HELMHOLTZ
Centre for Environmental Research

Frontiers in Experimental Research on Changing Environments

7–9 June 2022 – Leipzig / Bad-Lauchstädt, Germany

https://www.ufz.de/longtermfieldexperiments

BOOK OF ABSTRACTS

Tuesday, 7 June 2022

time / room	Hall 1 AB	
09:00	**OPENING**	
09:30	**KEYNOTE SPEACH** Simulating climate change in drylands: Amount and variability of precipitation *Osvaldo Sala (Arizona State University, USA)*	
10:30	Coffee break	
	Hall 1 A	Hall 1 CD
	T4: Context dependencies and interactions among drivers Alexandra Weigelt, Leipzig University	**T2: Climate change impacts** Francois Buscot, UFZ Halle
11:00	The heterogeneity–diversity–system performance nexus *Nico Eisenhauer (Leipzig University / iDiv)*	AnaEE: the European research infrastructure for experimentation on ecosystems *Michel Boer[1]; Karel Klem[2]; Klaus Steenberg Larsen[3]; Marcello Donatelli[4] ([1] AnaEE ERIC; [2]CzechGlobe; [3] University of Copenhagen; [4] CREA)*
11:20	Joint impacts of climate and predation on multitrophic interactions and ecosystem functioning *Malte Jochum; Merlin Helle; Ines Laude; Benjamin Bischoff; Helge Bruelheide; Julia Tiede; Nico Eisenhauer (Leipzig University / iDiv)*	Unearthing the mechanisms behind soil carbon sequestration *Luiz Domeignoz-Horta; Seraina Cappelli; Anna-Liisa Laine (University of Zurich)*
11:40	Varying responses of flowering phenology and functional traits to future climate on meadows versus pastures *Carolin Plos[1]; Christine Römermann[2]; Isabell Hensen[1] ([1]Martin Luther University Halle-Wittenberg; [2] Friedrich Schiller University Jena)*	Long-term crop and flux data from SoilCan lysimeters at Dedelow, Uckermark *Horst H. Gerke[1]; Jannis Groh; Thomas Pütz; Michael Sommer ([1] ZALF)*
12:00	Historical context modifies plant diversity–community productivity relationships in alpine grassland *Shan Luo*	Climate impacts on metal bioavailability in agricultural phytoremediation systems *Natalia Sánchez; Carolina Vergara Cid; Sören Drabesch; Mika Tarkka; Marie Muehe[1] ([1]UFZ)*
12:20	The multitrophic processes are shaped by mycorrhizas and tree diversity *Huimin Yi*	Strategies to mitigate municipal waste and greenhouse gas emissions in kira municipality in Wakiso District. *Haruna Lubega[1]; Evelyne Ivy Kabasuga[1]; Faridah Nakanwagi[2] ([1] KISANA; [2] Makarere University, Uganda)*

12:40	Lunch	
14:00	**KEYNOTE SPEACH** The Power of Experimental Macroecology in Disentangling Global Change Impacts on Plants, Vegetation, & Ecosystems *Vigdis Vandik (University of Bergen, Norway)*	
	T4: Context dependencies and interactions among drivers Nico Eisenhauer, Leipzig University / iDiv	**T2: Climate change impacts** Francois Buscot, Lotte Korell, UFZ Halle
	Hall 1 A	Hall 1 CD
15:10	Plant diversity and soil history effects on community assembly of arbuscular mycorrhizal fungi *Cynthia Albracht[1]; Marcel Dominik Solbach[2]; François Buscot[3]; Anna Heintz-Buschart[4]* *([1] UFZ Halle; [2] University of Cologne; [3] UFZ / iDiv; [4] University of Amsterdam / UFZ Halle)*	Irrigation induced changes in organic carbon stocks of agricultural soil - what do we really know? *David Emde (Thünen Institute of Climate-Smart Agriculture)*
15:30	Response of soil microbial communities to mixed beech - conifer forests varies with site conditions *Jing-Zhong Lu; Stefan Scheu (University of Göttingen)*	Soil structure turnover by biotic and abiotic drivers under two different environmental conditions *Frederic Leuther[1]; Robert Mikutta[2]; Maximilian Wolff[2]; Klaus Kaiser[2]; Steffen Schlüter[3] ([1]Swedish University of Agricultural Sciences; [2] Martin Luther University Halle-Wittenberg; [3] UFZ)*
15:50	Heatwave and warming induce distinctive community responses through their interactions with a novel, range-expanding species *Jinlin Chen, Owen T. Lewis (University of Oxford)*	Effects of experimental droughting on litter decomposition by tropical millipedes and other invertebrates *Mukhlish Jamal Musa Holle; Owen T. Lewis (University of Oxford)*
16:10	Coffee break	
16:40	Multifactorial and multidisciplinary approaches to study adaptation of wheat rhizosphere communities to drought *Claudia Breitkreuz[1]; Anna Heintz-Buschart[2]; François Buscot[3]; Sara Fareed Mohamed Wahdan[4]; Mika Tarkka[3]; Thomas Reitz[3] ([1] UFZ - Halle/Julius Kuehn-Institute (JKI); [2] UFZ - Halle, / iDiv / University of Amsterdam; [3] UFZ - Halle, / iDiv; [4] UFZ - Halle)*	Warming effects on greenhouse gas fluxes from Wadden Sea salt marshes *Miriam Fuss; Peter Mueller; Norman Rueggen; Lars Kutzbach (University of Hamburg)*
17:00	An innovative sensor platform for in-situ studies of dynamics and underlying processes, driving spatio-temporal water, carbon and greenhouse gas flux pattern in a heterogeneous arable landscape *Mathias Hoffmann; Maren Dubbert; Shrijana Vaidya; Adrian Dahlmann; Marten Schmidt; Norbert Bonk; Peter Rakowski; Gernot Verch; Michael Sommer, Jürgen Augustin (ZALF)*	The formation and loss of warm-adapted microbial temperature relationships in response to summer heatwaves in the Subarctic *Dániel Tájmel; Carla Cruz-Paredes; Johannes Rousk (Lund University)*

17:20	Plant age, soil texture and drought rather than the presence of root hairs affect maize and its rhizosphere microbiome *Mika Tarkka[1]; Minh Ganther[2]; Michael Santangeli[3]; Bunlong Yim[4]; Eva Lippold[2]; Manuela Désirée Bienert[5]; Marie-Lara Bouffaud[6]; Patrick Bienert[5]; Kornelia Smalla[4]; Eva Oburger[3]; Doris Vetterlein[2]; Anna Heintz-Buschart[7] ([1]UFZ / iDiv; [2]UFZ; [3] BOKU Vienna; [4] Julius Kühn-Institut (JKI); [5] Technical University of Munich; [6] UFZ; [7] University of Amsterdam)*	Tree growth resistance to the 2018-2020 drought as modulated by tree diversity and mycorrhizal type *Lena Sachsenmaier[1]; Florian Schnabel[1]; Peter Dietrich[2]; Nico Eisenhauer[1]; Sylvia Haider[3]; Olga Ferlian[2]; Bernhard Schuldt[4]; Fon Robinson Tezeh[4]; Christian Wirth[1] ([1] iDiv / Leipzig University; [2] iDiv; [3] (iDiv / Martin-Luther University of Halle-Wittenberg; [4] University of Würzburg)*
17:40	Root hairs matter at field scale for maize shoot growth and nutrient uptake, but root trait plasticity is primarily triggered by texture and drought *Doris Vetterlein[1]; Maxime Phalempin; Eva Lippold; Steffen Schlüter; Susanne Schreiter; Mutez Ahmed; Andrea Carminati; Patrick Bienert; Patrick Duddek; Manuela Désirée Biener Mika Tarkka; Minh Ganther; Eva Oburger; Michael Santangeli; Helena Jorda; Mathieu Javaux; Jan Vanderborght ([1] UFZ)*	
18:00	**POSTERSESSION & GET TOGETHER (Foyer)**	

Wednesday, 8 June 2022

time / room	Hall 1 AB	
09:00	**KEYNOTE SPEACH** Biodiversity-mediated effects of global changes on ecosystems: scaling up and predicting responses *Forest Isbell (University of Minnesota, USA)*	
10:00	Coffee break	
	Hall 1 A	Hall 1 CD
	T4: Context dependencies and interactions among drivers Nico Eisenhauer, Leipzig University/ iDiv	**T1: Ecosystem responses to landuse change** Ute Wollschläger, UFZ Halle
10:30	Impacts of climate change and land use on soil energy fluxes *Marie Sünnemann (iDiv)*	Long-term study of different crop residue managements (green fallow, straw, fallow land) on biomass yields and soil properties *Bernd Honermeier[1]; Yavar Vaziritabar[1]; Janna Macholdt[2] ([1] Justus Liebig University Gießen; [2] Martin Luther University Halle-Wittenberg)*

10:50	Reproduction and population growth of plants in a changing environment *Martin Andrzejak[1]; Lotte Korell[1]; Tiffany Knight[2] ([1]UFZ / iDiv; [2] UFZ / iDiv / Martin-Luther-University Halle-Wittenberg)*	Arbuscular mycorrhizal colonization and functional root traits of winter wheat in an early stage silvoarable agroforestry system following a standardized transect sampling protocol *Eva-Maria Minarsch[1]; Christoph Ormos[1]; Philipp Weckenbrock[1]; Joana Bergmann[2]; Andreas Gattinger[1] ([1] Justus-Liebig-University Gießen; [2] ZALF)*
11:10	Land-use intensity modulates climate change impacts on annual decomposition dynamics in temperate agricultural systems *Thomas Reitz[1]; Rachel Sophie Zimmer[2]; Claudia Breitkreuz[3]; Mika Tarkka[2]; Luise Ohmann[2] ([1] UFZ / iDiv; [2] UFZ ; [3] UFZ / JKI)*	Soil and microbial C:N:P stoichiometric ratios are shaped by fertilization strategy and affect ecosystem-relevant traits of the microbial community. *Evgenia Blagodatskaya[1]; Vusal Guliyev[1]; Thomas Reitz[2] ([1] UFZ; [2] UFZ / iDiv)*
11:30	Estimating the effects of climate change and land-use on rodent dynamics, associated parasites and pathogens *Philipp Koch[1]; Martin Pfeffer[2]; Anna Obiegala[2]; Erik Schmolz[3]; Jens Jacob[1] ([1]JKI, [2] University of Leipzig; [3] UBA)*	Influence of different fertilization regimes on carbon sequestration in the Thyrow long-term field experiment DIV.2 *Christina-Luise Roß; Michael Baumecker; Frank Ellmer; Timo Kautz ([1] HU Berlin / ADTI)*
11:50	Metagenomic analysis of soil microbiomes responses to climate and land-use change during the summers of 2014-2019 *Qicheng Bei[1]; Thomas Reitz[2]; François Buscot[2]; Anna Heintz-Buschart[2] ([1] iDiv; [2] UFZ)*	Land use impact on carbon mineralization in well aerated soils is mainly explained by variations of particulate organic matter rather than of soil structure *Steffen Schlüter[1]; Tim Roussety[1]; Lena Rohe[2]; Vusal Guliyev[1]; Evgenia Blagodatskaya[1]; Thomas Reitz[1] ([1] UFZ; [2] Thünen Institut für Agrarklimaschutz)*
12:10	Management intensity in croplands and grasslands affect earthworm biomass differently under ambient and future climatic scenario *Qun Liu[1]; Stefan Scheu[2]; Nico Eisenhauer[3]; Martin Schädler[1] ([1] UFZ; [2] Johann-Friedrich-Blumenbach Institute of Zoology and Anthropology; [3] iDiv)*	Response of subsoil organic matter contents and physical properties to long-term, high-rate farmyard manure application *Maximilian Wolff[1]; Frederic Leuther; Klaus Kaiser; Lena Schumann; Ines Merbach; Steffen Schlüter; Robert Mikutta ([1] Martin-Luther-University of Halle-Wittenberg)*
13:15	Departure to Bad Lauchstädt	
20:00	**Conference Dinner in Leipziger KUBUS**	

Thursday, 9 June 2022

time / room	Hall 1 AB	
09:00	**KEYNOTE SPEECH** Understanding and managing organic carbon sequestration in soils as delineated from long-term observations and field experiments *Ingrid Kögel-Knabner (Technical University of Munich)*	
10:00	**Panel Discussion**	
11:00	Coffee break	
	Hall 1 A	Hall 1 CD
	T1: Ecosystem responses to landuse change Hans-Jörg Vogel, UFZ Halle	**T2: Climate change impacts** Lotte Korell, UFZ Halle
11:30	Effects of catch crops on yields and nitrate leaching under different N-fertilization levels to silage maize on a sandy soil in Northwestern Germany *Norbert Bischoff[1]; Linda Noltemeyer[1]; Annegret Fier[1]; Marie-Christin Albers[2]; Andrea Knigge-Sievers[2] ([1] State Authority for Mining, Energy and Geology; [2] Chamber of Agriculture in Lower Saxony)*	Do field experiments underestimate global change effects? – the case of drought and aboveground biomass *György Kröel-Dulay[1]; Andrea Mojzes; Katalin Szitár; Michael Bahn; Péter Batáry; Claus Beier; Mark Bilton; Hans J. De Boeck; Jeffrey S. Dukes; Marc Estiarte; Petr Holub; Anke Jentsch; Inger Kappel Schmidt; Juergen Kreyling; Sabine Reinsch; Klaus Steenberg Larsen; Marcelo Sternberg; Katja Tielbörger; Albert Tietema; Sara Vicca; Josep Peñuelas ([1] Centre for Ecological Research)*
11:50	Modelling long-term dynamics of soil functions under agricultural management *Sara König[1]; Ulrich Weller[1]; Birgit Lang[2]; Bibiana Betancur-Corredor[2]; Thomas Reitz[1]; Hans-Jörg Vogel[1]; Martin Wiesmeier[3]; Ute Wollschläger[1] ([1] UFZ; [2] Senckenberg Museum of Natural History; [3] TUM Technical University of Munich)*	Plant community dynamics in a 13 year seasonal warming experiment *Yujie Niu; Max Schuchardt; Anke Jentsch (Bayreuth University)*
12:10	Biodiversity Exploratories: experimental research in managed landscapes *Markus Fischer[1]; Victoria Grießmeier[2] ([1] University of Bern/ Institute of Plant Sciences; [2]Senckenberg - Biodiversität und Klimaforschungszentrum (BiK-F))*	Marsh ecosystem response to increased temperature (MERIT): a novel in situ salt marsh warming experiment. *Viktoria Unger[1]; Roy Rich[2]; Miriam Fuß[1]; Salomé Gonçalves[1]; Peter Mueller[1]; Eva Ostertag[1]; Svenja Reents[1]; Hao Tang[1]; Allegra Tashjian[2]; Simon Thomsen[1]; Kai Jensen[1]; Stefanie Nolte[3] ([1] Universität Hamburg; [2] Smithsonian Environmental Research Center; [3] University of East Anglia)*

12:30	Species losses, gains, and changes in persistent species are associated with distinct effects on ecosystem functioning in global grasslands *Emma Ladouceur[1,2,3], Shane A. Blowes[1,4], Jonathan M. Chase[1,4], Adam T. Clark[1,2,5], Magda Garbowski[1,2], ... + The Nutrient Network,... W. Stanley Harpole[1,24] ([1] iDiv / [2] UFZ / [3] University of Leipzig, [4] Martin Luther University Halle-Wittenberg, [5] Karl-Franzens University of Graz)*	
12:50	Lunch	
	Hall 1 A	Hall 1 CD
	T1: Ecosystem responses to landuse change Harald Auge, UFZ Halle	**T4: Context dependencies and interactions among drivers** Alexandra Weigelt, Leipzig University
14:00	Deciphering the effects of tree species richness and mycorrhizal association on community productivity – first five-year results of the long-term tree diversity experiment MyDiv *Peter Dietrich; Olga Ferlian; Yuanyuan Huang; Shan Luo; Julius Quosh; Nico Eisenhauer (iDiv)*	Indirect effect of fertilization on tree overyielding via change in species dominance *Dai Saito[1]; Friderike Beyer[1]; Grégoire T. Freschet[2]; Anja Klingler[3]; Charles Nock[4]; Michael Scherer-Lorenzen[3]; Jürgen Bauhus[1] ([1]University of Freiburg; [2] Université Toulouse III; [3] University of Freiburg; University of Alberta)*
14:20	Mycorrhiza in Tree Diversity-Ecosystem Function Relationships: the first seven years of the iDiv platform MyDiv *Olga Ferlian (iDiv)*	Microbial processes impacting soil carbon cycling under anthropogenic change: trait-based scaling from individuals to the ecosystem *Ashish Malik[1]; Robert Griffiths[2]; Steven Allison[3] ([1] University of Aberdeen; [2] UK Centre for Ecology & Hydrology; [3] University of California Irvine)*
14:40	Effects of low ammonia concentrations on N-sensitive higher plant species in a greenhouse and field study *Jürgen Franzaring; Julia Kösler (Universität Hohenheim)*	A new era in landscape ecology: Raising a flag for landscape experiments. *Anna Pereponova[1]; Kathrin Grahmann[1]; Gunnar Lischeid ([1]ZALF)*
15:00	Using agroecosystem models to design newly diversified cropping systems in combination with new field arrangements in spatially heterogeneous landscapes *Ixchel Hernandez-Ochoa[1]; Thomas Gaiser[1]; Kurt-Christian Kersebaum[2]; Heidi Webber[2]; Kathrin Grahmann[2]; Sabine Seidel[1]; Frank Ewert[3] ([1]University of Bonn; [2] ZALF; [3] University of Bonn / Leibniz Center for Agricultur)*	
15:20	**CLOSING (hall 1 A)**	

Keynotes

in alphabetical order

Biodiversity-mediated effects of global changes on ecosystems: scaling up and predicting responses

Forest Isbell

Department of Ecology, Evolution & Behavior, University of Minnesota, USA

The long-term impacts of global change drivers on ecosystem functioning and stability can strongly depend on how these drivers alter biodiversity and shift community composition. For example, although chronic nitrogen enrichment initially increases productivity, it can also lead to loss of plant species, including initially dominant species, which can then cause substantial diminishing returns from nitrogen fertilization. Land use change and climate change are similarly eroding biodiversity, with consequences for ecosystem functioning and stability. Importantly, land use change and climate change alter biodiversity at multiple spatial scales and have substantial inertia. Thus, two important next steps in understanding the biodiversity-mediated effects of global changes on ecosystems are to: (1) consider changes in beta diversity and their consequences for ecosystems at larger spatial and temporal scales and (2) predict ecosystem responses to climate change. In this talk, we will explore how long-term and new field experiments that manipulate habitat fragmentation, warming, and drought are advancing understanding in both these ways.

