed mixtures on biomass yield and fodder quality – a mesocosm experiment Speaker: Kathrin Möhrle NC2-O11 - Bringing back bumblebees: Modest diversification in intensively used grasslands promotes pollinators Speaker: Regine Albers
16:00–17:30	**CM1: Bringing together theory and data to understand ecological communities** ***Location: Forestry, HS23*** CM1-O7 - Ecological coexistence, in theory and practice Speaker: Adam Clark CM1-O8 - An empirical validation test of modern coexistence theory to forecast time-toextinction under rising temperatures Speaker: Chris Terry CM1-O9 - Combined land-use and climate change: Using a metabolic community model to simulate drought effects on species coexistence in fragmented landscapes Speaker: Leonna Szangolies CM1-O10 - Revealing species coexistence mechanisms through the lens of causations among environmental hypervolume niches, functional traits, and phylogeny Speaker: Guanzhen Liu CM1-O11 - Foreseeing forest futures: ARIMA vs. Neural Networks vs. TBATS in tree growth predictions Speaker: Carlos Landivar CM1-O12 - Mechanistic insights into animal movement and its ecological implications Speaker: Myriam Hirt

Time	Event
16:00–17:30	**SL1: Illuminating the black box of soil food webs across ecosystems, scales, and approaches** *Location: Forestry, HS24* SL1-O7 - Introducing the Circum-Arctic Present and Future Ecology of the Soil Food Web group Speaker: Sylvain Monteux SL1-O8 - High litter and root- derived resources quality enhance plant energy channelling by earthworms Speaker: Linlin Zhong SL1-O9 - Macro-decomposers can rapidly transfer litter carbon and nitrogen into soil mineral-associated organic matter: direct evidence from a novel microcosm experiment of tropical forest Speaker: Niu Guoxiang SL1-O10 - Widespread occurrence of plant cell wall degrading enzymes (PCWDEs) in Oribatida: Revisiting their role in soil food webs Speaker: Bastian Heimburger SL1-O11 - Root–nematode economics space drives the carbon cycle Speaker: Chongzhe Zhang Wrap-up discussion
18:00–18:45	**Keynote: Harnessing agricultural landscapes for biodiversity and ecosystem services: key evidence and knowledge gaps** *Location: ZHG, HS14* Speaker: Emily Poppenborg Martin
19:00–22:00	**Welcome mixer** Location: ZHG, foyer

Tuesday 10.09.2024

Time	Event
08:00–08:45	**Keynote: Persistent problems in plant functional ecology: Why can't we predict traits from climate?** *Location: ZHG, HS14* Speaker: Leander Anderegg
08:00–21:00	**Recharge, Reflect, Revive pt 1** *Location: ZHG, S3*
08:00–21:00	**Recharge, Reflect, Revive pt 2** *Location: Forestry, S4*

Time	Event
09:00–10:30	**NC3: Conserving and restoring biotic interactions** ***Location: ZHG, HS14*** NC3-O1- Restoration success through socio-ecological interactions Speaker: Elena Velado-Alonso NC3-O2 - Recovery dynamics of the functional diversity of plant-frugivore interactions after deforestation Speaker: Anna Rebello Landim NC3-O3 - Disrupted connections: Rainforest fragmentation affects the robustness of interaction networks between frugivorous birds and fruit-bearing trees Speaker: David Becker NC3-O4 - Forest composition shapes seed-rodent interactions in a gradient of broadleaves and conifers Speaker: Pedro Uchoa Mittelman NC3-O5 - Restoration models based on diversity and facilitation that benefit nature and people Speaker: Gislene Ganade NC3-O6 - Seasonally changing interactions of species traits of termites and trees promote complementarity in coarse wood decomposition Speaker: Chao Guo
09:00–10:30	**PE1: Plant responses to the environment across scales** ***Location: ZHG, HS15*** PE1-O12 - Hydraulic constraints at low root temperatures as cause for the cold limit of tree growth Speaker: Günter Hoch PE1-O13 - Do functional composition gradients mimicking land-use intensification affect grassland performance under and after increasingly severe drought? Speaker: Yvonne Künzi PE1-O14 - Natural root grafting: A vector for hydraulic redistribution? Speaker: Marie-Christin Wimmler PE1-O15 - From root to shoot: understanding plant hydraulic regulation across different soil moistures Speaker: Samantha Spinoso Sosa PE1-O16 - Modelling dry-season response of two tree species in a tropical dry forest in Costa Rica Speaker: Gregor Rickert PE1-O17 - Does climate constrain woody species distribution according to their phloem anatomical properties? Speaker: Yan Wang

Time	Event
09:00–10:30	**FE1: Reconciling forest conservation, forest protection and forest management in the climate crisis** ***Location: ZHG, HS16*** FE1-O12 - Assessing the impact of multi-year droughts on German forests in the context of increased tree mortality Speaker: Rico Fischer FE1-O13 - Dynamic forest models and decision support tools for silvicultural decisionmaking in Swiss mountain protection forests Speaker: Gina Marano FE1-O14 - How to adapt forests? – Exploring the role of leaf trait diversity for long-term forest biomass under new climate normals Speaker: Maik Billing FE1-O15 - Inventory and tree-ring based estimates from young tropical trees of five species to identify climate extremes Speaker: Viktoria Dietrich FE1-O16 - Forest recovery patterns in managed and unmanaged forests in Central Europe Speaker: Kirsten Krüger FE1-O17 - LabForest - Consequences of disturbance management and silvicultural treatments on ecosystem services Speaker: Wolfgang Obermeier
09:00–10:30	**EE1: Pollinators and pollination services under global change** ***Location: Forestry, HS21*** EE1-O1 - Pollinator dependency and regional climate affect crop yield development under climate change Speaker: Paula Prucker EE1-O2 - Trait-based responses of wild pollinators in fragmented calcareous grasslands to habitat-associated and agricultural matrix variables Speaker: Carolin Biegerl EE1-O3 - Small-scale, mixed food production systems and semi-natural grasslands support complementary pollinator populations Speaker: Maxime Eeraerts EE1-O4 - Buzzing in the city: How garden features affect bee functional diversity along an urban gradient Speaker: Astrid Neumann EE1-O5 - How plants and bees are exposed and affected by something tiny: micro plastics Speaker: Kenneth Kuba Wrap-up discussion

Time	Event
09:00–10:30	**UE1: Urban biodiversity: how to assess the social-ecological value of urban environments** ***Location: Forestry, HS22*** UE1-O1 - Urban biodiversity: how to assess the social-ecological value of urban environments Speaker: Marco Moretti UE1-O2 - Urbanization affects freshwater macroinvertebrate richness in tropical reservoirs Speaker: Christina Belle UE1-O3 - Quantifying functional contrasts between native and commercial plant species in Swiss urban green spaces Speaker: Vivien Grothe UE1-O4 - Hierarchical filtering of plant traits in urban ecosystems Speaker: Louise Dädlow UE1-O5 - The seasonal influence of vegetation structure on the cooling potential of urban greenspaces in Munich, Germany Speaker: Sophie Arzberger UE1-O6 - Plant communities and their management practices in park green space affect pollinator diversity – A case study of Chongqing city, China Speaker: Fengping Yang
09:00–10:30	**SC1: Fostering collaboration between ecological sciences and the arts: opportunities and challenges** ***Location: Forestry, HS23*** SC1-O1 - Connecting theater performance to science: on the creation of the play 'The Circus of the Trees - about the Future Role of Trees in the City' Speaker: Somidh Saha SC1-O2 - City soundscapes as an artistic way to understand links between people and nature SC1-O3 - Ways of knowing - Potentials of a transdisciplinary integration of knowledge through art-science collaborations Speaker: Florian D. Schneider SC1-O4 - iDiv Artist Residency 2023 - 'From the perspective of the safety net' Speaker: Thore Engel SC1-O5 - Szabadonbalaton: Methodology of a science–art collaboration around Lake Balaton, Hungary Speaker: Diana Berecz SC1-O6 - On facilitating the imagination of regenerative futures Speaker: Oliver Szasz