Understanding and managing organic carbon sequestration in soils as delineated from long-term observations and field experiments

Ingrid Kögel-Knabner and Martin Wiesmeier

Chair of Soil Science, School of Life Sciences, Technical University of Munich, Freising-Weihenstephan, Germany

Soil organic matter is decisive for almost all soil properties and functions and plays a central role in the global carbon cycle. SOM is of central importance for the formation of a stable soil structure through microstructure formation and aggregation. In this way, it has a significant influence on the air and water balance of the soil, the aeration and microbial activity, the infiltration and storage of water, the stability of the soil aggregate, and the trafficability and workability of the soil. Soil compaction and erosion can be reduced by a sustainable supply with OM. In addition to its importance for soil fertility and functionality, humus is the largest terrestrial carbon reservoir on earth and thus plays a crucial role in climate regulation. A targeted buildup of SOM, especially in agricultural soils, could make a significant contribution to climate mitigation and adaptation. In order to store more OM in the soil with a positive effect on the climate, not only must the existing OM stocks be preserved, but more carbon (C) must also be sequestered from the atmosphere by accumulating C in the soil (C sequestration). Long-term observations and field trials are of utmost importance to quantify the basic strategies to build up OM: either the input of organic matter into the soil is increased by changing management/land use, or the decomposition of organic matter is reduced by increasing its residence time in the soil or promoting its stabilization.

Simulating climate change in drylands: Amount and variability of precipitation

Osvaldo Sala

Global Drylands Center and School of Life Sciences, Arizona State University, USA

Drylands account for more than 40% of the terrestrial surface and play a key role in the global carbon cycle accounting for most of its interannual variability. In addition, drylands are home for 30% of the human population and support 50% of livestock in the world. The major impacts of climate change in drylands occur through changes in precipitation. Global scenarios predict two impactful changes for drylands: a decrease in precipitation amount and an increase in interannual variability with more severe and prolonged droughts followed by periods of high precipitation. Increased variability is a dimension of climate change that has received less attention than changes in amount of precipitation.

Experiments are the only way to address cause-effect relationships and they complement observations. Field experiments manipulate precipitation amount or variability while isolating the effects of other variables such as previous conditions, temperature and seasonality. Observations although cannot determine cause-effect relationships, they determine patterns broadly distributed in space and time that can reject or support hypotheses.

Climate change impacts on ecosystems depend on the change in climate and the ecosystem sensitivity to those changes. Future precipitation conditions depend on the scenario chosen and the time target, usually 2050 or 2100. Sensitivity, on the contrary, is a property of each ecosystem. Precipitation manipulative experiments aim at assessing sensitivity to changes in precipitation and unraveling mechanisms behind those changes.

Rainout shelters became popular experimentation tools because of their low cost, reliability, no-electricity requirements and minimal impact on other environmental variables. Rainout shelters are sometimes combined with passive irrigation plots to enhance the range of precipitation conditions and explore the full response surface. Enhanced precipitation variability can be simulated by using drought plots combined with irrigated plots. The irrigated and drought plots are swapped every year. So, throughout an 8-year period, treatments will have received the same amount of precipitation but the coefficient of variation of precipitation variability has changed according to proportion of precipitation that is intercepted and re-routed.

Inexpensive and easily to deploy drought experiments have been distributed all over the world. This program named Drought-Net, International Drought Experiment, coordinates drought experiments. Analysis of the global distribution of several climate and soil variables justifies the need to have distributed experiments in most continents. Distributed experiments create novel insights difficult to obtain with other methods.

Climate change simulation and specifically field experiments that manipulate amount and variability have a great potential as a tool to enhance predictions about the impact of climate change on the functioning of ecosystems

The Power of Experimental Macroecology in Disentangling Global Change Impacts on Plants, Vegetation, & Ecosystems

Vigdis Vandvik

Department of Biological Sciences (BIO), University of Bergen, Norway

Predicting the rate, magnitude, and consequences of ecological responses to unprecedented rates of global environmental change present a pressing challenge for today's ecologists. Both experimental and macroecological approaches are yielding important insights, and while these approaches originated from very different schools of thought we are now increasingly seeing collaborative efforts to combine them, for example by replicating experiments across gradients, regions, and biomes. In this talk, I will give examples of such experimental macroecological approaches, and highlight some of the insights we have gained from these approaches but also explore challenges and discuss opportunities and priorities for the future of experimental macroecology. In particular, by replicating climate change experiments across landscapes and climate gradients we can explicitly assess and disentangle climate context-dependencies in the responses, and thereby arrive at greater generality about why and how climate change effects vary across landscapes and regions. We manipulate climate per se, but also experimentally isolate the direct and indirect effects of climate change to understand to what extent responses are driven by direct physiological responses to the climatic variables or indirect effects, operating through changes in species' interactions.

An often-overlooked opportunity lies in the use of field experiments as educational platforms. Opportunities for hands-on experiences with 'real' research, and especially when local field sites and experiments can be set in a broader regional or even global context, has great potential for enhancing educational outcomes. I will discuss how 'real-life' research experiences can enhance student learning, engagement, and motivation for future roles in science and society.

Oral presentations

The abstracts are sorted by topic and within topics alphabetically by first author.

Topic 1: Ecosystem responses to landuse change

Effects of catch crops on yields and nitrate leaching under different N-fertilization levels to silage maize on a sandy soil in Northwestern Germany

Norbert Bischoff[1]; Linda Noltemeyer[1]; Annegret Fier[1]; Marie-Christin Albers[2]; Andrea Knigge-Sievers[2]

[1] State Authority for Mining, Energy and Geology, Germany; [2] Chamber of Agriculture in Lower Saxony, Germany

Nitrate (NO_3) leaching is a severe threat to groundwater and thus to the quality of drinking water. Particularly on arable fields nitrate leaching can be high, depending on nitrogen (N) fertilization levels and cultivation techniques. Two methods have been shown to effectively reduce nitrate leaching on mineral soils high in organic matter (OM): (a) the use of catch crops and (b) reduced fertilization of silage maize. However, it remains unclear to what extend the N supply of a catch crop could compensate for yield losses under reduced fertilization in silage maize. In a two-factorial strip-plot design we investigated the effects of three catch crop treatments (no catch crop, catch crop unfertilized and catch crop fertilized with 60 kg N/ha slurry) under different N-fertilizer levels to silage maize (0, 120, 180 kg N/ha) on yields and nitrate leaching during the period 2012 – 2020. The experiment was set up in Northwestern Germany on a sandy soil (Plaggic Anthrosol) with high soil OM content (ca. 2 % organic carbon in the topsoil). The crops rotated were silage maize and winter rye with an N supply of 140 kg N/ha. A mix of oil radish and mustard was the catch crop. Both main crops were cultivated yearly on two blocks. Nitrate concentration in seepage water was measured by collecting water with suction cups in a depth of 80 cm and subsequent analysing for nitrate. N loads (kg NO_3-N/ha) were calculated by modelling the daily amount of seepage water and multiplying this amount with the interpolated nitrate data. Without a catch crop, the average N load in the seepage water over the entire rotation was 45 – 60 kg N/(ha*year), with the loads increasing with fertilization. In contrast, the N loads were substantially lower for the unfertilized and fertilized catch crop treatments (24 – 43 kg N/(ha*year) and 29 – 51 kg N/(ha*year), respectively). Thus, the unfertilized catch crop reduced the N load by 28 – 46 %, while the fertilized catch crop lead to a reduction of 15 – 35 %, depending on the fertilization in silage maize. Yields of silage maize increased by 1 – 8 % when planted after the unfertilized catch crop as compared to no catch crop, while the fertilized catch crop lead to 0 – 13 % higher yields. Our results showed substantial interaction between the two tested factors. The effects of the catch crop, a reduction of nitrate leaching and higher yield, increased as fertilization levels decreased. Additionally, decreased N-fertilization levels in silage maize reduced N loads in seepage water over the entire rotation on average over all three catch crop treatments by 6 – 18 % when 120 kg N/ha were applied and 26 – 43 % when maize was not fertilized. Yields of silage maize decreased concurrently by 1 – 3 % and 16 – 26 %, respectively, while yield decreases were lower when catch crops were cultivated. We conclude that on a sandy soil with high OM content the cultivation of a catch crop has a higher potential to reduce nitrate leaching in the short term than a reduced fertilization of silage maize. However, a combination of both measures seems promising, as a catch crop can compensate for yield losses under reduced N-fertilization to silage maize.

Topic 1: Ecosystem responses to landuse change

Deciphering the effects of tree species richness and mycorrhizal association on community productivity – first five-year results of the long-term tree diversity experiment MyDiv

Peter Dietrich; Olga Ferlian; Yuanyuan Huang; Shan Luo; Julius Quosh; Nico Eisenhauer

German Centre of Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig

There is a plethora of studies, which have shown positive biodiversity—ecosystem functioning relationships; however, only few experiments use trees as model organisms and investigate the roles of symbiotic mycorrhizal fungi in mediating tree diversity effects on productivity. To shed light on the role of these biotic interactions, we established in 2015 a tree diversity experiment (MyDiv experiment) by growing tree communities with varying species richness (1, 2 or 4), and with either single or mixed mycorrhizal types, i.e., communities with either only arbuscular mycorrhizal (AM), only ectomycorrhizal (EM) tree species, or communities containing both AM and EM tree species. We used basal area and annual increment from 2015 to 2020 as proxy for community productivity. Results of the first five years show that species-rich communities were more productive than species-poor communities, although it took three years for this positive diversity-productivity relationship to become significant. Moreover, our findings indicate that AM and EM tree species promote community productivity through different mechanisms. AM tree communities were most productive across all tree communities and species richness levels, but showed a loss of increment over time and only a weakly positive relationship between species richness and productivity. Consistently, we found only low net biodiversity effects in these communities (medium complementarity effects and no to weak selection effects). EM tree communities, in contrast, showed lowest productivity, but an increase of increment over time and a strong diversity-productivity relationship, caused initially by high selection effects, which were replaced by high complementarity effects after five years. Despite these fundamental differences, there was no overyielding when AM and EM trees grew together in the first five years of the experiment. In general, tree communities containing both AM and EM tree species showed medium productivity and net biodiversity effects. In conclusion, while young trees did not benefit from the presence of the other mycorrhizal type, fundamental different growth strategies in AM and EM tree communities indicate that maximizing tree species and mycorrhizal diversity may increase ecosystem functioning in the long run.

Topic 1: Ecosystem responses to landuse change

Mycorrhiza in Tree Diversity-Ecosystem Function Relationships: the first seven years of the iDiv platform MyDiv

Olga Ferlian

German Centre for Integrative Biodiversity Research (iDiv) Halle-Jena-Leipzig

The widely observed positive relationship between plant diversity and ecosystem functioning is thought to be driven by complementary resource use of plant species. Biotic interactions among plants and between plants and soil organisms are suggested to drive key aspects of resource-use complementarity. The young tree diversity experiment MyDiv aims to integrate biotic interactions across guilds of organisms, more specifically between plants and mycorrhizal fungi, to explain resource-use complementarity in plants and its consequences for competition and multitrophic interactions. Our overarching hypothesis is that ecosystem functioning increases when more plant species associate with functionally dissimilar mycorrhizal fungi (arbuscular and ectomycorrhizal fungi). Here, we present results from the first seven years of MyDiv. We investigated tree mycorrhization with classical and novel techniques as well as different ecosystems functions ranging from tree productivity to herbivory and energy fluxes in the food web as affected by tree species richness and mycorrhizal type. The studies largely showed that tree species richness and identity effects dominate over mycorrhizal type effects in the early stage of the experiment. Furthermore, tree communities with two mycorrhizal types experienced rather additive effects that were in between that of arbuscular and ectomycorrhizal communities. We showed that plant communities differ in their preferred fungal communities. Overall, results of the first seven years of the experiment point to strengthening distinct mechanisms of the two mycorrhizal types with time driving life strategies of trees and biodiversity-ecosystem functioning relationships.

Topic 1: Ecosystem responses to landuse change

Effects of low ammonia concentrations on N-sensitive higher plant species in a greenhouse and field study

Jürgen Franzaring ; Julia Kösler

Universität Hohenheim

Atmospheric deposition of oxidized and reduced nitrogen causes widespread eutrophication so that critical loads were derived to protect the most sensitive habitats, e.g. heaths and peatlands. While atmospheric N inputs are composed of wet, dry gaseous and particular deposition that together lead to the fertilization of soils, N containing gases may directly be absorbed by the aboveground plant parts. Annual critical levels for NO_2 (25 µg m^{-3}) and NH_3 (1 to 3 µg m-^{3}) have been recommended in the Convention on long-range transboundary air pollution (CLRTAP).

In order to test the effects of ammonia concentrations lower than 10 µg m^{-3} on N-sensitive perennial and annual plant species, we performed a fumigation experiment and a field gradient study. In the greenhouse, fumigation was controlled via the gentle vaporization of liquid ammonia. In the field gradient study, plants were exposed at fixed distances in the lee of a small farm. Selection of the sites was based on a dispersion model and an NH_3 monitoring before the study. NH_3 concentrations in the chambers and the field were measured with passive samplers. Since in the greenhouse, realized ammonia levels and temperatures were too high, plants were moved to the field in the second year. The concentrations in the field gradient study well represented the intended low range and spanned from 1.8 to 9.4 µg m^{-3}. Furthermore, the plants showed a normal phenological response outdoors, while in the greenhouse only a few species developed flowers.

The selected taxa stem from acidic dry and wet heath and grasslands with *Arnica montana* as a rare flagship species and *Molinia caerulea* as a graminoid known to profit from eutrophication. In total, seven perennials were used in the fumigation and the field study, while five annuals and one additional perennial were only used in the second year. In the first year, half of the plants were subjected to a slight drought to address the effect of NH_3 on plant:water relationships and an intermediate harvest should clarify whether mowing increases the readiness of plants to absorb the gas via the shoot. All plants were grown in pots on nutrient poor substrates.

In the greenhouse *Koeleria glauca, Molinia caerulea, Arnica montana, Antennaria dioica, Carex arenaria* and *Dianthus deltoides* but not *Pulsatilla vulgaris* produced significantly less aboveground biomass after experiencing drought. In no case did the highest ammonia concentrations lead to significant changes in growth. Only the grass *Molinia caerulea* seemed to be influenced from the highest concentration when enough water was supplied.

In the field, the growth of three out of five annuals (*Erodium cicutarium, Bromus hordeaceus* and *Iberis amara*) was influenced from the higher ammonia concentrations. The legume *Trifolium arvense* tended to produce less biomass at the highest concentrations and *Legousia speculum-veneris* did not react to the different concentrations.

We conclude that direct effects of NH_3 did not evolve throughout the experiments. Annuals seem to be influenced more from NH_3, even if they naturally occur on N-limited sites.

Topic 1: Ecosystem responses to landuse change

Biodiversity Exploratories: experimental research in managed landscapes

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The Biodiversity Exploratories are a long-term, large-scale and interdisciplinary research platform for comparative and experimental biodiversity and ecosystem research. All researchers examine how land-use intensity affects biodiversity and ecosystem functions and services in grasslands and forests. For optimal synergy, all research groups work with the same set of study plots in forests, pastures and meadows, in three study regions in Germany. Each region represents gradients of land-use intensity from semi-natural to intensely used. Project ambition is to investigate all facets of biodiversity and ecosystem processes. This is done in combination of a comparative between-plot approach with several experiments replicated in many plots, including two large-scale experiments established in 2020.