Time	Event
09:00–10:30	**ME1: Macroecology: investigating large-scale biodiversity patterns under global change** ***Location: Forestry, HS24*** ME1-O1 - Modelling the impact of forest loss and fragmentation on bird species richness at large spatial and temporal scales Speaker: Stav Gelber ME1-O2 - Exploring the drivers of ecological specialization in the geography Speaker: Axel Arango ME1-O3 - Rethinking functional equivalence in island bird communities Speaker: Ana Maria Bastidas Urrutia ME1-O4 - Species traits and community structure can drive scale-dependent propagation of effects in ecosystems Speaker: David Garcia-Callejas ME1-O5 - The importance of biotic interactions among Fynbos Proteaceae for ecological niches, geographical ranges and species' vulnerability to global change Speaker: Joern Pagel ME1-O6 - Land use effects on freshwater biodiversity: synthesis based on a new global database Speaker: Minghua Shen
10:30–11:00	**Coffee break** ***Location: Foyers***
11:00–12:30	**NC3: Conserving and restoring biotic interactions** ***Location: ZHG, HS14*** NC3-O7 - Impact of increased honeybee densities and landscape conservation measures on flower-visitor networks Speaker: Kathrin Czechofsky NC3-O8 - Effects of local and landscape restoration on plant-pollinator networks in calcareous grasslands across Europe Speaker: Ira Hannappel NC3-O9 - Comparison of plant and insect diversity on different flowering field mixtures and densities Speaker: Franziska Mück NC3-O10 - Small scale spatial repartition of plant and pollinator communities shape the structure of plant-pollinator networks in semi-natural grasslands Speaker: Demetra Rakosy NC3-O11 - Balancing biodiversity and yield: Innovative agricultural practices in the Swiss lowlands Speaker: Maura Ganz Poster pitches

Time	Event
11:00–12:30	**PE1: Plant responses to the environment across scales** ***Location: ZHG, HS15*** PE1-O18 -The effects of elevated CO_2 and phosphorus limitation shaping fine root functioning in Central Amazon forests Speaker: Laynara Lugli PE1-O19 - Nutrient dynamics and potential limitations of *Quercus petraea* L. under experimental canopy nitrogen deposition Speaker: Daniel Minikaev PE1-O20 - The underground economy: Reassessing the ecological impact of trade imbalances in common mycorrhizal networks Speaker: Anupa Alice Mathew PE1-O21 - How grassland plant-soil relationships shift under moderate and extreme climate change Speaker: Tyson Terry PE1-O22 - Exploring the influence of floral chemodiversity on alpine plant-microbepollinator dynamics Speaker: Maximilian Hanusch Poster pitches
11:00–12:30	**FE1: Reconciling forest conservation, forest protection and forest management in the climate crisis** ***Location: ZHG, HS16*** FE1-O18 - Forest protection measures in Germany only marginally rely on plant protection products Speaker: Nadine Bräsicke FE1-O19 - Regeneration gap in climate-resilient tree species Speaker: Leonie Gass FE1-O20 - Exploring climate change effects on Alpine forests: a Swiss case study from the Eco2Adapt project Speaker: Maximiliano Costa FE1-O21 - Modelling of natural forest development under climate change in Europe Speaker: Samuel Zweifel FE1-O22 - Assessing climate change adaptation gaps in Germany’s forests using simulation of future potential natural vegetation Speaker: Jonas Kerber Poster pitches

Time	Event
11:00–12:30	**EE1: Pollinators and pollination services under global change** ***Location: Forestry, HS21*** EE1-O6 - Nutrient-driven foraging behavior: Pollen collection patterns among alpine bumble bee species Speaker: Marielle Schleifer EE1-O7 - How can we better understand the impact of global change on bees using mechanistic simulation models and monitoring campaigns? Speaker: Jürgen Groeneveld EE1-O8 - Using complex networks to understand species persistence in empirical plantpollinator communities Speaker: Virginia Domínguez-García EE1-O9 - How resilient are tropical pollinators? Flower-visiting insect communities show diverse recovery trajectories in a neotropical rainforest biodiversity hotspot Speaker: Ugo Mendes Diniz Wrap-up discussion Poster pitches
11:00–12:30	**UE1: Urban biodiversity: how to assess the social-ecological value of urban environments** ***Location: Forestry, HS22*** UE1-O7 - Night shift in the city: Temporal and spatial patterns of wildlife in relation to residents' perceptions Speaker: Simon Sebastian Moesch UE1-O8 - Multi-functional solar parks promoting biodiversity – an ecological-industrial perspective Speaker: Nora Adam UE1-O9 - Opportunities for nature conservation in heavily utilised recreational areas in the city – the success story of the former Tempelhof airfield, Berlin Speaker: Moritz von der Lippe UE1-O10 - NDVI and green volume as proxies for urban bird diversity Speaker: Andrew Fairbairn UE1-O11 - Rethinking urban co-habitats through the lens of a novel agnostic four-level classification Speaker: Gabriele Oneto Poster pitches

Time	Event
11:00–12:30	**SC2: Biodiversity and citizen science** ***Location: Forestry, HS23*** SC2-O1 - Counting butterflies - Are old-fashioned ways of recording data obsolete? Speaker: Elisabeth Kühn SC2-O2 - 'Nature of the Year' organisms in Germany: Awarding does not make a flagship species Speaker: Hilke Hollens-Kuhr SC2-O3 - Tracking the phenology of invasive hogweeds using citizen-science photo observations Speaker: Yves P. Klinger SC2-O4 - Butterfly assembly along space and season: The role of body size and colour Speaker: Roberto Novella Fernandez SC2-O5 - Emerging technologies in citizen science - potential for monitoring, data integration and visibility Speaker: Julie Sheard Poster pitches
11:00–12:30	**ME1: Macroecology: investigating large-scale biodiversity patterns under global change** ***Location: Forestry, HS24*** ME1-O7 - On the role of microclimatic heterogeneity on biodiversity in mountain landscapes: Impacts on organisms of different strata Speaker: Sebastian König ME1-O8 - Interactive effects of macro- and microclimate on species diversity Speaker: Lisa Geres ME1-O9 - How rising temperatures might elevate rates of evolution Speaker: Susanne Fritz ME1-O10 - Projected impacts of climate and land-use change on terrestrial mammal diversity Speaker: Alke Voskamp ME1-O11 - Stop stubbornness: needs, opportunities and obstacles for integrative research in climate change ecology Speaker: Christian Hof Poster pitches
12:30–14:00	**Lunch break** ***Location: Foyers***
12:45–13:45	**Publishing tips and tricks from the other side** ***Location: ZHG, HS15***
12:45–13:45	**A disco in city soundscapes** ***Location: IGZW, rooftop***

Time	Event
13:15–13:45	**Yoga** ***Location: Forestry, foyer***
14:00–15:30	**Poster sessions** ***Location: Foyers***
15:45–16:30	**Award ceremony: Honour medal talk** ***Location: ZHG, HS14*** Speaker: Christian Körner
16:30–17:00	**Coffee break** ***Location: Foyers***
17:00–18:30	**NC3: New perspectives on biodiversity conservation and restoration success through biotic interactions** ***Location: ZHG, HS14*** NC3-O12 - Flower-bee vs pollen-bee metanetworks in fragmented landscapes Speaker: Felipe Librán Embid NC3-O13 - Fitness of four parasitoid Hymenoptera species is related to nest quality and the size of their 15 bee and wasp host species, but not to the wider environment Speaker: Riko Fardiansah NC3-O14 - Community dynamics modifies pollutant-driven species extinction risk: Simulation study with dynamic food web models Speaker: Rajaditya Das NC3-O15 – From the FFH directive to practical implementations Speaker: Juliane Vogt NC3-O16 - Towards climate-smart rewilding Speaker: Gavin Stark NC3-O17 - Rewilding indicators across Europe Speaker: Magali Weissgerber
17:00–18:30	**PE1: Plant responses to the environment across scales** ***Location: ZHG, HS15*** PE1-O23 - Causes and consequences of phenotypic variation in plants Speaker: Bernhard Schmid PE1-O24 - A developmental perspective on phenotypic plasticity of tree xylem traits: how life history trajectories in the species' morphospace define opportunities and risks for tree acclimatization Speaker: Martin Zwanzig PE1-O25 - Genetic response of a perennial grass to warm and wet environments interacts and is associated with trait means as well as plasticity Speaker: Zuzana Münzbergová PE1-O26 - The great trait debate Speaker: Emma Sayer