Since 2006, many insights have been gained. This talk will highlight important findings and how they were made possible by interdisciplinary synergy. These findings include impacts of land use on the biodiversity of thousands of species above and below ground and on various ecosystem processes and services, show how plot land use and diversity affect the outcome of experimental treatments, and they exemplify how experiments provide insights into mechanisms driving the comparative results.

The talk will present the basic principles according to which the Exploratories were developed, followed by important findings and finally lessons learned for experimental research across landscapes.

Topic 1: Ecosystem responses to landuse change

Using agroecosystem models to design newly diversified cropping systems in combination with new field arrangements in spatially heterogeneous landscapes

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Over the past decades, intensive agriculture in Germany has been highly productive, characterized for large fields, high mechanization, high resources input use and simplified crop rotations. However, it has resulted in a series of environmental problems that compromise the delivery of ecosystem services (ESS) and biodiversity levels from the agroecosystem. Crop diversification in combination with new field arrangements (i.e. smaller field units) considering soil heterogeneities stand as an option to improve resource use efficiency (RUE), ecosystem services (ESS) and biodiversity. Moreover, agroecosystem models are a tool to understand and design diversified cropping systems as they provide the flexibility to virtually explore spatial and temporal arrangements of a diverse set of crops. The main goal of the current study was to review to what extent agroecosystem models have been used for crop diversification design at field and landscape scale by considering soil heterogeneities, and to understand the model requirements in terms of their capability on simulating the dynamics of diversified field but also in the quantification of the delivery of ESS. Results showed that a number of agroecosystem models are available for simulating spatio-temporal crop diversification at the field scale. For spatial crop diversification, simplified modelling approaches consider the important crop interactions for light, water, and nutrients, particularly for cereal-legume and cereal-cereal combination. However, they can be limited when using them for design purposes due to the restricted crop combinations. As for temporal crop diversification, agroecosystem most models include the major cereal, legume, and tuber crops. However, limited crop parameterization for marginal crops and soil carbon and N multi-year dynamics are a shortcoming. At the landscape scale, static decision making frameworks are a common approach to crop diversification. Crop configuration and composition arrangements define the spatial landscape patterns. Within-field soil heterogeneities are rarely considered in the field or landscape design. Many models at field and landscape scale account for the provision food, feed, fiber and the regulation of water quality (N retention) and to a lesser extent, soil erosion and pesticide fate, but they often lack biodiversity dynamics. We conclude that adapting agroecosystem model to design crop diversification in heterogeneous landscapes will involve model improvements but also field experimentation to quantify the effects of spatio-temporal crop diversification on ESS and biodiversity.

Topic 1: Ecosystem responses to landuse change

Long-term study of different crop residue managements (green fallow, straw, fallow land) on biomass yields and soil properties

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In arable farming, plant residues play a central role in maintaining and improving soil properties. They can influence the C/N content of the soil as well as the physical and biological soil parameters and thus also exert a lasting influence on biomass yields of the crops.

It has not been sufficiently researched how quickly these processes take place and what influence the duration of cultivation measures have. Therefore, long-term studies are needed to clarify these questions. The aim of the study carried out was therefore to clarify what influence different soil uses (with different return of plant residues) have on biomass yields and soil properties when these are carried out over a long period.

For the study carried out, an ongoing long-term experiment located in the research station Giessen (50.6 N, 8.65 E, 158 m a.s.l., 9.8 °C, 672 mm) was evaluated over a period from 1982 to 2021. The soil of the site is a Fluvic Gleyic Cambisol characterised by a clay loam texture with clay content of 36% (0-25 cm).

The trial simulates a four-year crop rotation in which different soil uses (maize, oats, field bean, year-round green mulch and year-round fallow land) are included every four years, followed by uniform winter wheat, winter rye and spring barley. The subsequent cereals are each combined with four different mineral fertiliser variants (without, PK, NPK 50%, NPK 100%). Thus, the trial is composed by two test factors (soil use x NPK fertilisation) which are combined with each other and are each repeated four times.

The present results show that the different soil use (crop residue management) significantly influences the biomass yields of all three subsequent crops over the entire trial period. The year-round use of the soil with clover mulch produced the highest grain yields in all three subsequent crops over the entire experimental period, which is attributed to a sustainable change in soil properties. The increase in C/N content in the topsoil and the increase in soil microbial biomass (SMB C) could be identified as the main causes for this effect. In addition, higher mesofauna abundance characterized by a high proportion of mites followed by lower proportion of collembola was also observed because of regular green mulch application.

Surprisingly, the fallow land produced the same yield effects as the field bean in the first subsequent crop, which is also explained by phytosanitary effects. In contrast, the lowest yields were measured in the second and third subsequent crop in the fallow land, which is attributed to a reduction in SOC and SMB C. It was also observed that the negative effect of fallow land increased from the second to the third subsequent crop.

The different land use also influenced the effectiveness of NPK fertilisation mainly by clover mulch. The additional yields from clover mulch were, on average for all trial years, significantly higher in the first subsequent crop than in the second and third subsequent crop, which indicates a direct N effect from N mineralisation.

Topic 1: Ecosystem responses to landuse change

Modelling long-term dynamics of soil functions under agricultural management

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Mechanistic simulation models are an essential tool for predicting the influence of changing external factors on ecosystem functions. To render agriculture more sustainable, knowledge about the long-term effects of different land management activities on the various soil functions is mandatory.

In this contribution, we will discuss the importance of long-term field experiments for the development of systemic soil models capable to simulate the dynamics of soil functions. This is demonstrated for the Bodium model which integrates biological, physical and chemical processes to predict the effect of management activities on soil functions. For validating the simulated outcomes, data of long-term field experiments are essential.

Here, we simulated the Static Fertilization Experiment in Bad Lauchstädt and compared measured data of the last 40 years on yield, soil carbon, nitrogen, and microbial biomass with our simulation results. In this respect, we emphasize the enormous value of the various long-term experiments in Bad Lauchstädt. Such data are indispensable to gain a systemic understanding of soil processes which is highly required to evaluate the impact of soil management on soil functions. Towards a future perspective we want to highlight how additional measures of soil properties in long-term field experiments with a well-known land management history can provide valuable input for the development of new systemic modelling approaches.

Topic 1: Ecosystem responses to landuse change

Species losses, gains, and changes in persistent species are associated with distinct effects on ecosystem functioning in global grasslands

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Global change drivers such as anthropogenic nutrient inputs simultaneously alter biodiversity, species composition, and ecosystem functions such as aboveground biomass. These changes are interconnected by complex feedbacks among extinction, invasion, and shifting relative abundance. Here, we use a novel temporal application of the Price equation to quantify the functional contributions of species that are lost, gained, and persist under ambient and experimental nutrient addition in 59 global grasslands. Under ambient conditions, compositional and biomass turnover was high, but species losses (i.e., local extinctions) were balanced by gains (i.e. colonization). Under fertilization, there was biomass loss associated with species loss. Few species were gained in fertilized conditions over time but those that were, and species that persisted, contributed to net biomass gains, outweighing biomass loss. These components of community change are key to understanding the relationship between diversity and functioning, particularly in systems that are experiencing anthropogenic change. By partitioning the roles of individual species, this work provides a more detailed understanding of the relationships between biodiversity change and ecosystem function in natural systems and how global change drivers can affect them. This work invites future lines of research to adapt this approach and develop it further. With some adaptation and further work this approach may be directly applicable to quantifying stability as well.

Topic 1: Ecosystem responses to landuse change

Arbuscular mycorrhizal colonization and functional root traits of winter wheat in an early stage silvoarable agroforestry system following a standardized transect sampling protocol

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As complex and diverse agroecosystems, agroforestry systems (AFS) can provide multiple ecosystem services and have a fair potential for climate change adaptation and mitigation (Mayer et al. 2022). The establishment of an AFS goes along with a land-use change by field fragmentation through growing perennial vegetation and omitting soil tillage in the tree row zones. This has an influence on the above- and belowground environment in the tree rows and the adjacent arable field. Especially for silvoarable systems (woody plants and annual crops) different soil characteristics and associated services in the tree rows compared to the adjacent arable field have been shown (Beuschel et al. 2019). Already one and a half years after establishment of an AFS differences in soil fungal community compositions but not abundances were shown in poplar tree rows compared to the adjacent arable field (Beule and Karlovsky 2021). It is likely that these differences in the soil spill over into the adjacent arable field, influencing performance and nutrient acquisition strategies of the annual crop. Root functional traits and arbuscular mycorrhizal (AM) colonization are possible indicators of such changes, but little is known so far for annual crops in AFS (Isaac and Borden 2019).

To test if such effects are already present in an early stage silvoarable AFS we studied AM colonization and root functional traits of winter wheat in an AFS established in 2020 at the organic research farm Gladbacherhof, Germany (Minarsch et al. 2021). Sampling took place in spring 2021 during shooting and before flowering of the winter wheat. Plant root and bulk soil samples were collected in a gradient from the tree row interface towards the centre of the arable field following a standardized transect sampling protocol (Minarsch et al. manuscript in preparation). Accordingly, sample locations were in close vicinity to the tree rows, half way towards the field centre and in the field centre. After washing the plant roots, 1st to 3rd-order fine roots were sampled (McCormack et al. 2015), scanned and analysed using the WinRHIZO software. Dried and rehydrated fine roots were stained using ink-vinegar (Vierheilig et al. 1998) and AM colonization was analysed following the magnified intersection method (McGonigle et al. 1990). Bulk soil samples were analysed for pH, plant available phosphorus and total C and N. Data analysis follows classical statistics with analysis of variance and linear regression as well as mixed effects modelling to account for spatial autocorrelation.

First results in this early stage system indicate no strong overall influence of the tree rows on the AM colonization and root traits of the winter wheat. However, understory vegetation type and tree planting density seem to plastically influence various root traits. We discuss the effects observed and possible mechanisms as well as future perspectives and research designs for using AM colonization and root functional traits to study agroforestry systems.

Soil and microbial C:N:P stoichiometric ratios are shaped by fertilization strategy and affect ecosystem-relevant traits of the microbial community

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The soil environment shapes microbial functional traits through stoichiometric ratios of carbon (C) and nutrients, e.g., nitrogen (N) and phosphorus (P). These ratios indicate excess or limitation of elements and, thus, modulate transformation processes of soil organic matter resulting either in C sequestration or loss. Therefore, the type and the amount of fertilizer applied in agriculture have a vast impact on ecosystem processes mediated by soil microbes.

Here, we made use of the Static Fertilization Experiment (Bad Lauchstädt, UFZ), which was established in 1902, and investigated how contrasting long-term fertilization strategies (no fertilization, PK, N, NPK, farmyard manure as well as combinations of organic and mineral fertilizers) influenced C:N:P stoichiometry of the soil, and consequently of the microbial biomass. Furthermore, we studied a range of microbial functional traits related to respiration, growth and enzymatic activity.

We found that the total amount of C, N and P in soil were highly affected by the fertilization regime. Low amounts of C and N were detected in the unfertilized control as well as in the PK- and N-fertilized treatments. In the other treatments, the C and N contents were significantly higher (NPK < manure < NPK + manure). However, no significant differences between treatments were observed in both soil and microbial C:N stoichiometry. The C:N ratios in microbial biomass were approximately half of the ratios determined for soil, indicating N accumulation in the microbial pool. The pattern for available P content generally increased with fertilization intensity, with the remarkable exception of very low amounts of P in the solely N-fertilized treatment. This indicated a P limitation in soil as well as in the microbial pool. Contrary to that, the P content in microbial biomass was particularly high in the PK fertilized treatment, exceeding the NPK and manure treatments by more than 20%. This consequently resulted in particularly high and low C:P and N:P ratios in the N-fertilized and PK-fertilized treatments, respectively. Nutrient availability also affected soil hydrolytic enzymes involved in C, N and P cycling as well as basal respiration and kinetic parameters of unlimited microbial growth. For the latter, we observed that after addition of glucose and mineral solution the microbial growth started earlier in manure-fertilized soils than in the unfertilized, or solely mineral fertilized soils. However, the opposite pattern was observed for the steepness of the growth curves, resulting in an earlier peak maximum for the treatments with no fertilization or solely mineral fertilization. This surprising pattern can most likely be explained by the active fraction of, and competition between, microbial taxa with a low (fast growing and dying taxa) or high (slow growing but persistent taxa) turnover time.

Our results demonstrate the vast impact of the fertilization regime on microbial community traits and related ecosystem functions. Thus, a comprehensive understanding of fertilization effects on soil microbes is crucial for maintaining ecosystem services and developing sustainable agricultural strategies.

Influence of different fertilization regimes on carbon sequestration in the Thyrow long-term field experiment DIV.2 - LTE experiments

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Carbon sequestration has been proposed as a way to mitigate the impact of CO_2 on the climate. In 2015, the '4 per 1000 Soils for Food Security and Climate' initiative was launched at the COP21. Its goal is to increase global soil organic matter stocks by 4‰ per year to compensate for anthropogenic greenhouse gas emissions. However, the feasibility of this approach has often been doubted. The main argument is that effective C sequestration requires uneconomical practices like stopping crop production completely or allowing only rotations with multiple years of pasture. The Thyrow long-term field experiment DIV.2 was chosen to investigate if soil organic carbon (SOC) contents can be increased by 4‰ per year under the dry and sandy conditions in Eastern Germany. The field trial consists of treatments with different mineral and/or organic fertilization and has been carried out with the current fertilizing regimes since 1971. Harvest residues are removed and the soil is ploughed every year. Winter rye is grown since 1998 as monoculture in the experiment. For this study, the period from 2007 to 2018 was investigated, during which sampling and analyzing methods were unchanged.

In three out of four years, no yield difference was observed between mineral-only fertilization (120 kg ha^{-1} N) and a combined mineral and organic N (97.4 kg ha^{-1} plant available N) fertilization. Manure application appeared to stabilize yields in years with drought and heat stress (e.g. 2018). In the treatment with N coming from manure only, grain yields tended to increase over the years. In all treatments with mineral N fertilization grain yields tended to decrease.

Results showed that even after multiple decades the field trial is not in a steady-state condition regarding soil carbon. Over the investigated 12 years, SOC contents increased by 6 to 28 %. Highest overall SOC contents were found in treatments with manure only or combined manure and mineral fertilization. The 4 per 1000 goal was achieved in all treatments including the unfertilized control. A carbon sequestration of up to 0.5 t ha^{-1} a^{-1} was achieved by the combined mineral and manure fertilization. However, SOC content development was divided into two phases: From 2007 to 2012, SOC increased only in treatments with manure and in the treatment with high mineral N-fertilization (120 kg ha^{-1} N). In the other treatments, SOC either increased only on a very low level, or even decreased (unfertilized control). From 2013 to 2018, on the other hand, SOC contents increased steeply in all treatments.

During the first 6 years, mean temperature and climatic water balance (CWB) between September and July were 8.9 °C and 134.7 mm. In May, when most of the grain filling occurs, they were 14.4 °C and 67.2 mm, respectively. During the second period, mean temperature between September and July increased to 9.6 °C while CWB decreased to 95.6 mm. The mean temperature in May increased to 15.1 °C, while rainfall decreased to 44.9 mm. Spring and summer months might have become too dry to allow for microbial C degradation, while precipitation during autumn and winter is still high enough to allow for carbon production via plant growth.

Topic 1: Ecosystem responses to landuse change

Land use impact on carbon mineralization in well aerated soils is mainly explained by variations of particulate organic matter rather than of soil structure

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Land use is known to exert a dominant impact on a range of essential soil functions like water retention, carbon sequestration, organic matter cycling and plant growth. At the same time, land use management is known to have a strong influence on soil structure, e.g. through bioturbation, tillage and compaction. However, it is often unclear whether differences in soil structure are the actual cause for differences in soil functions or just co-occurring.

This impact of land use (conventional and organic farming, intensive and extensive meadow, extensive pasture) on the relationship between soil structure and short-term carbon mineralization was investigated at the Global Change Exploratory Facility, in Bad Lauchstädt, Germany. Intact topsoil cores (upper 10 cm, n=75) were sampled from all land use types at the early growing season. Soil structure and microbial activity were measured using X-ray computed tomography and respirometry, respectively.

Differences in microstructural properties between land uses were small in comparison to the variation within land uses. The most striking difference between land uses was larger macropore diameters in grassland soils due to the presence of large biopores that are periodically destroyed in croplands. Grasslands had larger amounts of particulate organic matter (POM), including root biomass, and also greater microbial activity than croplands, both in terms of basal respiration and rate of carbon mineralization during growth. Basal respiration among soil cores varied by more than one order of magnitude (0.08 – 1.42 µg CO_2-C h^{-1} g^{-1} soil) and was best explained by POM mass (R2 = 0.53, "p < 0.001"). Predictive power was hardly improved by considering all bulk, microstructure and microbial properties jointly. The predictive power of image-derived microstructural properties was low, because aeration was not limiting carbon mineralization and was sustained by pores smaller than the image resolution limit (" < 30 µm"). The frequently postulated dependency of basal respiration on soil moisture was not evident even though some cores were apparently water limited, as it was likely disguised by the co-limitation with POM mass. This finding was interpreted towards microbial hotspots which form on decomposing plant residues and which are decoupled from water limitation in bulk soil. The rate of glucose mineralization during growth was explained well by substrate-induced respiration (R2=0.84) prior to growth, which was in turn correlated with total microbial biomass, basal respiration and POM mass and not affected by pore metrics.

These findings stress that soil structure had little relevance in predicting carbon mineralization in well-aerated soil, as mineralization appeared to by predominantly driven by the decomposition of plant residues in intact soil. Land use therefore affects carbon mineralization in well-aerated soil mainly by the amount and quality of labile carbon.

Topic 1 Ecosystem responses to landuse change

Response of subsoil organic matter contents and physical properties to long-term, high-rate farmyard manure application

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Application of farmyard manure (FYM) is common practice to improve physical and chemical properties of arable soil and crop yields. However, studies on effects of FYM application mainly focussed on topsoils, whereas subsoils have rarely been addressed so far. We, therefore, investigated the effects of 36-year FYM application with different rates (0, 50, 100, 200 Mg ha^{-1} a^{-1}), corresponding to an annual organic carbon (OC) addition of 0, 469, 938, and 1875 g C m^{-2} a^{-1}, on OC contents of a Chernozem in 0−30 cm (topsoil) and 35−45 cm (subsoil) depth. We also investigated its effects on soil structure and hydraulic properties in subsoil. X-ray computed tomography was used to analyse the response of the subsoil macropore system (≥ 19 µm) and the distribution of particulate organic matter (POM) to different FYM applications, which were related to contents in total OC (TOC) and water-extractable OC (WEOC). We show that manure application of 50 Mg ha^{-1} a^{-1} caused increases in TOC and WEOC contents only in the topsoil, whereas rates of ≥ 100 Mg ha^{-1} a^{-1} were necessary for TOC enrichment also in the subsoil. At this depth, the subdivision of TOC into different OC sources shows that most of the increase was due to fresh POM. The increase in subsoil TOC went along with increases in macroporosity and macropore connectivity, possibly due to the stimulation of root growth and bioturbation. We neither observed increases in plant-available water capacity nor in unsaturated hydraulic conductivity. In conclusion, only very high application of FYM over long periods can increase OC content of subsoil at our study site, but this increase is largely based on fresh, easily degradable POM and likely accompanied by high C losses when considering the discrepancy between OC addition rate by FYM and TOC response in soil.

Topic 2: Climate change impacts

AnaEE: the European research infrastructure for experimentation on ecosystems

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Analysis and Experimentation on Ecosystems (AnaEE) is a landmark European research infrastructure devoted to the study of ecosystem functioning through a large, distributed network of experimental facilities. AnaEE is fully open to the scientific community and all interested users on a competitive basis.

The platforms feature all types of aquatic and terrestrial continental ecosystems across the major climate zones of Europe, including additional platforms overseas, allowing for powerful gradient studies to be performed. Characteristic to AnaEE is its versatile open-air and enclosed platforms – including ecotrons – that can simulate environmental drivers from land-use change, pollution, biological invasions, rising atmospheric greenhouse gases concentrations, as well as changes in climate and extreme events, such as droughts and heatwaves.

AnaEE has a special focus on understanding the impact of climate change on ecosystem functions, as well as on unravelling the mechanisms of adaptation at different hierarchical levels from the molecular level to the ecosystem as a whole. The AnaEE analytical platforms help to provide sophisticated data from experiments. The obtained data are of high value for modelling future climate change impacts on ecosystems – using the modelling platforms – and for proposing possible climate mitigation and adaptation strategies to society.

The added value of AnaEE is mainly in the ability to provide experiments across gradients of climate, soils, and ecosystem types, and combining them with state-of-the-art technologies and analytical tools to gain new, mechanistic understanding of ecosystem processes and behaviour. AnaEE integrates all the steps of the scientific experimental method, including true integration of experimentation and modelling, as well as remote sensing for upscaling. We will present the main features of AnaEE, as well as the opportunities it represents for the scientific community.

Topic 2: Climate change impacts

Unearthing the mechanisms behind soil carbon sequestration

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Soils are the largest and most dynamic terrestrial carbon (C) pool, storing 2000 Pg of C – more than the atmosphere and biosphere combined. However, agriculture has caused the loss of approximately 60 Pg soil C since the beginning of industrial period. Despite this, improving agricultural practices can also be used to counteract rising CO2 levels. As agroecosystems represent over 40% of earth surface today, they must be part of the solutions put in action to mitigate climate change. The utility of "carbon farming" – or the use of management practices to maximize soil carbon storage – is currently limited by a poor understanding of how the plants which input carbon to soil and the microbes which determine its fate there interact with one-another. Here, studying an agricultural experiment in which barley is grown under different levels of diversity (i.e. from 1 up to 8 undersown species) we observed that increasing diversity enhances carbon use efficiency of the microbial community and soil organic carbon stocks. Preliminary results indicate that increasing plant diversity strengthen positive interactions in relation to the negative interactions within the microbial community. This project is shedding light into the mechanisms behind soil carbon retention in soils and disentangling how farmers can implement more sustainable practices and help sequester carbon back into soils.

Topic 2: Climate change impacts

Irrigation induced changes in organic carbon stocks of agricultural soil - what do we really know?

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Changing global precipitation patterns and the increasing intensities and frequencies of drought in many parts of the world as a result of climate change has the potential to significantly alter the requirement for agricultural irrigation. However, despite the importance of agricultural irrigation in regulating aridity and drought stress, the effects on SOC of cropping systems that incorporate irrigation are poorly understood. Given the large, and expanding, agricultural landbase under irrigation, this is a critical knowledge gap for climate change mitigation. We undertook a systematic literature review and subsequent meta-analysis of 42 field study sites from across the globe that examined changes in SOC on irrigated agricultural sites through time. We investigated changes in SOC by climate (aridity), soil texture, and irrigation method with the following objectives: i) to examine the impact of irrigated agriculture on SOC storage, and ii) to identify the conditions under which irrigated agriculture is most likely to enhance SOC. Overall, irrigated agriculture increased SOC stocks by 5.9% (95% CI; 3.3% to 8.5%), with little effect of study length (2 – 47 years). However, changes in SOC varied by climate and soil depth, with the greatest increase in SOC observed on irrigated semi-arid sites at the 0 - 10 cm depth (14.8%; 95% CI; 11.8% to 17.8%). Additionally, irrigation increased SOC in fine- and medium-textured soils but not coarse-textured soils. Furthermore, while there was no overall change to SOC in flood/furrow irrigated sites, SOC tended to increase in sprinkler irrigated sites, and decrease in drip irrigated sites, especially at depths below 10 cm. Because drought stress has the potential to decrease SOC stocks significantly, understanding how irrigation affects SOC stocks in agricultural soils is increasingly important. Based on the systematic review of Emde et al. (2021), we will discuss properties that make agricultural soil particularly susceptible to drought-induced changes in SOC stocks.

Emde, D., Hannam, K.D., Most, I., Nelson, L.M. and Jones, M.D. (2021), Soil organic carbon in irrigated agricultural systems: A meta-analysis. Glob Change Biol, 27: 3898-3910.

Topic 2: Climate change impacts

Warming effects on greenhouse gas fluxes from Wadden Sea salt marshes

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Vegetated coastal ecosystems like salt marshes are effective soil organic carbon sinks due to high rates of photosynthetic CO_2 uptake, and storage of organic material under reducing soil conditions. At the same time, salt marshes emit only small amounts of the non-CO_2 greenhouse gases N_2O and CH_4. Their biogeochemistry is characterised by a complex interplay of abiotic and biotic factors driven by periodical and episodical inundation with seawater. This complexity further increases when global change impacts like rising temperatures are taken into account.

To study the impact of warming on an ecosystem scale, we measured land-atmosphere fluxes of CH_4, N_2O and CO_2 at the MERIT (Marsh Ecosystem Response to Increased Temperature) field study site at Hamburger Hallig, Nordfriesland, Germany. This unique warming experiment enables passive aboveground and active belowground warming of +1.5°C and +3°C compared to ambient temperatures. We combined a closed chamber approach with in situ measurements of portable infrared gas analysers in biweekly campaigns during the main vegetation period from July 2020 to September 2021.

Our findings show that greenhouse-gas fluxes of salt marshes strongly vary in time and space. Salt marshes of the Wadden Sea area show the ability to take up the strong greenhouse gases CH_4 and N_2O, emphasizing their important role in mitigating global warming. Land-atmosphere fluxes under experimentally warmed conditions are currently under analysis, aiming to elucidate the effect of future warmer temperatures and to clarify how changes through warming effects compare to preexisting spatial and temporal variability.

Topic 2: Climate change impacts

Long-term crop and flux data from SoilCan lysimeters at Dedelow, Uckermark

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The high-precision weighing lysimeters at Dedelow are operating now for about 10 years. These lysimeters are part of the nation wide TERENO-SOILCan lysimeter-network that is observing soil processes, crop growth, and plant diversity as influenced by climate change.

The first set of six lysimeters (hexagon) contains intact soil monoliths of the characteristic soil type of the post-glacial arable hummocky soil landscape, the eroded Lusivol. Each three of monolith lysimeters with the same soil were moved to stations at Bad Lauchstädt (BL), and Selhausen (Se) sites of the TERENO SOILCan network. They were transferred to the drier and warmer BL site and the wetter and warmer Se site, which allowed a comparison of similar soil and crop under varying climatic conditions based on the so-called "space-for-time" substitution approach.

The second hexagon consists of three pairs of soil monoliths from the eroded hilltops and the colluvial depressions to complement for most of the variation in the landscape. The crop dynamics and the water and element fluxes allow analysing the dynamics of water and nitrogen use efficiencies during drier and wetter periods and for the differently-eroded soils.

This contribution gives an overview on the results obtained from the lysimeter and analyses and discusses the limitations of such empirical approach.

Topic 2: Climate change impacts

Effects of experimental droughting on litter decomposition by tropical millipedes and other invertebrates

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Climate change is expected to cause altered diversity and richness of invertebrate assemblages in tropical forests. However, little is known about the effects of these changes on ecosystem functions, and how altered biotic communities will perform under novel and extreme climatic conditions. Decomposition, facilitated by litter invertebrate macrofauna, is a key ecosystem function in forest ecosystems with relevance to soil fertility and crop yields in adjacent agricultural areas. We used mesocosm experiments to investigate how rates of decomposition mediated by invertebrates are likely to change under altered biotic and abiotic conditions arising from climate change. We compared decomposition, soil nutrients, crop seedling biomass and post-experiment litter invertebrate community when leaf litter was processed by millipedes (*Salpidobolus sp*.), alone and in combination with other litter invertebrates, and under ambient, elevated, and reduced-rainfall scenarios. In a separate set of experiments, we assessed whether millipede-mediated decomposition is affected by inter-specific density-dependent interaction. Rates of decomposition increased significantly with rainfall. Diverse invertebrate assemblages including both millipedes and other litter invertebrates achieved the highest rates of decomposition. There was no evidence that the effects of altered rainfall on decomposition differed depending on the biotic community of decomposers present. Seedlings planted into mesocosms where millipedes and other litter invertebrates occurred in combination achieved the highest biomass, paralleling the results documented for litter decomposition. However, levels of phosphorus and nitrogen responded more idiosyncratically to experimental treatments. Post-experiment litter invertebrate abundance was not affected significantly by any treatment. The results highlight the importance of invertebrate communities, particularly *Salpidobolus sp*., and altered rainfall for decomposition dynamics in tropical forests, and the potential implications for plant growth.

Topic 2: Climate change impacts

Do field experiments underestimate global change effects? – the case of drought and aboveground biomass

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To assess how climatic changes will affect ecosystems, field researchers commonly use one of two approaches: in situ observations or manipulative experiments. Observations have the advantage of being able to cover large areas and long time periods, but the links between ecosystem processes and climatic conditions are only correlational. In contrast, experiments can directly test responses to a given factor (e.g., a manipulated climate variable) and isolate the effects of individual factors that often correlate with others in real-world settings. But experiments face logistical limits to their size and duration, and manipulated variables may poorly mimic natural changes or cause unwanted side effects. Despite the differences between experiments and observations, few data syntheses compare the two types of studies

We compared responses of aboveground biomass to experimentally applied versus observed drought events in grasslands and shrubland in a systematic review using hierarchical meta-analyses. We tested for effects of potential confounding factors such as drought severity (% reduction in annual precipitation), drought length (years), and site aridity (MAP/PET, where MAP is mean annual precipitation and PET is mean annual potential evapotranspiration). Our focal analysis included 158 data points (75 experimental and 83 observational) from 80 studies. Drought plots were compared to control plots in the experimental studies, and drought years were compared to control (non-drought) years in observational studies.

The estimated mean effect of drought was 53% (95% confidence interval: 90%; 16%) weaker in experimental than observational studies, after controlling for potentially confounding factor. Drought responses increased with increasing aridity and, marginally, with increasing drought severity. The discrepancy between experimental and observational results may in part occur because experiments typically cover small areas, and conditions in the surrounding landscape may dilute intended treatment severity (“island effect”). Another potential reason for weaker responses in experiments could be that they simulate less rain, but do not control for increased evaporative demand associated with high temperatures, low humidity, and clear skies. Given that droughts in reality are typically accompanied by these intensifying factors, we assert that drought experiments underestimate drought effects as manifested in nature.

We conclude that while ecosystem experiments are an invaluable tool for studying the impacts of climate change, especially to distinguish amongst the effects of factors that change simultaneously and to unravel the mechanisms of ecosystem responses, they may underestimate the magnitude of the effects of climate change. Thus, innovative new work that integrates experimental and observational data sets could more reliably quantify the effects of climate change on terrestrial ecosystems.

Topic 2: Climate change impacts

Soil structure turnover by biotic and abiotic drivers under two different environmental conditions

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Soil structure is a dynamic property of soils which undergoes continuous changes due to various abiotic and biotic drivers. At the same time, the spatial arrangement of pores, organic matter and minerals influences soil functions, such as storage and filtering of water, nutrient cycling, or habitat for soil organisms and plants. In terms of carbon storage and matter turnover, the rearrangement of soil structure and herewith the change in accessibility of soil carbon for microbial decomposition is highly relevant. However, the turnover of soil structure and its constituents is difficult to quantify. In this study, a new method of structure labelling with inert garnet-particles in combination with X-ray µCT was used to determine the turnover rate of macro-aggregates and their drivers in two field experiments. Trials were conducted in topsoils of a Chernozem and a Luvisol under grassland, both with a silty loam texture but developed under different climatic conditions and, hence, provide different environmental conditions. Over the course of 4 years, soil structure was regularly determined by X-ray µCT at two resolutions, 60 µm and 15 µm, to track soil structure development with time and in response to seasons. By excluding roots and soil fauna > 30 µm in half of the samples, it was possible to estimate the contribution of abiotic and biotic drivers. The distribution of garnet particles was determined in order to quantify the rate of soil structure turnover as related to potential biotic drivers. It is shown that soil structure turnover by natural processes is slow and that both abiotic and biotic drivers affect soil structure. Turnover under dry climatic condition was significantly slower due to lower biological activity. When soil is mixed by fauna > 30 µm activity, the distribution of garnet particles originally located at the surfaces of macro-aggregates became increasingly randomised, indicating rearrangement of soil structure and establishment of new pore–soil matrix interfaces. In near future, the trials will be used to evaluate the calculated times until complete structural turnover.

Topic 2: Climate change impacts

Strategies to mitigate municipal waste and greenhouse gas emissions in kira municipality in Wakiso District

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Background: Kira municipality generates an estimated 8,195 tons of waste per month, with a composition of food and yard waste 90.64, paper 1.67%, plastic 1.77%, metals 0.15%, glass and porcelain 1.16%, textiles and miscellaneous 1.03%. The average per capita solid waste generation rate is 0.579 kg/ capital/day with a high organic content. The municipality generates about 273 tons of this waste daily but only 40% is collected and land filled with no energy recovery with the rest either burnt or left to decay posing a danger to the environment and health. In order to meet the energy demand and future needs of kira municipality in a sustainable and low-cost manner, there is need to explore the different renewable energy options available in the country as stipulated in the country's energy policy.

Methodology: A greenhouse gas emission inventory was conducted using the Global Protocol for Community-Scale Greenhouse Gas Emissions. Emissions were calculated based on activity data acquired from multiple sources and checked for minimization of overestimate and underestimate. Informal activity data is based on sector-based activities of production and service provision in economic zones including small-medium-large scale industrial-commercial areas within and out of the municipality adjusted to the reference estimates. Emission factors for the different sectors are applied to calculate in-boundary and out-boundary emissions to establish the relationships between municipality -specific and other influenced emissions. Estimates of CH_4 and N_2O are calculated as CO_2 equivalents using the standard warming factors.

Results: The total CO_2e emissions stand at 54,530 tCO_2e distributed as 9,262 tCO_2e from stationary units, 4,359 tCO_2e from mobile units, 35,413 tCO_2e from wastes, 5,448 tCO_2e from Industrial Processes and Product uses and 48 tCO_2e from Agriculture, Forestry and Land Use. Using the adjusted population of the municipality, the percapita emission stands at 0.17 tCO_2e for in-boundary population and 0.08 tCO_2e for combined in-boundary and out-boundary population. Waste sector in general and the solid waste and waste treatment sub-sectors in particular ranked first and second at 43% and 22% respectively. Further analysis showed industrial energy use as the third with 13% of the emissions while 9% of the total emissions are from residential buildings. This distribution is related to the population and the different practices for waste and wastewater treatment, which are characterized by pit-latrines and scattered dumping grounds for solid wastes. The emissions from wastes also relate to the chemical transformation characterized by methane from decomposing wastes.