Time	Event
17:00–18:30	**FE1: Reconciling forest conservation, forest protection and forest management in the climate crisis** ***Location: ZHG, HS16*** FE1-O23 - Identifying forest refugia under climate change in the central European mountains Speaker: Sarah Le Berre FE1-O24 - Observations of forest functioning following climate extremes and bark beetle infestation at the Wetzstein long-term study site Speaker: Daniel Magnabosco Marra FE1-O25 - Risks and benefits of managing non-native tree species in the European alpine space Speaker: Reneema Hazarika FE1-O26 - Douglas fir (*Pseudotsuga menziesii*) in European forests: consequences for wood decomposers and wood decomposition Speaker: Nicolas Roth FE1-O27 - Assessing multiple dimensions of resilience to compounded disturbances and related management drivers in a mixed forest landscape Speaker: Matteo Cerioni FE1-O28 - Resilience and vulnerability: distinct concepts to address global change in forests Speaker: Judit Lecina-DiazPoster
17:00–18:30	**EE2: Manipulation and control - the experimental foundation of global change research** ***Location: Forestry, HS21*** EE2-O1 - Artificial Light At Night drives diel shifts in soil respiration Speaker: Jes Hines EE2-O2 - AgraSim: an experimental simulator for the comprehensive analysis of global change impacts on biogeochemical, hydrological and physiological processes in agricultural systems Speaker: Nicolas Brüggemann EE2-O3 - Does hypobaria affect *Arabidopsis thaliana* along an elevational gradient? Effects of prolonged low air pressure exposition in Ecotron chambers Speaker: Silvia Lembo EE2-O4 - Eco-physiological responses of alpine plant species to low air pressure Speaker: Bouchra el Omari EE2-O5 - Putting the 'Change' into 'Climate' – current methods of simulating climate in modern controlled environment facilities and ecotrons Speaker: Bálint Jákli EE2-O6 - How to optimize sampling effort in ecological experiments and observational studies Speaker: Andreas Schweiger

Time	Event
17:00–18:30	**UE2: Collaborative insights: A transdisciplinary perspective on urban biodiversity projects and lessons learnt** ***Location: Forestry, HS22*** UE2-01 - Designing and implementing evidence-based insect conservation interventions with and for city neighborhoods Speaker: David Schoo UE2-02 - Co-creation of pollinator conservation interventions: Experiences from working with urban community gardeners Speaker: Susan Karlebowski UE2-03 - 'GrüneLunge' (green lung) project in the city of Karlsruhe – map applications showing urban biodiversity Speaker: Ferdinand Betting UE2-04 – Bon appetit! Using citizen science and deep learning to study the foraging activity of ants Speaker: Julie Sheard UE2-05 - InsectMobil: Impacts of landscape on insect diversity and composition through the use of citizen science and DNA metabarcoding Speaker: Birte Peters UE2-06 - FLOW - Citizen science shows that Germany's small streams are in poor ecological status Speaker: Julia von Gönner
17:00–18:30	**SC3: Bridging the gap between knowledge and action: applying biodiversity knowledge in society, policy and economy** ***Location: Forestry, HS23*** SC3-01 - Is that normal? How to encourage farmers to stay calm when perennial wild flower strips go wild Speaker: Anne-Kathrin Schneider SC3-02 - Tackling biodiversity decline within the agricultural landscape – Development of future pathways based on an expert-based scenario analysis in Germany Speaker: Amibeth Thompson SC3-03 - From experience to action: the role of knowledge and nature-relatedness on pro-conservation behaviour intentions in adolescents and adults Speaker: Tanja Straka SC3-04 - Can closer-to-nature forest management help maintain biodiversity and ecosystem services in European forests? Speaker: Ana Stritih SC3-05 - Brazilian dry forests: from science to conservation actions Speaker: Carlos Roberto Fonseca SC3-06 - Implementing a bottom-up stepping stone program in Austria Speaker: Janine Oettel

Time	Event
17:00–18:30	**ME1: Macroecology: investigating large-scale biodiversity patterns under global change** ***Location: Forestry, HS24*** ME1-O12 - Burrowing facilitated the distributional success of mammals and imposes contrasting responses to climatic stability Speaker: Stefan Pinkert ME1-O13 - Phylogenetic diversity patterns and drivers of trees in mountains across the globe Speaker: Maria Laura Tolmos ME1-O14 - Tracing the impact of global change on populations of marine gastropods: A phylogeographic perspective from the Macaronesian islands Speaker: Frederik Feldmann ME1-O15 - Distributions, drivers, and trends of submerged macrophytes: Insights from lakes and rivers in Bavaria Speaker: Anne Lewerentz ME1-O16 - Macroecology of host-parasite interactions: patterns and drivers of the variation of parasitism across latitudinal gradients Speaker: Kawsar khan ME1-O17 - Species distribution modeling of freshwater invertebrates in the Guineo-Congolian region: A Predictive conservation approach Speaker: Emmanuel Akindele
18:45–19:45	**AK meetings** ***Location: div.***
20:00–20:20	**Award Ceremony: Best dissertation award** Speaker: Vera Wersebeckmann
20:20–20:40	**Award ceremony: GfÖ Award** Speaker: Rachel R.Y. Oh
20:45–21:30	**Public talk: Changing forest disturbance regimes – implications for sustainable land use** ***Location: ZHG, HS14*** Speaker: Rupert Seidl

Wednesday 11.09.2024

Time	Event
08:00–08:45	**GfÖ Award 2023: Pathways to climate-smart rural landscapes** ***Location: ZHG, HS14*** Speaker: Sandra Lavorel
08:00–22:00	**Recharge, Reflect, Revive pt 1** ***Location: ZHG, S3***

Time	Event
08:00–22:00	**Recharge, Reflect, Revive pt 2** *Location: Forestry, S4*
09:00–10:30	**NC4: Emerging challenges in wildlife ecology and management in the Anthropocene** *Location: ZHG, HS14* NC4-O1 - Feed on fire: Forage quality dynamics after wildfire in semi-natural grassland grazed by red deer Speaker: Friederike Riesch NC4-O2 - Estimating human and wildlife activities in a Bavarian multi-use forest ecosystem Speaker: Phil Garthen NC4-O3 - Mountain ungulates and humans - Experimental behavioural analyses of the reaction of male chamois (*Rupricapra rupricapra*) to hiker Speaker: Nicolas Cybulska NC4-O4 - Seasonal habitat selection by Alpine chamois (*Rupicapra rupicapra*) in the Bavarian Alps Speaker: Daniela Nagl NC4-O4 - Modelling seasonal space-use of multiple ungulate species in mountain forest ecosystems using camera traps Speaker: Hendrik Edelhoff Wrap-up discussion
09:00–10:30	**PE2: Root traits across biomes - links between belowground traits, species diversity and ecological implications** *Location: ZHG, HS15* PE2-O1 - Root traits across biomes - links between belowground traits, species diversity and ecological implications Speaker: Laynara Lugli PE2-O2 - Rhizosphere engineering: Mind the soil textures Speaker: Bahareh Hosseini PE2-O3 - Dynamics of fine root biomass and morphology of European beech (Fagus sylvatica) in sandy soils with different moisture regimes Speaker: Alexandra Koller PE2-O4 - Tree carbon allocation to root exudates in temperate biomes under varying environmental conditions Speaker: Benjamin Hafner PE2-O5 - Simulating ecosystem adaptation in response to a changing climate by capturing belowground plant functional traits in an eco-evolutionary vegetation model (Plant-FATE) Speaker: Florian Hofhansl PE2-O6 - Experimental warming effects on hyphal growth and depth distribution in a wet-tropical forest of Puerto Rico Speaker: Ana Caroline Miron Pereira

Time	Event
09:00–10:30	**FE2: Silviculture beyond the climax phase: Adaptation strategies for a dynamic forest management in times of change** *Location: ZHG, HS16* FE2-01 - Promoting diverse forest landscapes: How landscape structural complexity affects forest understorey vegetation Speaker: Pia Bradler FE2-02 - Impacts of forest management on the spatio-temporal variability of forest microclimates Speaker: Martin Ehbrecht FE2-03 - Restoration of coniferous monocultures towards mixed broad-leaved forests in Central Europe – Dynamics of stand structure, tree composition, and understorey vegetation Speaker: Alexander Seliger FE2-04 - Drought risk spreading through admixtures of Douglas fir and silver fir with European beech Speaker: Isabelle Lanzrein FE2-05 - Sustainable management of forests on poor soils and in increasingly drier and hotter climate Speaker: Frank Sterck FE2-06 - Safeguarding reforestation efforts on former spruce plantations: Exploring forest irrigation to mitigate drought stress Speaker: Leonie Hahn
09:00–10:30	**EE3: Understanding and safeguarding wetland functioning and ecological networks** *Location: Forestry, HS21* EE3-01 - The use of amino acid isotopes and fatty acids to track the utilization of blue, green and brown carbon by predators in riparian habitats Speaker: Bastiaan Drost EE3-02 - Contrasting drivers of occurrence and fertility in an endangered species of a dynamic riparian habitat Speaker: Sabine Fink EE3-03 - A day on the shore: the impact of recreation activities oncomposition, diversity and structure of lakeshore vegetation Speaker: Nora Meyer EE3-04 - Species-specific elevational niches at the salt marsh edge mediated by biotic interactions and site-specific characteristics Speaker: Boris Schröder-Esselbach EE3-05 - Reviving alpine wetlands in China: How ecological restoration boosts soil carbon stability Speaker: Hao Tang EE3-06 – Rice paddies can help amphibian populations in Swiss agricultural landscapes Speaker: Yvonne Fabian