Conclusion: The GPC provides an opportunity to estimate in-boundary emissions, which requires detailed activity data for the geographic units. This bounding is useful in attributing the estimates to the communities where activities are undertaken but it also has challenges including the availability and reliability of detailed data. In cities where databases are non-existent or not up-to-date, the activity data is adjusted on basis of assumptions in order to calculate sector-based emissio

Topic 2: Climate change impacts

Climate impacts on metal bioavailability in agricultural phytoremediation systems

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Global food demand of a growing and developing population is postulated to increase to more than three billion tons of cereals by year 2050, requiring more than 70% increase in overall food production[1]. 90% of that increase is expected to be met by higher yields and cropping intensity, thereby depleting agricultural soils of nutrients and increasing the probability of enhanced soil contamination. The remaining 10% of food production would be achieved by expanding to more arable land, currently about 51 million km^2 or 50% of habitable land[2], albeit in soils that are inferior in quality in terms of contaminant content and suitability for high demand crops[1]. Such soils could be relieved off their metal burden by phytoremediation. Besides total contaminant loadings in soils, their availability to biota is crucial for ecosystem health, food quality, and ultimately human health. The partitioning of contaminants between soil solids and solution depend strongly on prevailing environmental conditions. We currently have a scarce understanding of how soil metal/loid bioavailability is affected by climate change, namely increases in atmospheric CO_2, temperature and precipitation shifts and whether phytoremediation would be an effective tool in the future for agricultural soils. We postulate that climate change will increase metal/loid mobility and availability in soils making phytoremediation a prominent tool of the future. We investigated what impact climate change has on metal/loid mobility in agricultural soils of different origin, management strategy, texture, pH, natural and spiked contamination extents. In sum for our soils with a pH below 7, imposed future climatic conditions shifted metal/loid partitioning from solids to solution rendering these non-degradable contaminants more bioavailable. Underlying biogeochemical processes responsible for shifts in metal mobility will be discussed and first data on the extent of metal-hyperaccumulation of the model hyper-accumulating plant *Arabidopsis halleri* will be presented.

[1]UN Food and Agriculture Organization. (2009). How to Feed the World 2050, Global Agriculture Towards 2050, Issue Brief.

[2]UN Food and Agriculture Organization. Our World in Data.

Topic 2: Climate change impacts

Plant community dynamics in a 13 year seasonal warming experiment

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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 2021, we have altered seasonal temperature (ambient, winter warming, summer warming; as part of the EVENT II experiment) in temperate semi-natural grassland in Bayreuth, Germany. Aboveground biomass production (AGB) of different functional groups and plant-community composition based on species-specific cover data under different experimental treatments were collected in 13 consecutive years. Results from previous years in the experiment showed that winter warming was ecologically more relevant for community composition and biomass production than summer warming. Prolonged growing seasons and changes in plant-community composition caused by winter warming accounted for increased AGB. However, our long-term data analysis is still in progress. We will include species turnover (changes in species ID) and species reordering (changes in abundance) to explain plant community compositional dynamics and interannual changes in AGB.

Tree growth resistance to the 2018-2020 drought as modulated by tree diversity and mycorrhizal type

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The frequency of consecutive drought years is predicted to increase due to climate change. Strong negative impacts of the unprecedented 2018-2020 drought years were observed across Central European forests. Mixing tree species is proposed to increase the long-term stability of tree communities and to mitigate drought impacts. However, this promising diversity effect has not yet been investigated with the focus on consecutive drought years and on how responses are modulated by different tree mycorrhizal associations. With this study, we aim at answering the question of whether tree diversity can increase growth resistance to consecutive drought years using inventory data (2015 – 2021) of a young tree diversity experiment in Germany (MyDiv) which manipulates tree species richness (1, 2, 4 species) and tree mycorrhizal type (communities containing either arbuscular mycorrhizal (AM) or ectomycorrhizal (EM) tree species, or both). For all tree communities, we calculated drought resistance as the ratio of stem growth during the drought years to stem growth in the pre-drought period (previous two years). Initial results indicate, that mixed communities were in general not more resistant to the drought years than monocultures. Interestingly, EM communities showed higher resistance to the drought years than communities with predominantly arbuscular mycorrhizal fungi. Further analyses currently in progress aim to provide more detailed information on the underlying processes generating these initial results, i.e. using a functional diversity approach and including tree species traits related to the leaf economic spectrum and drought tolerance. This study contributes towards understanding the relevance of tree diversity and belowground mycorrhizal associations for forest responses to drought.

Topic 2: Climate change impacts

Effects of extreme drought and changes in rainfall patterns on ecosystem functioning in Mediterranean shrublands

Marcelo Sternberg; Ofer Cohen

Tel Aviv University, Israel

Understanding the responses of terrestrial ecosystems to global environmental change is a major challenge of current ecological research. Major research efforts are currently being invested to produce reliable scenarios for future plant communities and ecosystem functioning under the uncertainties imposed by climate change. Here, I will present results from a rainfall manipulation experiment carried out in a Mediterranean shrubland ecosystem in Israel testing the effects of changes in rainfall patterns under extreme drought conditions on ecosystem function and plant community dynamics. The results showed significant differences in biomass production and diversity indexes between drought vs. control plots. However, no significant changes were noted when comparing changes in rainfall distribution under drought conditions. The results are explained under the resistance and resilience properties of this type of ecosystem. Strong natural climatic variability and high spatial and temporal heterogeneity in which these systems evolved, allowed the development of biological traits that enhanced the stability of this ecosystem in the short term. Future scenarios for long-term dynamics in the region will be discussed.

Topic 2: Climate change impacts

The formation and loss of warm-adapted microbial temperature relationships in response to summer heatwaves in the Subarctic

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Climate change poses a severe threat to terrestrial ecosystems by rising temperatures and increasing the intensity and frequency of extreme weather events. In arctic and subarctic regions, cold temperatures often limit the microbial decomposition of soil organic matter (SOM), which leads to accumulations of carbon (C). Simultaneously, these regions are expected to experience a disproportional amount of extreme weather events, with rates of temperature increase twice as high as other terrestrial ecosystems. Soil microorganisms regulate biogeochemical cycles by controlling the C release from soils to the atmosphere through respiration and forming SOM with long residence time via microbial growth. We simulated summer heatwaves in a subarctic birch forest in North Sweden with infrared (IR) heaters to test how fast the microbial community adapts its temperature relationships to the heatwaves and how long the adaptation persists. The temperature increased by 14.5 °C on the surface and by 3 °C in the soil, closely matching extreme summer conditions occurring in arctic Siberia during the year of study. We determined the bacterial growth, fungal growth, and microbial respiration temperature relationships. We found that the microbial community adapted its temperature relationship of growth to the heatwaves, becoming more temperature-sensitive (higher Q_{10}); changes in microbial functions lasted one year before dissipation. However, this shift in microbial temperature relationships could not be explained by differences in α or β - diversity of the microbial community. For respiration, we did not observe any change in the temperature relationships. The carbon use efficiency (CUE) of the microbial community decreased by 33 %, suggesting that the microbial responses would exacerbate C losses from soils.

Topic 2: Climate change impacts

Marsh ecosystem response to increased temperature (MERIT): a novel in situ salt marsh warming experiment.

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Salt marshes provide an array of ecosystem services, and are recognized as a significant global carbon store. Climate-induced warming, however, is likely to alter salt-marsh ecosystem functioning, with potential implications for the biogeochemical cycling of climate-relevant compounds. With regards to warming effects on salt marsh ecosystems, there is a dearth of experimental data, particularly for subsurface soils. Established in 2018, the MERIT (Marsh Ecosystem Response to Increased Temperature) in situ salt marsh warming experiment combines both passive aboveground warming with feedback-controlled active belowground and soil surface warming. This setup allows assessment of warming-induced changes to both above- and belowground plant and soil characteristics. Three replicate plots for three temperature scenarios (ambient, 1.5°C, and 3.0°C) were established in each of the three salt marsh zones: pioneer zone, low-marsh, and high marsh (n=27). Mixed models show that the experimental setup is effective at warming the ecosystem. Initial results show earlier plant greening and later senescence, slightly increased seed mortality, and increased rates of organic matter decomposition in experimentally warmed plots.

Plant diversity and soil history effects on community assembly of arbuscular mycorrhizal fungi

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Recent extensive research has shown that the relationship between biodiversity and ecosystem functioning (BEF) strengthens over time. Insight on underlying mechanisms, however, is still scarce. One potential driver are soil fungi as interaction partners of plants, in particular the symbiotic arbuscular mycorrhizal fungi (AMF). As obligate biotrophs, they transfer mineral nutrients to plant roots in exchange for photo-assimilates. It is unclear, whether this interaction strengthens over time, and more basically, whether the effect of plant diversity on AMF communities changes over time.

To address this gap of knowledge on mechanisms and BEF dynamics, the long-term biodiversity experiment The Jena Experiment was re-established. Within the existing platform of grassland plots with varying plant biodiversity (1, 2, 4, 8, 16, 60 plant species) and composition (herbs, grasses, legumes) three treatments were set up: One comprises old soil and old plant communities, by using the since 2002 existing plots of The Jena Experiment. The second treatment consists of newly re-sown plant communities in old soil. And the third treatment combines new soil and new re-sown plant communities. In June 2021, we sampled bulk soil of the 19 and 5 year old plots. We used nested PCR and amplicon sequencing with Illumina MiSeq to analyse arbuscular mycorrhizal fungi (AMF) communities.

Preliminary results show an increase of AMF sequence variants (ASV) richness with increasing plant diversity across all three treatments. However, Shannon and Simpson diversity indices are lowest in plots with new plants and new soil and highest in old plants / old soil plots. The new plots showed higher relative abundance of *Septoglomus* and *Paraglomus*, but less of *Funneliformis*, *Claroideoglomus* and *Glomus* in comparison to plots with new plants in old soil. In comparison to plots with old plant and soil, the new plots show higher relative abundance of *Archaespora, Otospora, Septoglomus* and *Paraglomus* and again less *Claroideglomus*. Between the new plants in old soil and old plants in old soil we see an increase in relative abundance of *Rhizophagus* with plant community age. A PERMANOVA model revealed significant influence of the treatments, the presence/absence of plant functional groups grasses and legumes, and plant functional diversity in the plots. Calculations of matrix correlation for ASV abundances revealed low correlation between all treatments, with the lowest correlation between new plants in new soil and old plants in old soil plots. The treatments and sown plant diversity also significantly affected plant productivity, but AMF richness had no effect on plant productivity. However, the pairwise beta-diversity of fungi and total plant biomass, as well as biomasses of individual plant functional groups, do correlate.

With these first results we can confirm temporal changes in AMF community compositions in the Jena Experiment grassland plots. We further see influence of plant communities on AMF communities. The found differences between all three treatments, however, suggest that soil also plays an AMF-independent role on BEF dynamics which needs to be further examined.

Topic 4: Context dependencies and interactions among drivers

Reproduction and population growth of plants in a changing environment

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Responses of plant communities to climate and land use change are often variable across studies. This variation is due to several factors, including experimental design, spatial and temporal grain of analyses, and context-dependent factors such as the environmental conditions that occur during the duration of the experiment and the traits of species. Here, we examine the causes of variable responses to climate through global synthesis of climate change experiments, and discuss the role of context dependency using cases studies from the GCEF. Our global synthesis of 76 studies that manipulate climate show that there are vast differences in experimental design. Few studies manipulate both temperature and precipitation, and even fewer consider interactions with other environmental factors. These climate experiments typically manipulate temperature and/or precipitation at one level that is well outside the level expected in the future for the region. We show that these differences in experimental design have consequences for the study results. Plant diversity responses increase with the magnitude of the precipitation manipulation. Results also depend on the spatial grain of the analysis and background climate conditions, as higher diversity responses were observed at smaller spatial grains and in more arid biomes. In a case study in the GCEF, we examine whether climate change influences plants indirectly by altering ecological interactions. We suggest that the results of experiments manipulating pollination and climate also depends on the context. Pollen limitation is expected in environments with high precipitation, but might not be observed for highly generalized and drought-tolerant plant species. In another case study in the GCEF, we highlight how demographic studies allow for a mechanistic understanding of the pathways in which environmental factors change population size. We find that climate and land use interactively influence demography and population growth of the perennial grass, *Bromus erectus*. Under ambient climate conditions, population growth of *B. erectus* was higher in mowed than grazed grassland plots, while population growth rates were similar across both management types under future climatic conditions. We expect that the effects of climate and land use treatments are likely to vary across plant species based on their trait differences, and understanding the context dependency of these population responses will enable a deeper understanding of results on community level patterns of composition and biomass.

Topic 4: Context dependencies and interactions among drivers

Metagenomic analysis of soil microbiomes responses to climate and land-use change during the summers of 2014-2019

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Research into climate and land-use change has mainly focused on soil microbial community changes, rather than identifying and analyzing the functional mechanisms. Here, we investigate the soil microbiomes responses to a future climate scenario (ambient climate vs. increased temperature by +0.6 °C and altered rainfall patterns) across three land-use types (conventional farming, organic farming and intensively used grassland) at the Global Change Experimental Facility (GCEF) in central Germany. Soils were sampled for metagenomic analysis during the summers of 2014-2019. Prolonged heatwave and drought unexpectedly occurred throughout central Europe in 2018 and 2019 summers, thus they were considered as extreme summers. In contrast to normal summers, extreme summers resulted in substantial changes in the soil microbial community composition and function. The alpha diversities at both taxonomic and functional levels in extreme summers were significantly decreased compared with that in normal summers. The relative abundance of *Actinobacteria* was markedly increased from 19% in normal summers to 41% in extreme summers. Compared to ambient climate, future climate significantly affected the abundance of *Thaumarchaeota* and *Candidatus Eisenbacteria*, although the majority of microorganisms remained largely unaffected. Results also demonstrated the significant effects of two main land-use types (cropland vs. grassland) on soil microbiomes under different climate conditions. In addition, we recovered 459 near-complete metagenome-assembled genomes (MAGs) from 180 metagenomic datasets. Functional annotation of MAGs further supported that future climate change has affected the genes involved in carbon and nitrogen cycling, such as CAZymes, ammonia oxidation and denitrification. Overall, our results revealed previously unreported soil microbial genomes and extend our understanding of microbial functional traits as influenced by climate and land-use change.

Topic 4: Context dependencies and interactions among drivers

Multifactorial and multidisciplinary approaches to study adaptation of wheat rhizosphere communities to drought

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Wheat production is highly threatened by drought periods that increase in the frame of climate change. Research on plant beneficial microorganisms has steadily increased and novel means are developed to support plant growth during drought stress. However, since most studies have not incorporated the interactions between drought and other factors, the aim of this study was to investigate structural and functional adaptation of wheat rhizosphere microorganisms by using multifactorial experiments.

Here we used the Global Change Experimental Facility and associated pot experiments to study the impact of drought on bacteria in the rhizobiome of wheat in dependency of single and interacting effects of soil type (loamy vs. sandy), farming management (conventional vs. organic), wheat cultivar (demanding vs. non-demanding) and plant growth stages (vegetative vs. mature). Thereby, changes at individual species or community level were considered by applying cultivation-dependent (in-vitro bioassays) and independent methods (extracellular enzyme activities and amplicon next generation sequencing), respectively.

Results indicated an overall strong effect of the soil type, followed by the farming management, on structural adaptation of the rhizobacterial communities to drought. Thereby, relative abundances of Actinobacteria increased while Proteobacteria decreased under drought conditions. With regard to the community functions, farming management was the major driver of extracellular enzyme production with less activity in organically compared to conventionally farmed fields. A particular exception from this pattern was found in sandy soil under organic farming suggesting a positive plant-soil-feedback after drought conditioning. Despite a low effect of the wheat cultivar, the growth phase significantly altered both, rhizosphere community composition as well as related functions. A complementary approach comprising bacterial species isolation and their trait assessment revealed members of the genus Phyllobacterium as novel promising candidates to support wheat growth under future drought conditions.

Our results demonstrate that soil type, farming system and growth phase each constitute important factors during the structural and/or functional adaptation of rhizobacterial communities in response to drought. They indicate common adaptation processes to drought in the field and pot experiments, underlining the importance of multifactorial approaches to reveal community- or species-specific plant-soil-feedbacks.