Time	Event
09:00–10:30	**UE3: Urban ecology meets urban planning - using ecological insight to increase peoplenature interactions** *Location: Forestry, HS22* UE3-O1 - What urban planners need from urban ecologists Speaker: Thomas Hauck UE3-O2 - Planning cities for a nature positive future for people and biodiversity conservation Speaker: Assaf Shwartz UE3-O3 - Ecological objectives for the built-up area of a city Speaker: Wolfgang Weisser UE3-O4 - Assessing functional connectivity in 3-D and the importance of green roofs as stepping-stones in urban areas Speaker: Julia Schiller UE3-O5 - Urban biogeography to enhance city ecosystems for people and nature Speaker: Joan Casanelles Abella Wrap-up discussion
09:00–10:30	**CM2: The future of bio- and eco-acoustic monitoring across scales and ecosystems: Methods, challenges and applications** *Location: Forestry, HS23* CM2-O1 Exploring the impact of forest management on diurnal soundscape dynamics: insights from a forest experiment Speaker: Dominik Arend CM2-O2 - Large-scale acoustic monitoring and automated identification of bird species in an Alpine environment Speaker: Jarek Scanferla CM2-O3 - Exploring the application of bioacoustics for monitoring the biodiversity, health, and functional diversity of wetland environments Speaker: Ian Thornhill CM2-O4 - Recent technological developments allow for passive acoustic monitoring of Orthoptera (grasshoppers and crickets) in research and conservation across a broad range of temporal and spatial scales. Speaker: David Bennett CM2-O5 - Landscape-level monitoring of farmland birds using automated recordings and BirdNET identification Speaker: Marit Kasten CM2-O6 - Towards individual bird counting with deep learning Speaker: Alexander Gebhard

Time	Event
09:00–10:30	**ME2: Collection-based research in plant ecology** *Location: Forestry, HS24* ME2-O1 Plant photographs: an important resource for biodiversity research Speaker: Negin Katal ME2-O2 - What can we learn from individually based phenology data in a botanical garden? Speaker: Tereza Mašková ME2-O3 - Seasonal patterns in flowering intensity in herbaceous species are strongly influenced by temperature and flowering duration Speaker: Robert Rauschkolb ME2-O4 - Exploring historical plant archives – their potential to reveal long-term changes in arthropod-plant interactions and biodiversity. Speaker: Lisa Mahla ME2-O5 - Revealing global macroecological gradients from open-access biodiversity data Speaker: Daria Svidzinska Wrap-up discussion
10:30–11:00	**Coffee break** *Location: Foyers*
11:00–12:30	**NC4: Emerging challenges in wildlife ecology and management in the Anthropocene** *Location: ZHG, HS14* NC4-O6 - Red deer habitat selection in the face of forest and human disturbances Speaker: Juliana Eggers NC4-O7 - Maternal and neonatal behavioral components of roe deer bed-site selection in grassland habitats: implications for mowing activities Speaker: Sophie Baur NC4-O8 - An experimental assessment of acceleration, energy expenditure and behavior-specific metabolic rates in European brown hares Speaker: Jonas Roth NC4-O9 - Hot topics in butterfly research: filling gaps in our knowledge of the vulnerability of butterflies to climate change Speaker: Esme Ashe-Jepson NC4-O10 - Thirty years of Smooth-coated Otter presence in Singapore: Emerging challenges and future research perspectives on the return of charismatic freshwater fauna into an urban environment Speaker: Christina Belle Poster pitches

Time	Event
11:00–12:30	**PE2: Root traits across biomes - links between belowground traits, species diversity and ecological implications** *Location: ZHG, HS15* PE2-O7 - Fine roots in the litter layer: an efficient nutrient acquisition mechanism in the Amazon rainforest Speaker: Nathielly Pires Martins PE2-O8 - Convergence of leaf and root traits is driven by different environmental factors in Hengduan Mountain forests Speaker: Ya-Huang Luo PE2-O9 - Impacts of vegetation diversity on invertebrate fauna and microbial communities on agroecosystems Speaker: Paula Thitz Wrap-up discussion Poster pitches
11:00–12:30	**FE3: Understanding the impacts of climate and land Use change on tundra and northern boreal forest ecosystems** *Location: ZHG, HS16* FE3-O1 - Determining drivers of boreal mountain treeline ecotone responses in changing climates Speaker: Sarah Haupt FE3-O2 - Differential sensitivity of sub-arctic peatland versus tundra heath CO_2 fluxes to drough Speaker: Valentin Heinzelmann FE3-O3 - Impacts of climate change on ecosystem functions of moss and lichen communities at high latitudes Speaker: Philipp Porada FE3-O4 - Using remote sensing data in arctic tundra conservation planning Speaker: Antonia Ludwig FE3-O5 - Monitoring progress towards adequate and representative protection of the Arctic tundra Speaker: Hao Xia Poster pitches

Time	Event
11:00–12:30	**EE3: Understanding and safeguarding wetland functioning and ecological networks** *Location: Forestry, HS21* EE3-O7 - Paludiculture can support biodiversity conservation in rewetted fen peatlands Speaker: Alexander Drexler EE3-O8 - Greenhouse gas fluxes in tidal marsh soils along a salinity gradient in the Elbe Estuary Speaker: Fay Lexmond EE3-O9 - Livestock grazing controls methane emissions from Baltic and North Sea coastal wetlands Speaker: Clarisse Gösele EE3-O10 - Mesocosm study: How does warming affect the carbon cycle of Baltic coastal marshes? Speaker: Ella Logemann EE3-O11 - Understanding warming effects on soil microbial communities, redox conditions and their interactions along the elevational gradient of salt marshes Speaker: Julian Mittmann-Götsch Poster pitches
11:00–12:30	**UE3: Urban ecology meets urban planning- using ecological insight to increase peoplenature interactions** *Location: Forestry, HS22* UE3-O6 - The spatial distribution inequity and relationship between green surface area and green volume: a perspective from public and private green Speaker: Xia Yao UE3-O7 - Demographic and experience-based correlates of attitudes towards and preferred proximity of 32 different animals among the population of Munich Speaker: Fabio Sweet UE3-O8 - Roadsides as novel ecosystems and potential ecological traps: reviewing the state of knowledge Speaker: Johannes Kollmann UE3-O9 - The effect of optimizing a building envelope for plants and humans: a case study using simulated green roof communities Speaker: Laura Windorfer UE3-O10 - Biologische Vielfalt in der Städtebauförderung berücksichtigen – Ergebnisse und Empfehlungen Speaker: Rieke Hansen Poster pitches

Time	Event
11:00–12:30	**CM3: Advancing ecology with deep learning** *Location: Forestry, HS23* CM3-O1 - Next-generation biodiversity assessment: An automated approach Speaker: Philipp Meyer CM3-O2 - From pixels to populations: AI-driven insights into grassland insect ecology Speaker: Robert Künast CM3-O3 - Automated plant-pollinator interaction monitoring with an open-source DIY camera trap Speaker: Maximilian Sittinger CM3-O4 - Computer-vision based automated assessment of post-disturbance forest resilience Speaker: Kilian Hochholzer CM3-O5 - Integrating empirical connectivity models and deep learning to prioritize sites for greening to improve ecological connectivity for urban birds Speaker: Lisa Merkens Poster pitches
11:00–12:30	**ME3: Insights from globally coordinated and distributed experiments and surveys** *Location: Forestry, HS24* ME3-O1 - General independent negative effect of drought and positive effect of nutrients on grassland biomass production Speaker: Viviana Bondaruk ME3-O2 - Decade-long active restoration of extremely degraded alpine meadows improved turnover and stability of soil carbon Speaker: Yanfu Bai ME3-O3 - LegacyNet – An international voluntary network investigating multi-species grassland leys to support sustainable agriculture Speaker: Sebastian T. Meyer ME3-O4 - Controlled environment experiments: key findings from the Montpellier European Ecotron Speaker: Alexandru Milcu ME3-O5 - 15-year seasonal warming effects on plant community dynamics Speaker: Yujie Niu Poster pitches
12:30–14:00	**Lunch break** *Location: Foyers*
12:45–13:45	**Open data publishing in biodiversity science and ecology: The viewpoint of a scholarly publisher** *Location: ZHG, HS15*
13:15–13:45	**Yoga** *Location: Forestry, foyer*

Time	Event
14:00–15:30	**Poster sessions** *Location: Foyers*
15:45–16:30	**Keynote: Designing Cities for Everyday Nature** *Location: ZHG, HS14* Speaker: Sarah Bekessy
16:30–17:00	**Coffee break** *Location: Foyers*
17:00–18:30	**NC4: Emerging challenges in wildlife ecology and management in the Anthropocene** *Location: ZHG, HS15* NC4-O11 - Crop diversity but not smaller field size benefits bats in landscapes dominated by agriculture Speaker: Thomas Hiller NC4-O12 - The spatial configuration of maize fields and its impact on bird diversity in summer and autumn Speaker: Mirjam Rieger NC4-O13 - The raptor lockdown menu—Shifts in prey composition suggest urban peregrine diets are linked to human activities Speaker: Brandon Mak NC4-O14 - Birdie, albatross, eagle? - Avian diversity on golf courses Speaker: Pia Tappe NC4-O15 - A death trap in the nest. Anthropogenic nest material entanglement causes significant nestling mortality in a terrestrial bird Speaker: Ursula Heinze NC4-O16 - Interactive effects of forest quality and weather on nestling conditions of a cooperative breeding Afro-tropical bird Speaker: Gladys Nyakeru Kungu

Time	Event
17:00–18:30	**NC5: The future of biodiversity in interdisciplinary research** *Location: ZHG, HS16* NC5-O1 - Novel natures: New technologies in nature conservation require interdisciplinary debates Speaker: Tina Heger NC5-O2 - What can environmental ethics do? A critique of the use of 'relational values' in nature conservation Speaker: Sonja N. K. Daum NC5-O3 - Eco-cultural comparison of alpine farming methods in Val Senales and Verçenik Valley under traditional ecological knowledge Speaker: Oguz Basar NC5-O4 - Joint environmental and social benefits from diversified agriculture Speaker: Ingo Grass NC5-O5 - Promoting insect appreciation in urban areas: Combining social and natural sciences to improve system and transformation knowledge Speaker: Deike Lüdtke NC5-O6 - Bridging ecological, interdisciplinary research and public engagement: Insights from the BioDivKultur project Speaker: Johanna Berger
17:00–18:30	**PE3: Carbon allocation in plants and ecosystems under climate change** *Location: Forestry, HS21* PE3-O1 - Long-term warming effects on carbon allocation dynamics in a subarctic grassland Speaker: Fabrizzio Protti PE3-O2 - High vapour pressure deficit hampers carbon allocation in tropical trees through turgor limitation Speaker: Richard L. Peters PE3-O3 - No future growth enhancement expected at the northern edge for European beech due to continued water limitation Speaker: Stefan Klesse PE3-O4 - Tree growth responses to drought – stress type and timing matters Speaker: Nadine Ruehr PE3-O5 - Carbon dynamics in beech and spruce saplings under future climate change scenarios Speaker: Qiao-Lin Gu PE3-O6 - Using bomb ^{14}C to study nonstructural carbon dynamics in European beech and Norway spruce Speaker: Boaz Hilman

Time	Event
17:00–18:30	**EE4: Lighting up the landscape: Effects of artificial light at night on natural, agricultural and urban landscapes** ***Location: Forestry, HS22*** EE4-01 Light pollution of freshwater ecosystems: ecological impacts and remedies Speaker: Franz Hölker EE4-02 - Combining field and lab experiments: the impact of different streetlights on the flight behaviour of moths Speaker: Jacqueline Degen EE4-03 - Effects of artificial light at night on alien plant invasions Speaker: Yanjie Liu EE4-04 - Exploring a cryptic diversity of parasitoid wasps affected by Artificial Light at Night (ALAN) Speaker: Manuel Dietenberger EE4-05 - Slugs hide in the dark: Impact of Artificial Light at Night on herbivory Speaker: Eva Knop EE4-06 - Exploring conservation approaches for nocturnal biodiversity Speaker: Gregor Kalinkat
17:00–18:30	**CM4: Can good modeling practices foster sustainable land management?** ***Location: Forestry, HS23*** CM4-01: Beyond guides, protocols and acronyms: adoption of good modelling practices depends on challenging academia's status quo in Ecology Speaker: Tatiane Micheletti CM4-02 - Reusable building blocks for strengthening agent-based modelling and theory of socio-ecological systems Speaker: Jürgen Groeneveld CM4-03 - Developing multidisciplinary models for sustainable land use: challenges and approaches Speaker: Daniel Vedder CM4-04 - pyMANGA: Harnessing the power of modularity and reusability for robust ecological modeling Speaker: Marie-Christin Wimmler CM4-05 - BeeScapeR: The Swiss Army Knife for BEE-STEWARD Research Speaker: Max Luttermann Wrap-up discussion

Time	Event
17:00–18:30	**UE4: Potential and challenges of urban restoration** ***Location: Forestry, HS24*** UE4-01 - The potential of tree-related microhabitats (TreMs) and other ecosystem services among cemetery trees in Karlsruhe city Speaker: Somidh Saha UE4-02 - The role of roadsides for urban rehabilitation: Trait–environment and trophic interactions in cavity-nesting bees, wasps, and their antagonists Speaker: Simon Dietzel UE4-03 - Maintenance effects on the biodiversity of floodplain grasslands: vegetation, ground beetles and general arthropod fauna Speaker: Andrea Schneider UE4-04 - The acceptability of urban rewilding among local communities Speaker: Brenda Maria Zoderer UE4-05 - Blooming beauty or withered weeds? Empirical study of public perception and acceptance of insect-friendly urban meadows over the course of the year Speaker: Barbara Zaunbrecher UE4-06 - What hinders the restoration of urban ecosystems? Results from a pan-European survey Speaker: Ann Solveig Krouthén
18:45–19:45	**General assembly** ***Location: ZHG, HS16***
20:00–22:00	**Theatre: The Circus of the Trees - about the future role of trees in the city** ***Location: ZHG, HS14***

Thursday 12.09.2024

Time	Event
08:00–08:45	**Keynote: Planning urban green infrastructure to enhance social-ecological resilience** ***Location: ZHG, HS14*** Speaker: Sara Meerow
08:00–20:00	**Recharge, Reflect, Revive pt 1** ***Location: ZHG, S3***
08:00–20:00	**Recharge, Reflect, Revive pt 2** ***Location: Forestry, S4***

Time	Event
09:00–10:30	**NC6: New developments in the field of insect declines in Central Europe** *Location: ZHG, HS14* NC6-O1 - Temperature stress for overwintering ground-nesting bees Speaker: Marie Tuchtfeldt NC6-O2 - Neonicotinoids negatively affect life history functions of widespread dung fly species Speaker: Aditi Rawal NC6-O3 - Perception and effects of pesticedes in the food of Bombus terrestris Speaker: Carmen Nebauer NC6-O4 - New insights into the impact of land use on taxonomic and phylogenetic insect diversity Speaker: Mareike Kortmann NC6-O5 - Simplification of insect communities across land-use and elevational gradients: conservation insights from an alpine region Speaker: Elia Guariento NC6-O6 - Pitfalls in measuring insect populations and biodiversity trends Speaker: Jörg Müller
09:00–10:30	**EE5: Biodiversity Exploratories (BE): the value of long-term research platforms in the real world-land-use, biodiversity, ecosystem processes and services** *Location: ZHG, HS15* EE5-O1 - 18 years Biodiversity Exploratories: Review, developments and future perspectives Speaker: Victoria Grießmeier EE5-O2 - Data management within the BE - a key factor for enabling successful research Speaker: Andreas Ostrowski EE5-O3 - Effects of spatiotemporal variation of land-use intensity in grasslands Speaker: Nico Blüthgen EE5-O4 - Long-term assessment of the impact of mowing intensity on grassland biodiversity Speaker: Margarita Hartlieb EE5-O5 - From microscale to landscapes: the importance of nitrifiers and soil mineral associations for N storage in grasslands under different land use intensities Speaker: Narda Pacay-Barrientos EE5-O6 - IntraFlor – How do grazing, mowing, and fertilization intensities affect floral cues and rewards of common meadow plants, their pollinator interactions and pollination outcome? Speaker: Vidisha Bansal