Topic 4: Context dependencies and interactions among drivers

Heatwave and warming induce distinctive community responses through their interactions with a novel, range-expanding species

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The speed and scale of range shifts vary widely among species and regions. Part of this variability is driven by differing effects of different climate components (e.g. gradual warming versus heatwaves) on organismal physiology, and by direct and indirect interactions with other species. We used laboratory experiments to compare the impacts of heatwaves versus gradual warming on a Drosophila-parasitoid community from the upland tropical forest of Australia, with or without invasion of a novel competitor from nearby lowland forests. Both parasitoid wasp species examined were sensitive to a rise in temperature, while the demographic responses of Drosophila species were idiosyncratic, reflecting the combined effects of thermal regimes, parasitism, competition and apparent mutualism. Heatwaves, but not warming, facilitated the establishment of the lowland species within upland communities. The introduction of the invading species correlated negatively with the abundance of parasitoids, while high parasitoids numbers tended to suppress the competitively-dominant Drosophila species and its effects on inferior competitors. Our study reveals contrasting impacts of heatwaves and warming on individual species within the same community. It also highlights how the scale and direction of the impact could be further modified by the indirect effects of a novel species within the bi-trophic network. Understanding the thermal performance of component species and their interactions when they are embedded within community networks may be crucial to understanding the direct and indirect impacts of climate change, and for designing practical strategies to mitigate them.

Topic 4: Context dependencies and interactions among drivers

The heterogeneity–diversity–system performance nexus

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Biodiversity determines the functioning of ecosystems, but there is some significant context-dependency in the strength and direction of this relationship. Recent evidence suggests that positive biodiversity effects are strongest in heterogenous environments, when the complementarity of different taxa can unfold. We discuss the implications of this finding across systems and disciplines.

Topic 4: Context dependencies and interactions among drivers

An innovative sensor platform for in-situ studies of dynamics and underlying processes, driving spatio-temporal water, carbon and greenhouse gas flux pattern in a heterogeneous arable landscape

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Improved agricultural practices increasing the water use efficiency (WUE), reducing greenhouse gas emissions (GHG) and/or improving atmospheric C sequestration rates within the soil are crucial for an adaptation and/or mitigation to the global climate crisis. However, processes driving water (H_2O), carbon (C) and GHG fluxes within the soil-plant-atmosphere continuum of agricultural used landscapes are complex and flux dynamics differ substantially in time and space. Hence, to upscale and evaluate the effects/benefits of any new agricultural practice aiming towards improving WUE, soil C sequestration and/or GHG emissions, accurate and precise information on the complex spatio-temporal H_2O, C and GHG flux pattern, their drivers and underlying processes are required.

Current approaches to investigate this topic are usually laborious and have to choose between high spatial or temporal resolution due to methodological constraints. On the one hand, often used eddy covariance systems are not suitable to account for small scale spatial heterogeneities and to separate the soil and farming impact, despite growing evidence of their importance. On the other hand, chamber systems either lack temporal resolution (manual chambers) or strongly interfere with the measured system (static automatic chambers). Hence, none of these systems enable a proper upscaling and evaluation of effects/benefits of new farming practices for WUE, C sequestration and GHG emissions at especially heterogeneous agricultural landscapes, such as present within inter-alia the also globally widespread hummocky ground moraine landscape of NE-Germany.

In an effort to overcome this, a novel, fully automated robotic field sensor platform was established and combined with an IoT network and remote sensing approaches. Here, an innovative, continuously operating, automated robotic field sensor platform is presented. The platform was mounted on fixed tracks, stretching over an experimental field (150m x 16m) which covers three different, distinct soil types. It carries multiple sensors to measure GHG and water vapour concentrations as well as water vapour isotope signatures of $\delta^{18}O$ and δD. Combined with two chambers which can be accurately positioned in three dimensions at the experimental field below, this system facilitates to detect small-scale spatial heterogeneity and short-term temporal variability of H_2O, C and GHG flux dynamics as well as crop and soil conditions over a range of possible experimental setups. The automated, continuous estimation of $\delta^{18}O$ and δD of evapotranspiration further provides the basis to partition water fluxes alongside the flux based partitioning of C and GHG fluxes. This particularly promotes to assess not only ecosystem but component specific WUE. Hence, this platform produces a detailed picture of H_2O, C and GHG dynamics across soil and farming practice combinations and crop rotations, with a high-degree of accuracy and reproducibility.

Topic 4: Context dependencies and interactions among drivers

Joint impacts of climate and predation on multitrophic interactions and ecosystem functioning

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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 EcoStressWeb, an iDiv Ecotron experiment to assess 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 two collembola species and 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 ~4 months, we harvested the experiment and sampled invertebrate and microbial 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. As such, the invertebrate data will be used to assess how multitrophic interactions, feeding preferences, and energy flux change with varying soil moisture and predator communities. Here, we will provide first 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.

Topic 4: Context dependencies and interactions among drivers

Estimating the effects of climate change and land-use on rodent dynamics, associated parasites and pathogens

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Rodents are hosts of parasitic arthropods and their pathogens can inflict serious diseases in humans and livestock. Future effects of climate change may affect reproduction, maturation and population dynamics of rodents as well as the host-seeking behavior of arthropod vectors and their ability to transmit disease agents. This project aims to examine the effect of climate change on ectoparasites and pathogens with zoonotic potential and consequences for rodent species which are regarded as pest species in agriculture and forestry.

The „Global Change Experimental Facility“ provides an ideal setting at a suitable spatial scale to identify such effects under field conditions. Altogether 10 plots, each consisting of randomly distributed 400 m2 patches of conventional farming, organic farming, intensively used grassland, extensively used grassland (mowing) and extensively used grassland (grazing) were used in the study. Climate conditions were manipulated in half of the plots while the other plots were unmanipulated experimental controls. Manipulated climate conditions reflected projections for the period of 2070-2100 with increased temperatures and a changed precipitation pattern, consisting of reduced precipitation in summer and increased precipitation in spring and autumn.

In 2019 and 2020, rodents, ectoparasites and pathogens were investigated. From about April to October, rodents were trapped and animals individually marked with PIT tags. Blood and tissue samples were taken, sex, weight and reproduction status documented, ectoparasites collected and individuals released at the point of capture.

4790 rodents of 5 species were caught, mainly *Microtus arvalis* and *Apodemus sylvaticus*. Both rodent species preferred similar land-use types. Most individuals were caught in intensively used grassland, least in organic farming. 11 % of *M. arvalis* and 3 % of *A. sylvaticus* were tested positive for *Borrelia afzelii* with most positive rodents found in extensively used meadow (grazing), least in organic farming.

7 % of all tested voles were infested with altogether 321 ticks. Only 25 ticks were tested positive for *B. afzelii* whilst 27 negative ticks originated from 21 *A. sylvaticus*.

First findings suggest some climate and land-use effects on species specific abundance of rodents, reproduction and taxon-specific occurrence of parasites. Preliminary results will be presented and will be supplemented and validated with further field data.

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Topic 4: Context dependencies and interactions among drivers

Management intensity in croplands and grasslands affect earthworm biomass differently under ambient and future climatic scenario

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Global change drivers, such as climate change and land-use intensification, may profoundly influence abundance and biomass of soil organisms. However, it is still not well known how these concurrent drivers interact in affecting ecological communities. Here, we present the results of an experimental field study assessing the interactive effects of climate change and land-use intensification (conventional farmland vs. organic farmland, intensively managed grassland vs. extensively managed meadow) on abundance and biomass of earthworms across seasons (spring and autumn). We found that the abundance and biomass of earthworms are significantly higher in grassland than in cropland. The intensive grassland use decreased the total abundance and biomass of earthworms with strong seasonal dynamics, but farmland intensification and the projected climate change had weaker effects. Strikingly, the negative effects of intensive land use on earthworm abundance and biomass were species-specific. Endogeic earthworms except for *Aporrectodea caliginosa* had higher abundance and biomass in extensively used meadows than intensively used meadows. However, intensive grassland management increased the abundance and biomass of the anecic earthworm *Lumbricus terrestris*. The influence of intensive cropland management earthworm abundance was slightly associated with altered climatic conditions. The earthworm abundance in organic croplands tended to be consistently higher than in conventional croplands under future climate conditions, but not under ambient climate. This finding indicates that negative effects of land-use intensification on earthworms vary greatly among different land-use types.

Response of soil microbial communities to mixed beech - conifer forests varies with site conditions

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Tree - soil interactions depend on environmental conditions. Planting trees may affect soil microbial communities and compromise their functioning, particularly in unfavorable environments. To understand the effects of tree species composition on soil microbial communities, we quantified structural and functional responses of soil microorganisms to tree species planted in various environments using substrate-induced respiration and phospholipid fatty acid analyses. Five forest types were studied including pure stands of native European beech (*Fagus sylvatica*), range expanding Norway spruce (*Picea abies*), and non-native Douglas-fir (*Pseudotsuga menziesii*), as well as the two conifer - beech mixtures. We found that microbial functioning depends strongly on soil nutrient concentrations in the studied forest sites. At nutrient-poor sites, soil microorganisms were more stressed in pure and mixed coniferous forests, especially in Douglas-fir, compared to beech forests. By contrast, microbial structure and functional indicators in beech forests varied little with site conditions, likely because beech provided ample amounts of root-derived resources for microbial growth. Since soil microbial communities are sensitive to Douglas-fir, planting Douglas-fir may compromise ecosystem functioning, especially at nutrient-poor sites. Overall, root-derived resources are important for determining the structure and functioning of soil microbial communities, so soil microbial responses to tree species will depend upon the provisioning of these resources as well as site-specific environmental conditions.

Topic 4: Context dependencies and interactions among drivers

Historical context modifies plant diversity–community productivity relationships in alpine grassland

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While most studies yield positive relationships between biodiversity (B) and ecosystem functioning (EF), awareness is growing that BEF relationships can vary with ecological context. The awareness has led to increased efforts to understand how contemporary environmental context modifies BEF relationships, but the role of historical context, and the mechanisms by which it may influence biodiversity effects, remains poorly understood. We examined how historical context alters plant diversity–community productivity relationships via plant species interactions in alpine grassland. We also tested how historical context modifies interactions between plants and arbuscular mycorrhizal (AM) fungal communities, which can potentially mediate the above processes. We studied biodiversity effects on plant community productivity at two sites with different disturbance histories related to grazing intensity — heavy versus light livestock grazing — but similar current management. We assembled experimental communities of identical species composition with plants from each of the two sites, ranging in species richness from one to two, three and six species. Moreover, we carried out a mycorrhizal hyphae-exclusion experiment to test how plant interactions with AM fungal communities influence plant responses to historical context. We detected a significantly positive diversity–productivity relationship that was driven by complementarity effects in communities composed of plants from the site without disturbance history, but no such relationship in plant communities composed of plants from the site with a disturbance history of heavy livestock grazing. Plants from the site with disturbance history had increased competitive ability and increased yields in low-diversity communities but disrupted complementarity effects in high-diversity communities. Moreover, plants of one species from that site benefitted more from AM fungal communities than did plants from the site without disturbance history. Using the same experimental design and species, communities assembled by plants from two sites with different historical contexts showed different plant diversity–community productivity relationships. Our results suggest that historical context can alter plant diversity–community productivity relationships via plant species interactions and potentially plant–soil interactions. As such, we suggest that considering historical contexts of ecological communities is of importance for advancing our understanding of long-term impacts of anthropogenic disturbance on ecosystem functioning.

Microbial processes impacting soil carbon cycling under anthropogenic change: trait-based scaling from individuals to the ecosystem

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Soil microbes act as gatekeepers of soil-atmosphere carbon exchange by balancing the rates of decomposition and stabilisation to either release or store carbon in soil. Land use and climatic changes are altering this balance often leading to loss of carbon, and soil microbiome composition and physiology are central in driving this loss. Still, understanding and predicting the ecosystem implications of microbial processes remains a challenge. To address this challenge, we have proposed a shift away from taxonomy to characterise the spectrum of microbial physiology as traits in single populations and collective communities. We hypothesised that individual-level investments and the resulting trade-offs among traits structure populations, and this determines the emergent community response to environmental change and consequences for organic matter transformations in soil.

In this seminar, I will present our research on identifying microbial life history strategies based on their phenotypic characteristics, or traits, and on ways to represent these strategies in models simulating different environmental conditions. By adapting several theories from macroecology, we define microbial high yield (Y), resource acquisition (A), and stress tolerance (S) strategies. Using multi-omics and stable carbon isotope tools, we empirically validated our Y-A-S framework by studying variations in population and community traits along gradients of resource availability and abiotic conditions arising from land use (across a UK-wide land use intensity gradient) and climate change factors (experimentally simulated drought in California grass and shrub ecosystems).

Along the land use intensity gradient, reduced community growth yield with intensification was linked to decreased microbial biomass and increased biomass-specific respiration due to greater investments in A and S strategies which translated into lower organic carbon storage in such soils. We concluded that less-intensive management practices have more potential for carbon storage through increased Y strategy with greater channelling of substrates into biomass synthesis. We also demonstrated how physiological shifts are linked to soil pH-dependent community turnover. In California Mediterranean ecosystems, we observed that drought causes discernable physiological stress adaptations in litter microbial communities. These adaptations increase microbial fitness such that overall decomposition rates are not impacted by drought. Using metagenomics-assembled genomes, we were also able to demonstrate population-level changes in bacterial and fungal physiology to shed light on the underlying adaptive mechanisms.

Overall, our findings suggest trade-offs between Y-A-S strategies in microbes across different ecosystems. These empirical studies demonstrate how trade-offs in key microbial traits at the population-level can have consequences on community traits with implications for soil carbon cycling. We recommend the use of our framework in experimental and modelling studies to mechanistically link microbial individuals to community and system-level processes.

Topic 4: Context dependencies and interactions among drivers

A new era in landscape ecology: Raising a flag for landscape experiments.

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Accelerating global changes call for decisive measures in the race for sustainability worldwide. Agriculture has been recognized as one of the most prominent drivers of such changes, and, at the same time, many of its functions are negatively affected by such changes. Meanwhile, adjusting management to more sustainable agricultural practices has the potential to turn it into a powerful tool for regulation towards achieving such urgent goals as satisfying the growing food demand, moderating global climate change, and protecting biodiversity, soil health and watershed integrity. As the basis to advance such transition, and the consideration of possible trade-offs, the processes taking place at different scales and interdependencies between them need to be well understood. For this reason, an increasing number of research has been done on agroecology and sustainable intensification in recent years. Extensive monitoring programs are a first step towards a better understanding of complex interactions in real-world setups. However, monitoring data hardly suffice to perform a sound test of postulated cause-effect relationships. Conventional experiments, on the other hand, fall short of elucidating complex interactions between numerous processes. Thus, it is necessary to rethink existing experimentation approaches in the direction of multiscale and transdisciplinary studies.

We see an urgent need for establishing a new category of experiments termed “landscape experiments”. We define landscapes as a spatial arrangement of interrelated entities rather than by size. Correspondingly, landscape experiments aim at elucidating interactions between various landscape structures and functions, encompassing both natural and anthropogenic features. That places high demands on the experimental design, on data collection, and on data analysis, differing fundamentally from those of classical field experiments. To name but a few challenges in landscape experimentation, single units cannot be considered homogenous, there are no real replicates, and spatial location of single units needs to be considered, e.g., in terms of exchange of energy, mass, or organisms. Starting with an analysis of approaches commonly used for experimentation in (agricultural) ecosystems, we take a look at the steps of experimental setup planning and experimental procedure in relation to the goals and research questions, spatial and temporal variability of related variables and data manipulation approaches, including scaling methods. Based on that we identify the existing challenges, as an essential step to direct future efforts in developing methods to conduct experimentation in agricultural landscapes considering the spatial and temporal diversity of the ruling processes and to make the most of available resources. The patchCROP landscape experiment will be presented as an example.

Topic 4: Context dependencies and interactions among drivers

Varying responses of flowering phenology and functional traits to future climate on meadows versus pastures

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Phenological shifts are "fingerprints of climate change". With increasing temperatures, changes in spring phenology have been widely reported, leading to an extension of the growing season. However, phenological changes remain highly species specific. Plant phenology is also reported to be adaptive to different land uses like grazing or mowing but whether the impacts of climate change are similar in grazed versus mown grasslands is not yet understood.

Plant functional traits as a proxy for plant fitness and performance have been shown to respond to changes in environmental conditions such as temperature or water availability. If the timing of phenological stages like the beginning of flowering and functional traits like the number of flowers is altered by future climate, pollination mismatches get more likely and can reduce reproductive success and thus plant fitness through pollen limitation. Furthermore, plant traits linked to competitive ability like plant height might be affected by future climate. Both altered plant fitness and competitive ability might change the structure and species composition of grassland communities.

The aim of our study was to investigate how a realistic scenario of climate change influences phenology and functional traits of common Central-European grassland plants under two different land-use types. More specifically, we compared extensive meadows and extensive pastures under ambient and future climate conditions (drier summers and wetter springs and falls) in the Global Change Experimental Facility, a large field experiment in Central Germany.

We weekly observed the flowering phenology and abundance of all grassland species throughout a whole vegetation period. To investigate the impact of climate and land-use on species performances, generative (e.g. flower size, number of flowers) and vegetative traits (e.g. plant height, specific leaf area) were assessed for a subset of six species expected to be responsive towards the climate treatment and land use types.

First results revealed that plant species responded species specifically to climate with advances, delays or no responses in first flowering day and that these responses differed between land use types. Even though flowering intensities themselves were mostly comparable between climates within meadows and pastures, respectively, we found pronounced effects when accounting for species abundances. Especially in late summer and on pastures, flower abundance decreased under future climate what in turn might have a negative impact on pollination. Thus, we advocate to take abundance information into account when analyzing plant phenology data in natural communities.