Time	Event
09:00–10:30	**FE4: Trends and advances in forest ecology: Ecological patterns and processes** ***Location: ZHG, HS16*** FE4-O1 - Creating biodiversity rich forest landscapes in Europe: What we know and what we can do Speaker: Britta Uhl FE4-O2 - Historical land use effects on biodiversity: A case study from southern Germany Speaker: Miriam Diez FE4-O3 - How long does it take? – Comparing the structure of beech forest reserves and virgin beech forests using the Development Stage Index Speaker: Eike Feldmann FE4-O4 - Community assembly history of initial decomposer insects can explain later successional communities and deadwood decomposition Speaker: Shamik Roy FE4-O5 - Elevation modifies associations between aboveground and belowground communities in forests across different climatic regions Speaker: Jiayun Zou FE4-O6 - Do forest fires have an impact on moth communities? Speaker: Cathrina Balthasar
09:00–10:30	**PE4: Water in plants under climate change - From cells to ecosystems** ***Location: Forestry, HS21*** PE4-O1 - Climate change sensitivity of Central Europe's major forest tree species – species comparison and options for forestry Speaker: Christoph Leuschner PE4-O2 - Drought legacy effects on tree water fluxes in a temperate Scots Pine forest at its tipping point Speaker: Simon Haberstroh PE4-O3 - Tree water status and root water uptake of mature European beech and Douglas fir in pure and mixed stands throughout the drought summer 2022 Speaker: Christina Hackmann PE4-O4 - Water use and growth patterns of European beech and Douglas fir in pure and mixed stands in wet and dry years, and the role of canopy structural traits and tree neighborhood Speaker: Sharath Paligi PE4-O5 - Simulating drought-stress of Lower Saxonian forests under climate change using regionalised climate projections Speaker: Ramona Riedel

Time	Event
09:00–10:30	**PE5: Multiple stressors in Global-Change Ecology** *Location: Forestry, HS22* PE5-O1 - Number of simultaneously acting global change factors affects composition, diversity and productivity of grassland plant communities Speaker: Benedikt Speißer PE5-O2 - Stress-resistant plant communities for urban stormwater management Speaker: Nadja Katharina Berger PE5-O3 - Over 100 years of change: stronger diversity decline in lowland than in mountain grasslands Speaker: Stefan Widmer PE5-O4 -Climate change and management independently affect the nutrition of grassland plants Speaker: Yva Herion PE5-O5 - Global change in experimental above-belowground multitrophic grassland communities Speaker: Hendrik Mohr PE5-O6 - Land use modulates resistance of grasslands against future climate and interannual climate variability in a large field experiment Speaker: Lotte Korell
09:00–10:30	**RS1: Remote sensing of biodiversity** *Location: Forestry, HS23* RS1-O1 Copernicus Data Space Ecosystem is transformative for landscape ecology Speaker: András Zlinszky RS1-O2 - Exploring the relation of forest height heterogeneity and tree species diversity using Remote Sensing Speaker: Elisabeth Rahmsdorf RS1-O3 - Reaching new heights: Unraveling the quality of global canopy height maps Speaker: Vitezslav Moudry RS1-O4 - Quantifying tree cover loss across European forests from 1984 to 2023 Speaker: Katja Kowalski RS1-O5 - Plant trait retrieval from spectral data: Collective efforts of the scientific community outperform data simulations Speaker: Daniel Mederer RS1-O6 - Establishing a novel training data set to aid circumboreal AI applications to detect individual trees and species in northern boreal forests and the tundra transition: BorFIT Speaker: Stefan Kruse

Time	Event
09:00–10:30	**AG1: Role of IPM-based biodiversity measures in agricultural landscape transformation** *Location: Forestry, HS24* AG1-O1 - The contribution of insect-promoting measures to IPM in agricultural transformation processes – Lessons learned from the FInAL project Speaker: Tiemo von Steimker AG1-O2 Positive effects of wildflower strips on invertebrate organisms and ecosystem services above and below ground Speaker: Sonja Knapp AG1-O3 Overwintering of ground-dwelling arthropods in wildflower strips: do agricultural practices matter? Speaker: Alfredo Venturo AG1-O4 The effect of strip cropping with oilseed rape and wheat on pest densities and natural enemies Speaker: Michelle Grote AG1-O5 - Understanding the impact of insect-promoting measures on beneficial and pest occurrence: The FInAL project approach Speaker: Niels Lettow AG1-O6 - Less yield for more biodiversity – seeking a compromise when undersowing maize with biodiversity-enhancing partners Speaker: Vera Wersebeckmann
10:30–11:00	**Coffee break** *Location: Foyers*
11:00–12:30	**NC7: Temporal biodiversity change analyses to support sustainable land management and conservation** *Location: ZHG, HS14* NC7-O1 - MonA: Mobilisation and analysis of raw vegetation data from German federal monitoring programs Speaker: Jana Bürger NC7-O2 - Consistent species trends across three federal states in Germany revealed by repeated habitat mapping data Speaker: Lina Lüttgert NC7-O3 - Half a century of vegetation changes across temperate non-forest habitats: minor changes in species richness, considerable shifts in taxonomic and functional composition Speaker: Klára Klinkovská NC7-O4 - Effects of habitat age and ploughing on ground-dwelling arthropods in perennial flower strips Speaker: Christopher Hellerich NC7-O5 - Herbivore community stability coupling with dynamics of tree communities in a subtropical forest Speaker: Ming-Qiang Wang NC7-O6 - Archived natural DNA samplers reveal four decades of biodiversity change across the tree of life Speaker: Isabelle Junk

Time	Event
11:00–12:30	**EE5: Biodiversity Exploratories (BE): the value of long-term research platforms in the real world-land-use, biodiversity, ecosystem processes and services** *Location: ZHG, HS15* EE5-O7 - Rethinking the quantification of land use in forests Speaker: Michael Staab EE5-O8 - Landscape structure and composition impact forest biodiversity and ecosystem services within the Biodiversity Exploratories Speaker: Leana Gooriah EE5-O9 - The role of tree species identity, forest management and abiotic conditions for biodiversity in deadwood and wood decomposition – synthesis of the 14-year BELongDead Experiment Speaker: Sebastian Seibold EE5-O10 - Tree microhabitat dynamics at the stand and tree scale Speaker: Peter Schall EE5-O11 - Canopy openness affects decomposer communities of carrion in forests Speaker: Marit Hertlein EE5-O12 - Changes in moth communities along land-use intensity gradients in forests and grasslands Speaker: Rafael Achury
11:00–12:30	**FE4: Trends and advances in forest ecology: Ecological patterns and processes** *Location: ZHG, HS16* FE4-O7 - Quantifying the impacts of lightning-induced tree mortality using a dynamic global vegetation model Speaker: Andreas Krause FE4-O8 - Exploring future disturbance scenarios for Europe's forests Speaker: Marc Grünig FE4-O9 - Beyond resilience: Responses to changing climate and disturbance regimes in temperate forest landscapes across the Northern Hemisphere Speaker: Christina Dollinger FE4-O10 - Effect of climate change on the recovery capacity of Fagus sylvatica after a severe disturbance event along its productivity gradient in Central Europe Speaker: Katarina Merganicova FE4-O11 - Quantifying the pace of succession: Turnover rates of tree functional composition after disturbances Speaker: Bettina Ohse FE4-O12 - Enhancing reforestation success through scale-adapted spatiotemporal coordination of natural and artificial regeneration: insights from simulation experiments with the iLand model Speaker: Xinying Zhou

Time	Event
11:00–12:30	**PE4: Water in plants under climate change - From cells to ecosystems** *Location: Forestry, HS21* PE4-O6 - Hydraulically redistributed water by mature oak trees is taken up by neighbouring seedlings of three different species during natural drought periods Speaker: David Dluhosch PE4-O7 - Comparing the drought vulnerability of mature and juvenile trees in a mixed temperate forest stand Speaker: Raphael Dups PE4-O8 - Pinpointing the shift from environmental to stomatal control of transpiration Speaker: Martin Bader PE4-O9 - Continuous monitoring of stem water potential in deciduous forests: Assessing a novel microtensiometer for ecosystem hydraulics research Speaker: Ruth-Kristina Magh PE4-O10 - Can we derive early warnings on tree drought stress intensity from stem shrinkage? Speaker: Yanick Ziegler PE4-O11 - City trees under drought – relating functional ecology to remote sensing Speaker: Tamalika Chakraborty
11:00–12:30	**PE5: Multiple stressors in Global-Change Ecology** *Location: Forestry, HS22* PE5-O7 - Fertilization alters resistance but not recovery responses to drought intensity in an experimental grassland community Speaker: Svenja Wanke PE5-O8 - Metacommunity processes shape multi-scale biodiversity dynamics in fragmented landscapes Speaker: Zachary Hajian-Forooshani PE5-O9 - Applying metacommunity theory to understand the dynamics of extinction debt Speaker: Beatriz Prado Bastos Monteiro PE5-O10 - Multi-resource dung beetle networks within the context of forest recovery Speaker: Karen Marie Pedersen PE5-O11 - Are ant and termite communities dispersal- or habitat-limited along a forest recovery gradient? Speaker: Nina Grella PE5-O12 - Multiple-stressor impacts on multitrophic interactions and ecosystem functioning – lessons learnt from experimental forest systems Speaker: Malte Jochum

Time	Event
11:00–12:30	**RS1: Remote sensing of biodiversity** ***Location: Forestry, HS23*** RS1-O7 - Phenological heterogeneity and forest stand improvement management in Southern Germany Speaker: Haiyin Ye RS1-O8 - Fresh leaves in fall: a binary indicator of stress in *Fagus sylvatica*? Speaker: Julia Joswig RS1-O9 - Grassland decline and land cover change in Lower Saxony – classification and quantification Speaker: Hauke Itzek RS1-O10 - Monitoring of eco-hydrological changes following rewetting of European peatlands – Towards the integration of earth observation in restoration management Speaker: Laura Giese RS1-O11 - Ecosystem and landscape restoration across spatial and temporal scales to enhance biodiversity and climate resilience in agricultural landscapes Speaker: Ayushi Kurian Wrap-up discussion
11:00–12:30	**AG1: Role of IPM-based biodiversity measures in agricultural landscape transformation** ***Location: Forestry, HS24*** AG1-O7 - Including beneficial functional traits of weeds in control strategies Speakers: Mona Schatke AG1-O8 -Sound manipulation and proximity to natural vegetation augment bat abundance in Mediterranean vineyards Speaker: Itamar Giladi AG1-O9 - Differential contribution of biological control by bats and birds and the role of the landscape structure Speaker: Mina Anders AG1-O10 - Increases in ecological infrastructure and the potential of changing pest dynamics by structural complexity: a review of effective strategies in orchards Speaker: Tim Mark Ziesche AG1-O11 - Utilizing functional biodiversity in fruit and arable farming. Socioeconomic lessons learned from project experience Speaker: Bettina Wenzel AG1-O12 - Fruit production in coffee (*Coffea arabica* L.) crops is enhanced by the behaviour of wild bees (Hymenoptera: Apidae) Speaker: Patricia Landaverde
12:30–14:00	**Lunch break** ***Location: Foyers***
12:45–13:45	**What is the role of ecologists in the climate and environmental crisis? – A case for public action** ***Location: ZHG, HS15***

Time	Event
13:15–13:45	**Yoga** *Location: Forestry, foyer*
14:00–14:45	**Keynote: Blue nature-based solutions: value, knowledge, and rules hindering and leveraging river restoration.** *Location: ZHG, HS14* Speaker: Aude Zingraff-Hamed
15:00–16:30	**NC8: Evaluating protected areas for biodiversity conservation currently and in the future** *Location: ZHG, HS14* NC8-O1 - Evaluating ecological representation in protected area networks - metrics and tools from systematic conservation planning Speaker: Kerstin Jantke NC8-O2 - Single large or several small: Exploring the effect of reserve size on biodiversity in protected forest areas Speaker: Anne Huber NC8-O3 - Influence of land use on bird communities, taxonomic and functional diversity in the Vjosa River National Park in Albania Speaker: Dea Zyruku NC8-O4 - The impact of road traffic on protected areas and biodiversity across the globe Speaker: Maarten van Strien NC8-O5 - Identifying conservation and restoration potential of biodiversity under climate change Speaker: Sven Rubanschi NC8-O6 - Climate change is expected to severely impact protected designation of origin olive growing regions over the Iberian Peninsula Speaker: Inês Guise
15:00–16:30	**EE6: Beta diversity and beta ecosystem functioning: Landscape homogenization, new indices and the potential for beta BEF research** *Location: ZHG, HS15* EE6-O1 - BETA-FOR – Enhancing structural diversity in production forests – a blueprint for experimental beta diversity research in real world ecosystems Speaker: Oliver Mitesser EE6-O2 - Restoring structural beta-heterogeneity promotes diversity of higher trophic level taxa in a forest landscape Speaker: Clara Wild EE6-O3 - Shifts in seed disperser communities in spring: The diversity of ants and gastropods, and slug-mediated seed removal in temperate forests with enhanced structural heterogeneity Speaker: Lisa Albert EE6-O4 - Beta complexity Speaker: Ulrich Brose EE6-O5 - The global human impact on ecological communities Speaker: François Keck

Time	Event
15:00–16:30	**FE4: Trends and advances in forest ecology: Ecological patterns and processes** *Location: ZHG, HS16* FE4-O13 - Increasing frequency of drought years threatens the viability of beech forests in Central Germany Speaker: Nadja Rüger FE4-O14 - Drought resistance of Abies alba seedlings of different provenances to simulated drought Speaker: Thomas Medicus FE4-O15 - Deciphering the future dynamics of temperate montane forest: Early snowmelt's influence on winter herbivory and seedling drought resistance. Speaker: Miguel Munoz Mazon FE4-O16 - High nitrate and sulfate leaching in response to wetter winters in temperate beech forests Speaker: Aron Garthen FE4-O17 - Impacts of a thermohaline circulation shutdown on European tree-species distributions Speaker: Allan Buras Wrap-up discussion
15:00–16:30	**Water in plants under climate change - From cells to ecosystems** *Location: Forestry, HS21* PE4-O12 - SCC II Throughfall Exclusion Experiment: First results indicate high sensitivity and vulnerability of temperate tree species to progressing drought Speaker: Ansgar Kahmen PE4-O13 - Mature beech and spruce under five years of recurrent summer drought – The impact of stomatal regulation and leaf area adjustment on tree water use Speaker: Benjamin Hesse PE4-O14 - Mechanistic modelling of extreme drought stress in European forests Speaker: Phillip Papastefanou PE4-O15 - Effect of flooding on physiological vitality and survival of floodplain-forest tree species Speaker: Josef Urban PE4-O16 - Rooting for hyphae: Functional persistence of AMF water transport to plants during soil drying Speaker: Alora Kraus PE4-O17 - Beyond mean annual precipitation: How rainfall variability shapes tree water use in a semi-arid savanna Speaker: Tim Herkenrath

Time	Event
15:00–16:30	**PE5: Multiple stressors in Global-Change Ecology** *Location: Forestry, HS22* PE5-O13 - Earthworm invasion derails belowground multidiversity and ecosystem multifunctionality Speaker: Olga Ferlian PE5-O14 - Centuries of change: The role of climate, pollution, and eutrophication in shaping Lake Biodiversity Speaker: Miklós Bálint PE5-O15 - Eco-phenotypic feedbacks differ in multi-stress environments Speaker: Lynn Govaert PE5-O16 - Diversity and climate are main drivers of riverine fish stability across spatial scales Speaker: Fei Ma PE5-O17 - A mechanistic description of the interplay of soil moisture and soil water salinity as abiotic driving factors for the establishment of vegetation patterns in tropical saltmarshes Speaker: Ronny Peters PE5-O18 - Flexible foraging behaviour increases predator vulnerability to climate change Speaker: Benoit Gauzens
15:00–16:30	**RS2: Remote sensing for understanding sustainable land use across scales** *Location: Forestry, HS23* RS2-O1 - Remote sensing and machine learning-based maps of the environment and the need to account for the area of applicability Speaker: Hanna Meyer RS2-O2 - Branch biomass estimation for urban trees based on TLS data Speaker: Leila Parhizgar RS2-O3 - Leaf to Landscape: Deciphering Vegetation's Effect on Rainfall Erosivity by Lidar Speaker: Johannes Senn RS2-O4 - Drone models to predict rangeland resources are transferable in space and time Speaker: Vistorina Amputu RS2-O5 - A hybrid modelling approach to establish links between forest attributes and hyperspectral data Speaker: Samuel Fischer RS2-O6 - From pixels to birds: Remote sensing reveals habitat heterogeneity's role in Alpine bird communities. Speaker: Matteo Anderle