Generative traits did not respond to climate and land use, indicating that these traits are stable compared to vegetative traits which were more responsive, e.g. SLA increased for two species under future climate. Plant height increased for one species under future climate and decreased for another species.

Our results suggest that some species might benefit from additional spring precipitation under future climate and that phenological responses to climate change are contingent on land-use type.

Topic 4: Context dependencies and interactions among drivers

Land-use intensity modulates climate change impacts on annual decomposition dynamics in temperate agricultural systems.

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Litter decomposition is one of the most important terrestrial ecosystem processes. It is initially facilitated by physical comminution and partial decomposition of plant residues by the soil macro- and mesofauna. Subsequently, soil microorganisms further break down the plant material via production and secretion of oxidative and hydrolytic enzymes. It is widely recognized that decomposition is affected by a range of abiotic (e.g. soil temperature, moisture, pH) and biotic (soil fauna, microbial community, plants) factors, implying that land use, climatic conditions and seasonality exert a strong influence on decomposition rates.

For this reason, we investigated the seasonal dynamics of litter decomposition in different land-use scenarios of the Global Change Experimental Facility (GCEF). The range of agricultural land-use types included a conventional and an organic farming system, an intensively and an extensively farmed meadow, and an extensively grazed sheep pasture. Further, the GCEF allowed to study decomposition under ambient as well as under predicted future climatic conditions. The implemented climate change treatment included a general warming and rainfall manipulation (-20% in summer, +10% in spring and fall). To account for the latter, we collected soil from all treatments at the end of each season and determined soil hydrolytic enzyme activities. Simultaneously, a set of green and rooibos tea bags was buried each season and subsequently analyzed according to the standardized ”Tea Bag Index”. This approach allowed comparisons of patterns of initial (by weigh loss) and subsequent (by enzyme activities) decomposition processes.

Among the studied drivers, we expected that land-use intensity has the greatest effect on decomposition processes. Moreover, we hypothesized that climate effects are mainly driven by the season-dependent rainfall manipulation and expected a positive correlation between rainfall manipulation and decomposition. The results revealed highly dynamic patterns of the tea decomposition rates as well as of the soil enzyme activities along the studied seasons. These intra-annual variations were stronger than differences caused by the land-use and climate treatments. Nevertheless, we revealed a significant impact of land use, whereby decomposition rates and enzyme activities were mainly related to plant growth. The climate change treatment showed only minor effects in spring and fall. However, in summer, the reduced rainfall under future climatic conditions lowered decomposition rates and enzyme activities, whereby no systematic concordance between land-use intensity and the resilience of decomposition indices against the dryer conditions was observed. We further revealed land-use specific legacy effects of the summer drought, which modulated the response of the decomposition rate to climate manipulation in autumn.

The presented results enhance our understanding on current and expected decomposition dynamics, which is crucial for improving agricultural management, mitigating greenhouse gas emissions, and predicting soil carbon storage capacities.

Topic 4: Context dependencies and interactions among drivers

Indirect effect of fertilization on tree overyielding via change in species dominance

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In the context of anthropogenically accelerated eutrophication in the biosphere, the variable impact of nutrient addition on plant diversity-productivity relationship is a major concern. However, the indirect effect of nutrient addition on tree mixture overyielding via changes in the functional structure of tree communities has never been quantified experimentally, and may play a major role in mediating diversity-productivity relationships.

Here, we present results from young experimental tree communities four years after planting, including monocultures and two- and four-species mixtures of six European species (*Acer platanoides, Betula pendula, Larix decidua, Picea abies, Pinus sylvestris* and *Quercus robur*) with or without fertilization. Using a response-effect trait framework which links plant functional traits to ecosystem processes, we specifically examined how functional diversity (FD) and community-weighted means (CWM) of tree height and specific leaf area (SLA) are impacted by fertilization and mediate its effects on the magnitude of aboveground woody mass overyielding.

After four years of nutrient addition, we found that the influence of fertilization on the degree of community-level overyielding was highly variable and strongly dependent on species composition, although most of the mixtures showing no influence of fertilization in overyielding. Nonetheless, fertilization impacted community functional trait structure to some extent, by increasing CWM of SLA through dominance of species with high SLA rather than intraspecific trait variability. Interestingly, the fertilization-induced change in CWM of SLA negatively affected the degree of community-level overyielding. Irrespective of fertilization, CWM of tree height and SLA influenced community-level overyielding, while FD had no significant effects.

Our results indicate that changes in nutrient availability can influence the magnitude of overyielding indirectly through dominance of species with high SLA in young tree communities. This result has important consequences for our understanding of the context dependence of diversity-productivity relationships, which could strongly depend on the soil fertility effects on the competitive success of tree species over others. The occurrence of such effects early after tree planting may yield large consequences when accounted over the entire life of plantations, and even more so in naturally regenerating forests with less control on tree species selection.

Topic 4: Context dependencies and interactions among drivers

Impacts of climate change and land use on soil energy fluxes

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Soil organisms and their diverse interactions provide essential ecosystem functions and services through a variety of mechanisms, making them an important resource for human well-being. However, global change drivers such as climate change and modern land use threaten to alter this critical role, as they do not act in isolation from each other, making ecosystem consequences difficult to predict. To address this knowledge gap, we used a large-scale field experiment (GCEF) to investigate the interactive effects of climate change and land use type on the belowground food web. We measured soil microbial activity, identified soil nematodes, mesofauna and macrofauna, and measured their length and width to determine the energy flux of the belowground food web. We tested food web responses in an ambient and future climate scenario (+0.6°C temperature increase and changing precipitation patterns) in four land use types (conventional cropland, organic cropland, intensive grassland and extensive grassland) to draw conclusions about changes in key ecosystem functions such as decomposition, pest control, and belowground herbivory.

Topic 4: Context dependencies and interactions among drivers

Plant age, soil texture and drought rather than the presence of root hairs affect maize and its rhizosphere microbiome

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Laboratory studies have identified fundamental processes and genetic determinants affecting the growth and stress tolerance of maize, yet they ignore complex field conditions where soil and climate variables interact. We report on the relative importance of plant developmental stages, substrate, and the ability to form root hairs on field-grown maize in terms of root gene expression, shoot element status, resource allocation patterns, exudation and prokaryote microbiome composition.

In the fields of the Bad Lauchstädt experimental station, wild type and root hairless rth3 mutant maize were grown on two substrates, sand and loam, and sampled during the 4-leaf, 9-leaf and tassel emergence stages. Under the fertilization regime, maize plants were limited with respect to P, K and Zn during all growth stages, and plants suffered from drought stress during tassel emergence. Youngest leaf and whole shoot elemental compositions were assessed by shoot ionome analysis, root gene expression by RNA sequencing and qRT-PCR, root resource allocation of recently assimilated carbon and nitrogen by stable isotope labelling, root exudation by LC-MS, and rhizosphere prokaryote microbiome by amplicon sequencing.

In most analyses, growth stage accounted for the main differences, followed by substrate and root hair formation. Root exudation rate was at its highest for young maize seedlings, and higher in the root hairless maize plants. During tassel emergence, the concentrations of several elements in youngest maize leaves decreased, but nutrient transporter expression in roots increased. At the same time cell wall formation-related root gene expression and carbon allocation to roots decreased, and the composition of the rhizosphere microbiome changed. Substrate-related changes were pronounced during tassel emergence, including differential concentrations of mineral nutrients in maize leaves (mostly lower in sand) and enhanced phytosiderophore biosynthesis, transporter and cell wall gene expression in sand. The effect of root hairs was mainly manifested at the level of whole shoot elemental contents and shoot biomass, which were higher in wild type plants. Drought stress related gene expression was limited to the increased expression of some aquaporin genes on sand. Cross-comparisons between the gene expression, exudation, and rhizosphere microbiome analyses identified plant defence genes and metabolites that may induce the observed changes in rhizosphere microbiome. Top genes, exudates and bacterial families were identified by applying random-forest classification of the relative abundances of transcripts, exudates, and amplicon sequences against growth stage, substrate and the presence of root hairs.

Our results demonstrate strong effects and interactions between the growth stage and substrate on maize and rhizosphere microbiome, and indicate that root hairs are important for maize growth in the field.

Topic 4: Context dependencies and interactions among drivers

Root hairs matter at field scale for maize shoot growth and nutrient uptake, but root trait plasticity is primarily triggered by texture and drought

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Aims: Root hairs are important for uptake, especially for nutrients with low mobility in soils with high sorption capacity. Yet, this has rarely been demonstrated in the field during a whole growing season. Mutants with defective root hairs are expected to have lower nutrient uptake, unless they compensate with more root growth. Since root hairs can also contribute to the plant's water uptake their importance could change over the course of a growing season.

Methods: The root hair mutant rth3 of Zea mays and the corresponding wild-type were grown for two years under field conditions on sand and loam.

Results: Shoot growth and P and K uptake of the plants were promoted by the presence of hairs at all growth stages. Differences between genotypes were greater on loam than on sand until tassel emergence, because additional exploitation by hairs is more relevant in loam. Compensation for the absence of root hairs by increased root growth was not observed in absolute terms. The root to shoot ratio was higher for rth3 than for wild-type. Root traits showed high plasticity in response to texture, the most salient being a greater mean root diameter in sand, irrespective of genotype. The mechanism causing the increase in mean root diameter is still unknown. Root length density was higher in sand, which can be explained by a greater need for exploration than exploitation in this substrate.

Conclusion: The greater investment in root growth on sand compared to loam is expected to alter the long-term carbon balance.

Topic 4: Context dependencies and interactions among drivers

The multitrophic processes are shaped by mycorrhizas and tree diversity

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The relationship between biodiversity and ecosystem functions (BEF) in forests compared to grasslands remains partly unclear. For example, tree identity has been suggested to play an important role as well as species richness; even for the same ecosystem functions, different studies reported opposing results. On top of that, research on BEF relationships did not entirely disclose the roles of biotic interactions driving BEF, such as mycorrhiza, that strongly shape tree performance. To address these knowledge gaps, we used a field experiment (MyDiv) that comprises ten tree species associating with either arbuscular (AM) or ectomycorrhizal (EcM) fungi, to create gradients in species richness and different mycorrhizal associations. We investigated the effects of tree species richness and mycorrhizal type on crucial ecosystem functions, such as herbivory, predation, and soil fauna activity. More specifically, the effects were quantified by using log ratio of each function in polyculture to monoculture, namely as effect size. We, further, looked at the relationships among these functions. Three targeted functions were significantly influenced by mycorrhizal types and species richness. In tree communities with both mycorrhizal types, polycultures performed significantly better on depressing herbivory damage (with larger effect sizes) compared to plots of a single mycorrhizal type but the performance did not change with species richness. The effect sizes on predation were positive in the EcM plots and the effect strengthened with tree species richness. In contrast, the effect sizes were negative on soil fauna activity across all mycorrhizal types but only limited to deeper layers. We found significant correlations between herbivory and predation rates in AM plots that were, however, dependent on tree species richness and specific herbivory and predation types. Overall, our study showed that tree communities with both mycorrhizal types efficiently reduced herbivory damages, and higher tree species richness was beneficial for predators. Multi-trophic relationships were shaped by mycorrhizal types and tree species richness. Our results point to the importance of biotic interactions in trees for ecosystem functioning and contribute to broaden the mechanistic understanding of BEF relationships in trees.

POSTER

The avstracts are sorted by topic and within topics alphabetically by first author.

Topic 1: Ecosystem responses to landuse change

Measurement of short-term changes in CO_2 fluxes and storage on a heterogeneous cropland with diluted topsoil by a novel robotic chamber system

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The 4 per mille initiative has intensified the search for management options that ensure an increased and permanent storage of atmospheric CO_2 in cropland soils. The ameliorative tech-nique"fractional deep tillage" (aFDT) probably represents one of the few ways by which the 4p1000 goals might be achieved. The basic principle of aFDT is based on the initiation of a disequilibrium in soils C cycling: (i) C undersaturation in topsoils by an admixture of C-poor subsoil, and (ii) a simultaneous burial of topsoil material in subsoils. Due to the high small-scale variability of many croplands, e.g. induced by erosion, it is very difficult to precisely quantify the short-term effects of subsoil amendments on the dynamics of CO_2 exchange and SOC stocks in topsoils. To solve this problem, we developed a new approach consisting of the combination of a multifactorial small plot field experiment with a novel robotic chamber sys-tem for measuring CO_2 fluxes.

Its use take place on a strongly erosion affected cropland area of NE Germany (Uckermark region, 53° 23' N, 13° 47' E; ~50-60 m a.s.l), called CarboZALF-D. The field experiment consist of 36 measurement plots, of which each 12 covered one out of three erosion induced soil types; Calcic Luvisol (non-eroded), Nudiargic Luvisol (strongly eroded) and Calcaric Regosol (extremely eroded). In July 2020, the experiment was set up with 3 manipulative and three control plots per soil type. Topsoil dilution was simulated by removing the upper 6cm of the topsoil layer adding/mixing equivalent weight of subsoil into it.

The new robotic chamber system (length of 110 m, width of 16 m and height of 5 m) covers the entire field experiment. The system is comprised of a gantry crane mounted on two tracks transporting multiple gas and other sensors and two transparent closed chambers over all plots. The CO_2 fluxes were measured using the chambers according to a predefined but modifiable sequence continuously on all plots. C in aboveground phytomass was measured by weekly sampling on a nearby reference site and related to plot measurements of CO_2 through spectral reflectance measurements.

Here, we present first results on the effect of soil type and topsoil dilution on CO_2 and C ex-change of winter rye (one crop growth period). Our results show differences in cumulated ecosystem respiration, (Reco), gross primary production (GPP), and net ecosystem exchange (NEE) fluxes between the non-diluted and diluted topsoil treatments, and these differences are visible across all three soil types. Compared to the non-diluted topsoil, treatments with diluted topsoil showed a lower development of aboveground phytomass due to reduced soil fertility, leading to lower cumulated Reco, GPP, and lower spectral reflectance. Besides, the average of cumulated net ecosystem exchange is lower for diluted topsoil compared to the non-diluted topsoil and these differences are visible across all three soil types.

Topic 1: Ecosystem responses to landuse change

The Global Restore Project: A metacommunity approach to ecological restoration synthesis

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Ecological restoration has rapidly evolved from a local action taking place on an ad-hoc, site-by-site basis, to a major component of the United Nations Sustainable Development Goals, with the 'Decade on Ecosystem Restoration' announced to begin this year. Hundreds of millions of hectares of land are to be restored with billions of dollars spent. However, restoration outcomes are notoriously unpredictable making reliably meeting goals difficult. Setting and meeting these goals may be especially difficult when they focus on biodiversity. This difficulty may arise because compositional re-organization of ecological communities due to global change pressures interact metacommunity processes across space and time, which are also affected by anthropogenic disturbance. The paths to efficiently and effectively manage for or accelerate biodiversity recovery after anthropogenic disturbance and degradation remain unclear. We present the Global Restore Project (GRP) (globalrestoreproject.com), and point to how this project will help us to advance knowledge sharing for shared success in the United Nations Decade on Ecosystem Restoration. We highlight our metacommunity approach to synthesis and explain how this approach will help us to better understand and predict restoration outcomes and possibly plan restoration actions to better benefit biodiversity and people.

What effects does insect decline have on the microbiome of the oak clone DF159?

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Invertebrates deliver a vast variety of ecosystems services that regulate the functioning of ecosystems. In recent years, the biomass of flying insects decreased dramatically in Germany and the consequences are not yet known. The project Insect Armageddon tried to produce a realistic insight into possible effects of insect decline on plant biomass, diversity, nutrient availability and cycling and soil microbes. Within this project, insect decline was simulated with three levels of flying insect biomass (100%, 25%, 0 % insect abundance as of 2018) in EcoUnits of the iDiv Ecotron, to analyse effects on grassland ecosystems. Each EcoUnit also contained one oak of the *Quercus robur* clone DF159 taken as a phytometer. Here we report of the treatment effects on this phytometer.

Transcriptomes of oak leaves were analysed to investigate whether the oak responds to the insect treatments by induction of the expression of herbivory related genes. For this purpose, we used quantitative reverse transcriptase PCR with primers annealing on genes involved in jasmonate biosynthesis, volatile production and general defense response. While sampling, we did not observe any significant damage in the leaves of the oaks. Therefore we also did not expect any strong changes in gene expression levels, since these genes are induced upon leaf damage by herbivores. Indeed, none of the investigated genes were differentially expressed, confirming that the oak phytometer was not subject to herbivory at either insect abundances.

Microorganisms have a pivotal role in ecosystem functioning and for holobiont adaptation to environmental changes. For getting insights on effects of insect decline on the microbiome associated to the oaks, samples from rhizosphere, roots and leaves were taken to assess bacteria and fungi by next generation amplicon sequencing targeting 16S rRNA genes for bacteria and ITS2 regions for fungi. We expected to see differences in microbial community compositions due to effects of insect decline, for example on nutrient cycling. The microbial alpha-diversity was not affected by the insect abundance. However, the community compositions was shifted in the insect abundance levels, with fungi being more sensitive to the treatments than bacteria. While most microbial taxa were present in all treatments, we also found specific fungi and bacteria in each of the three insect abundance levels. Leaf microbial communities differed from the ones in roots and rhizosphere and did not respond to insect abundance, which concurs with the lack of herbivory response. Rhizosphere and roots contained similar microbial communities, and showed changes in species and functional identity along the insect abundance gradient.