Time	Event
15:00–16:30	**AG2: Above- and belowground structures and traits of agroforestry systems: chances and trade-offs** *Location: Forestry, HS24* AG2-O1 - From traditional to modern agroforestry systems: Benefits for biodiversity, animal welfare, productivity and climate resilience Speaker: Felix Herzog AG2-O2 - Long-term yield dynamics in arable alley cropping agroforestry under the influence of climatic water balance and soil properties – a case study Speaker: Olef Koch AG2-O3 - Drought resistance and regeneration ability of three savannah tree species from agroforestry systems in the Sahel zone – results of a greenhouse experiment Speaker: Karl-Heinz Häberle AG2-O4 Grafting as a method for the conservation of cacao genetic diversity and local biodiversity in tropical agroforests Speaker: Carolina Ocampo-Ariza AG2-O5 - Factors driving tree community structure in traditional home gardens in the Mayan forest. Speaker: Norka Maria Fortuny Fernández AG2-O6 - Boosting birds and bats with agroforestry Speaker: Martin Entling
16:30–17:00	**Coffee break** *Location: Foyers*
17:00–18:30	**NC8: Evaluating protected areas for biodiversity conservation currently and in the future** *Location: ZHG, HS14* NC8-O7 - Future climate and land use changes threaten the effectiveness of Swiss protected areas Speaker: Bertrand Fournier NC8-O8 - Where to do what – identifying focus zones for Swiss agricultural priority birds Speaker: Noëlle Klein NC8-O9 - Evaluating German development co-operation's approaches to support protected areas, their biodiversity and their people Speaker: Anna Sting NC8-O10 - Habitat associations of day-flying Lepidoptera and their foodplants: Lessons for the selection and management of protected areas Speaker: Esme Ashe-Jepson NC8-O11 - Efficacy of the Mexican protected areas network in representing species' ecological niches Speaker: Andrés Lira-Noriega NC8-O12 - Mapping 30% by 2030: An evidence base for creating resilient landscapes in Scotland Speaker: Fairlie Kirkpatrick Baird

Time	Event
17:00–18:30	**EE6: Beta diversity and beta ecosystem functioning: Landscape homogenization, new indices and the potential for beta BEF research** *Location: ZHG, HS15* EE6-O6 - Environmental filtering, not dispersal history, drives global patterns of phylogenetic turnover in seed plants at deep evolutionary timescales Speaker: Lirong Cai EE6-O7 - Exploring the interplay of area and beta diversity in scaling the diversitystability relationship Speaker: Julia Mayr EE6-O8 - Biodiversity at multiple spatial scales buffers ecosystem functioning against extreme climate events Speaker: Gaëtane Le Provost EE6-O9 - Spatial factors influence beta-diversity patterns of invertebrate communities in water-filled tree holes more than small-scale environmental factors Speaker: Francesca Cerroti EE6-O10 - Landscape complexity affects trap-nesting bee and wasp communities Speaker: Sara Tassoni EE6-O11 - Reconciling agriculture and biodiversity: high quality butterfly communities in Northern Italian agroecosystems Speaker: Michela Audisio
17:00–18:30	**FE4: Trends and advances in forest ecology: Ecological patterns and processes** *Location: ZHG, HS16* FE4-O18 - Diversity-enhanced canopy space occupation and canopy leaf trait diversity jointly promote overyielding in tropical tree communities Speaker: Tama Ray FE4-O19 - The interplay of carbon stocks and biodiversity in European managed forests and underlying mechanisms Speaker: Julian Lunow FE4-O20 - Overyielding in a mixed deciduous forest is driven by both above- and belowground adaptation, and influenced by ontogenetic changes in allometry Speaker: Boris Rewald FE4-O21 - Experimental canopy nitrogen deposition effects in temperate forests: The case of *Quercus petraea* L. and *Fagus sylvatica* L. ring width and wood density Speaker: Daniel Minikaev FE4-O22 - Forest Informed Neural Networks (FINN) - Combining deep learning and process-based models to improve inference and prediction of forest dynamics Speaker: Yannek Käber Wrap-up discussion

Time	Event
17:00–18:30	**PE4: Water in plants under climate change - From cells to ecosystems** *Location: Forestry, HS21* PE4-O18 - Effects of forest fires on tree hydraulics Speaker: Stefan Mayr PE4-O19 - Conifers and broad-leaved trees fundamentally differ in their water storage strategies Speaker: Roman Mathias Link PE4-O20 - Gas movement between xylem conduits can be slow and affects xylem vulnerability curves in flow-centrifuge experiments Speaker: Luciano de Melo Silva PE4-O21 - Wood anatomical and hydraulic traits of Tamarix species across a large geographical gradient: climate and phylogenetic relationships Speaker: Frank Thomas PE4-O22 - Similarity in hydraulic safety but not efficiency among 81 temperate tree species Speaker: Fon Tezeh PE4-O23 - Are established non-native tree species better suited for establishing climateresilient forests compared to their native counterparts within the same genus? Speaker: Bernhard Schuldt
17:00–18:30	**PE6: Ecosystem response to repeated climate extremes - an integrated approach across organizational scales** *Location: Forestry, HS22* PE6-O1 - Ecosystem response to repeated climate extremes – an integrated approach across organizational scales through functional traits Speaker: Qingqing Chen PE6-O2 - Divergent responses of plant, soil and ecosystem processes to recurrent drought events Speaker: Michael Bahn PE6-O3 - Tree diversity decreases the legacy effect of compound climate extremes on forest ecosystems Speaker: Xuetao Qiao PE6-O4 - Resource use strategies of biodiversity can buffer grassland productivity during climate anomalies Speaker: Daniela Hoss PE6-O5 - A win-win global climate change adaptation and mitigation: Evidence from sustainable cocoa management Speaker: Samuel Owusu PE6-O6 - The role of hydrochory in structuring a metapopulation along a fragmented river Speaker: Ilaria Rita Guiducci

Time	Event
17:00–18:30	**RS2: Remote sensing for understanding sustainable land use across scales** *Location: Forestry, HS23* RS2-O7 - Airborne assessment of evapotranspiration across tree islands in an oil palm landscape Speaker: Thorge Wintz RS2-O8 - Investigating post-disturbance forest recovery dynamics in the European Alps: What can be seen from Earth observation data? Speaker: Lisa Mandl RS2-O9 - Mapping species-specific tree dieback across Germany using Sentinel-2 time series and regression based unmixing Speaker: Jonas Alsleben RS2-O10 - Evaluating machine learning techniques and data sources for dead trees detection Speaker: Júlia Matejčíková RS2-O11 - From phreatophyte species to habitat probability for groundwater-dependent vegetation - A multiscale approach Speaker: Léonard El-Hokayem RS2-O12 - Assessing northern boreal forest migration and the extent of tundra losses in a warming climate Speaker: Stefan Kruse
17:00–18:30	**AG3: Ecological and social dimensions of future renewable energy systems** *Location: Forestry, HS24* AG3-O1 - Innovative hydropower: fish passage, mortality and habitat effects Speaker: Juergen Geist AG3-O2 - Environmental impacts of floating PV Speaker: Jocelyn Mitchell AG3-O3 - The role of stakeholders in corporate biodiversity management in the Middle East and North Africa (MENA) region Speaker: Ghada Amin AG3-O4 - Integration of nature-based solutions in ground mounted photovoltaic and onshore wind energy sites for a nature positive energy transition Speaker: Gayathri Mohan AG3-O5 - Red kites and wind power: Increasing the cut-in speeds of wind turbines can contribute to more effective protection of the species Speaker: Marcel Becker AG3-O6 - Wind turbines in forests: Implications for species conservation and regulatory responses using the example of Germany Speaker: Julia Ellerbrok

Time	Event
18:45–19:30	**Closing ceremony** *Location: ZHG, HS14*
19:30–22:00	**Conference dinner** *Location: Bräustüberl Weihenstephan*
21:30–01:30	**Disco night** *Location: Bräustüberl Weihenstephan*

Friday 13.09.2024

Time	Event
08:00–19:00	**Murnauer Moos: 1-day excursion with Hanno Schäfer** *Location: Freising*
08:30–13:00	**Weltacker Landshut: Half-day excursion with Theresia Endriß** *Location: Freising Bahnhof*
08:30–23:59	**Berchtesgaden National Park: 2-day field trip on science and conservation in an iconic mountain landscape with Rupert Seidl** *Location: Freising*
09:00–13:00	**Research data management for advancing sustainable land use practices** *Location: Forestry, HS24*
09:00–13:00	**Exploration, analysis and cloud processing of free Sentinel imagery for ecological monitoring with Copernicus Data Space Ecosystem** *Location: Forestry, S4*
09:00–12:00	**Improving the contribution of ecology to the planning of green cities** *Location: Forestry, S7b*
09:00–12:30	**Kranzberg Forest Roof Experiment (KROOF) - Half-day excursion with Karl-Heinz Häberle and Thorsten Grams**
09:30–13:00	**Effective digital note taking: How to organize your knowledge and streamline your workflow with Obsidian** *Location: Forestry, S7a*
09:30–17:00	**Exploring City Oases in Munich: 1 day excursion with Monika Egerer** *Location: Marienplatz, Munich*

Saturday 14.09.2024

Time	Event
12:00–17:00	**Berchtesgaden National Park: Two-day field trip on science and conservation in an iconic mountain landscape with Rupert Seidl**

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