Our results show, that the manipulated insect decline had no effect on oaks aboveground, neither at gene expression nor at the microbiome level, which was consistent with to the non-detection of herbivory damages. Belowground however, the oak microbiome did shift, suggesting an indirect effect of insect abundance through soil processes.

Topic 1: Ecosystem responses to landuse change

MyDiv: The role of mycorrhiza in tree diversity effects on ecosystem functioning and trophic interactions – An experimental platform

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The positive relationship between biodiversity and ecosystem functioning is often attributed to complementarity among functional traits between different species, thereby e.g., increasing nutrient uptake. Mycorrhizae play an important role in plant nutrient and water uptake from soil and, consequently, in nutrient cycling of the whole system. Ectomycorrhiza and arbuscular mycorrhiza are characterised by fundamentally different strategies. It has often been found that in plant communities with highly diverse mycorrhizae the utilisation of soil nutrients is more efficient as compared to less diverse ones. Moreover, from a trophic perspective, mycorrhizal fungi serve as food source for fungal feeding soil fauna and, therefore, contribute substantially to carbon flow between trophic levels. However, the roles of the two major mycorrhizal types within the soil food web are still poorly understood. The iDiv platform MyDiv aims to study the influence of a crucial biotic interaction – mycorrhizal association – on the relationship between tree diversity and ecosystem functioning. The experiment focuses on the following main hypotheses: (I) AM fungi and EM fungi are a source of functional complementarity between different tree species. (II) Diverse mycorrhizal associations enhance the positive relationship between tree diversity and ecosystem functioning. (III) Tree communities with diverse mycorrhizal associations foster more diverse soil animal communities compared to communities of only one mycorrhizal type.

Topic 1: Ecosystem responses to landuse change

Reduced tillage in a long-term experiment on Loess soil in Switzerland

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Reduced tillage has proven positive effects on topsoil carbon storage and consequently for the protection against erosion compared to conventional ploughing. However, in organic farming, crop management in systems with reduced tillage has to be improved to close the yield gap which still exists between reduced tilled and conventionally ploughed systems (Krauss et al., 2021). A field trial was set up 2010 on the organic farm Schlatthof, Aesch BL, Switzerland (47.48, 7.58; 349 m asl; 785 mm, 9.6°C) for the further development of organic arable farming in the area of reduced tillage. The focus of the experiment is on the interaction between tillage and the type of fertilization as well as the fertilization level. Fertilization with easily soluble mineral fertilizers is integrated as a fertilization treatment to find out if there is an interaction between tillage and fertilizer type. The soil type is a Luvisol with a silty loam texture. The design is a hierarchical design with tillage as main plot and fertilization as subplot with four replicates. The experiment is still ongoing. The tillage treatments are conventional tillage (annual ploughing, approx. 20 cm deep, CT) versus reduced tillage (chisel ploughing with occasional use of a skim plough for ley termination, approx. 10 cm deep, RT). The fertilization treatments are slurry versus mineral fertilizer on two levels each and no fertilizer. The crop rotation includes silage maize – faba bean – winter wheat – and two years of grass clover. Soil organic carbon (SOC) and soil microbial biomass carbon (Cmic; both 0-10 cm and 10-20 cm; every three years) and crop yields were measured from 2010 to spring 2019. The mean yield over nine years was about 5 % reduced with RT compared to CT. The range was from minus 14 % for grass clover in 2014 to plus 5 % for faba beans in 2016. In the other years and crops, there was an average yield reduction of 4 % to 6 % in RT compared to CT. We found no significant interaction between tillage and fertilization. Fertilization had a significant effect on yields in three years only. For SOC, it took nine years for a significant effect to become evident. The tendency for SOC at RT to increase in the 0-10 cm layer and decrease in the 10-20 cm layer compared to CT was already found in 2012. The difference in the 0-10 cm layer became significant in 2019, while the difference in the 10-20 cm layer did not. Fertilization did not have a significant effect on SOC in any stratum and there was no significant interaction. Cmic showed a tendency to increase in the 0-10 cm layer and decrease in the 10-20 cm layer in RT compared to CT although not significant yet. In conclusion, RT largely works in this location as the yield losses are low. The development of SOC and Cmic should be observed further. Measurements of the degree of siltation, which is possibly reduced by the concentration of SOC at the surface, would be an interesting task for the future.

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Soil respiration and CO_2 efflux of the soil surface in response to farming methods – current results from the long-term experiments “IOSDV”

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Soil respiration is a process that describes the release of CO_2 emitted by microorganisms and by plant roots. The CO_2 released in this way plays a major role in balancing the carbon budget of soils covered with vegetation. It has been shown that soil respiration depends, among others, on soil temperature, soil aeration and plant root activity. In addition, certain farming methods can also influence the activity of microorganisms in the soil and thus also the release of CO_2.

Therefore, the aim of the investigations was to clarify the influence of different farming methods on soil respiration and soil CO_2 efflux based on the long-term experiments "International Organic Nitrogen Fertilisation Trial" (IOSDV) at the sites in Rauischholzhausen (RH) (JLU Gießen) and Speyer (LUFA Speyer).

The trials include the variants organic fertilisation (control, farmyard manure, straw/catch crop/digestate), compost (only in RH) and soil tillage (only in Speyer) in combination with N fertilisation (N0, N+). The soil respiration measurements (SIR method) were carried out using the multi-channel system EGA 61 (ADC) with soil samples taken at 0-15 and 15-30 cm and CO_2 efflux of the soil surface was measured with the mobile device Licor-870.

The results of the respiration measurements show an influence of soil depth (higher respiration in 0-15 cm compared to 15-30 cm), soil type/site (higher values in RH compared to Speyer) and organic fertilisation (FYM, straw/catch crops). The C-efflux measurements (only in RH) mainly illustrate an influence of organic fertilisation (including compost). There was also a tendency for soil tillage and mineral N fertilisation to influence soil respiration.

Topic 1: Ecosystem responses to landuse change

Sensitivity of soil eco-physiological indicators to mirror plant-microbial interactions under monoculture of *Zea mays* L.

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Soil functioning and sustaining soil fertility is governed largely by the decomposition activity of the microorganisms, and therefore is often monitored by microbial-based indicators. Distinct soil microenvironments caused by different soil texture can induce highly variable microbial activity and functioning. The objective of our study was 1) to assess the effect of soil texture (sandy & loamy) on the microbial respiration, growth and biomass in a seasonal and annual dynamics and 2) to analyze how microbial eco-physiological indicators are influenced by soil depth and plant genotype. Bulk soil samples were taken at three growth stages (BBCH_14, BBCH_19, and BBCH_59) within one season and at the BBCH_19 stage within three years. Microbial specific growth rate (µmax) was generally 35-50% higher in loamy vs sandy soil. Basal respiration was unaffected by the soil substrates, however, specific respiration standardized by soil C content was up 1-2 times greater in sandy versus loamy soil. Microbial biomass carbon was more than 2 times higher in the loamy vs sandy soil. Soil effect on microbial biomass increased in the course of vegetation season and was 25% higher in loamy vs sandy soil at the BBCH_59 stage. Depth effect was only pronounced in the sandy soil. Generally, the sensitivity of eco-physiological indicators (C_{mic}/C_{org}, C_{basal}/C_{mic}) was mainly governed by soil texture followed by the sampling year and depth. This work was conducted within the framework of the priority program 2089 “Rhizosphere spatiotemporal organization – a key to rhizosphere functions”, funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – Project number: 403664478. Seeds of the maize were provided by Caroline Marcon and Frank Hochholdinger (University of Bonn).

Topic 1: Ecosystem responses to landuse change

Max Maercker - outstanding agricultural chemist and founder of the Bad Lauchstädt Agricultural Research Centre

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Max Maercker was born in Calbe on October 25th, 1842. He grew up in Halberstadt, where he finished high school in 1861. Then he studied chemistry in Greifswald and Tübingen. In 1864 he received his doctorate in Greifswald. Afterwards he was a scientific assistant at the agricultural experimental stations in Braunschweig and Göttingen-Weende. In 1871 Maercker was appointed head of the "Experimental Station of the Agricultural Central Association of the Province of Saxony in Halle-Saale". For three decades he was a pioneering researcher and teacher in the field of agricultural chemistry. From 1872 on he also worked as an associate professor for agricultural chemistry and physiological chemistry at the Agricultural Institute of the University of Halle. In 1892 he was appointed full professor. During his thirty years of activity, he developed the experimental station in Halle into one of the most important agricultural research facilities in Germany. Inspired by a trip to North America, he founded the Bad Lauchstädt experimental farm on October 1st, 1895.

His merits:

- Numerous variety and fertilisation experiments (e.g. Thomas slag as P-fertiliser, use of potash salts, treatment and application of manure, humus-forming effect of straw). His fertilisation recommendations for important crops, derived from field experiments, have become trend-setting for agricultural fertilisation practice. He carried out a field experiment on manure fertilisation for several years, which is regarded as a precursor of the Static Fertilisation Experiment.
- Great merits in experimental work (improved the methodology and organisation of field experiments, introduced repetition in field experiments and set up experimental series at different locations, established the 4 stages of agricultural research: laboratory experiment - pot experiment - field experiment - practical experiment). He saw the field experiment as an irreplaceable means in the process of finding knowledge up to the transfer of knowledge into practice.
- Great connection to practice: New findings in agricultural chemistry put to practical use, first investigation of the variety-specific baking capability of wheat, great commitment to the processing industry (production of spirit, discovery and introduction of beet pulp as a valuable animal feed, development of a starch scale), 30 years of scientific activity with 450 publications and over 1000 lectures to agricultural associations - gifted speaker and teacher, close cooperation with practice as "give and take".

Maercker has received wide recognition as a researcher, teacher and consultant. He was a member of the Leopoldina Academy of Natural Scientists in Halle and the Royal Society of Sciences in London. He died on October 19th, 1901 and is buried at the Stadtgottesacker in Halle. In 1904 a memorial stone was erected on the experimental field in Bad Lauchstädt. It can still be visited. The static fertilisation experiment for which he created the foundations still exists today. With its continued conservation and intensive use we still honour Max Maercker.

Topic 1: Ecosystem responses to landuse change

125 years of agricultural and environmental research Bad Lauchstädt: The history of the experimental station

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Max Maercker expressed the view that an agrochemical experimental station would have to be linked to an agricultural farm in order to test the research results in practice. A visit to experimental farms in North America more strengthened this opinion. The farmer Max von Zimmermann provided 50 hectares of arable land, so that Max Maercker was able to establish the Bad Lauchstädt experimental station on October 1st, 1895. The experimental programme was comprised of four focus areas: fertilisation and variety trials, treatment and effect of different stable manure and green manure, feeding trials. In 1902, Schneidewind and Gröbler set up the Static Fertilisation Experiment, which is one of the oldest and most important long-term field experiments in the world today. This was followed by an eventful history with meticulous agricultural research even during the two world wars. In 1953 the institution was taken over by the German Academy of Agricultural Sciences in Berlin. In 1966 the institute became the leading institute for field trials. A coordination office for field trials was established. In 1970 the research institute was incorporated into the Müncheberg Research Centre for Soil Fertility. The main focus of research was the quantification of the soil's demand for organic matter and its influence on soil fertility and yield. Scientists from different disciplines worked on this on the basis of long-term experiments and supplementary laboratory, pot, model and field experiments. Investigations on the conversion of soil organic matter as a function of soil temperature, moisture, density and texture became important. First models for C- and N-mineralization were developed. The results of the long term experiments were particularly suitable for the verification of the model algorithms.

After the collapse of the GDR in 1989, the Academy of Agricultural Sciences was closed on December 31st, 1991 and with it the Bad Lauchstädt site. On December 12th, 1991 the UFZ-Environmental Research Centre Leipzig-Halle GmbH was founded. The sections Soil Research, Community Ecology and Hydrogeology settled in Bad Lauchstädt until they moved to Halle in 1998. The experimental field was used jointly with the University and the State Variety Testing Department. Today, 11 UFZ employees work at the experimental station, supervising the 42 ha large experimental field and the pot experiments. Much has been invested in new buildings, agricultural machinery and experimental platforms (lysimeter, climate experiment GCEF), so that the site provides the infrastructural basis for the scale-dependent investigation of different ecological systems. This allows the simulation of influencing variables resulting from land use change, climatic changes and changes in species pools.

In 2012, the German Centre for Integrative Biodiversity Research (iDiv) was founded with the participation of the UFZ. In Bad Lauchstädt, it maintains field experiments that are part of global networks and, since 2017, the research platform iDiv Ecotron, with which the influence of multitrophic biodiversity manipulations on ecosystem functions can be investigated under controlled environmental conditions.

Topic 1: Ecosystem responses to landuse change

Influence of different biochars on some enzymatic activities of a calcareous sandy soil

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The present study investigated the effects of rice husk (RH) and sugarcane bagasse (SB) biochars on some chemical properties and enzymatic activities involved in carbon and phosphorus cycling of a calcareous sandy soil (control, U) after two (T2), four (T4), eight (T8), and twelve (T12) months incubation. For this purpose, the experiment was conducted as a factorial experiment in a randomized complete block design with four replications and two treatments (RH and SB). Organic amendments were added to soil in three quantity levels (w/w): L1= 1.25%, L2= 2.5% and L3= 5%. The results showed that soil organic carbon (SOC) values ($p < 0.001$) were significantly affected by the types of organic amendments, their application rate and incubation time. The level of organic amendments (96.6%) had the greatest effect on the amount of organic carbon in sandy soils treated with SB and RH biochars. The highest and lowest SOC values were observed in SBL3T2 (3.5%) and RHL1T12 (0.7%) (After the U treatment) treatments. The trend of changes in SOC and total nitrogen (TN) were similar, increasing with the quantity levels (L1 < L2 < L3) and decreasing with incubation time (T2 > T4 > T8 > T12). The SBL1T2 had the lowest content of available phosphorus after the U treatment, which were 39.1% lower than that of RHL3T12 (treatment with the highest content of available phosphorus). The treatments of RHL2T12 (0.99 µgPNP.gr^{-1}h^{-1}) and SBL1T2 (0.46 µgPNP.gr^{-1}h^{-1}) were characterized by the highest and the lowest activity of β-glucosidase. The RHL3T8 and SBL1T2 treatments exhibited the highest (590.6 µg Glu.g^{-1}3h^{-1}) and the lowest (101 µg Glu.g^{-1}3h^{-1}) invertase activity, respectively, whereas, it was the highest in T8. Also, the RHL3T12 and SBL2T12 treatments had the highest activity of alkaline (26.1 µg PNP g^{-1}h^{-1}) and acid phosphatases activity (8.5 µg PNP g^{-1}h^{-1}). Regarding the high pH of used biochars and their relatively alkaline nature, soil pH has increased after their addition to the soil. As a result, soil pH has increased alkaline phosphatase activity and decreased acid phosphatase activity at high levels of biochar application. In general, the addition of biochars with good quality to the soil can be a very good source of compensation for soil organic carbon deficiency because of its high carbon content, thereby improving chemical and biochemical properties and maintaining soil health. Therefore, based on the effects of SB and RH on the increasing SOC content as well as enzymatic activities, these organic amendments are suggested to improve the quality of calcareous sandy soils.

Topic 1: Ecosystem responses to landuse change

Effects of heavy metals on crop quality and soil microbiome health under different fertilization regimes.

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The rapidly increasing population on our planet and its developing wealth make it necessary to rethink current food production, as demand for agricultural products is predicted to increase by 15% in the next decade alone. Agricultural productivity is inextricably linked to soil health, which is currently degraded on an unprecedented scale, e.g. through widespread and still ongoing contamination with heavy metals. Because of their adverse impacts on metabolisms, heavy metals pose a serious threat to crop production and the entire soil ecosystem functioning. A diverse and well-functioning soil microbiome is essential for supporting plant performance because of its role in plant nutrient uptake, resistance to pathogens, or tolerance to environmental stress. Perversely, state of the art fertilizer- and pesticide-intensive agriculture has become one of the main anthropogenic sources of noxious heavy metals in soil, along with partly legacy and partly ongoing industry and mining. Although both mineral and organic fertilizers can contain heavy metals, the application of the latter contributes to an increase in adsorption capacity of soil, formation of organic matter-heavy metal complexes and prevents a decrease in soil pH. Under these conditions, metals are less mobile and therefore less bioavailable to crops and soil organisms.

We postulate that organic fertilizer application may support crops and soil microbiomes, by altering the biogeochemical properties of the soil in such a way that heavy metals partition more toward soil solids than solution. We investigated the effects of different long-term fertilization regimes (mineral, organic and combined mineral and organic fertilization), carried out for more than a century in the Bad Lauchstädt Static Fertilization Experiment on the levels of heavy metals in winter wheat grains. Moreover, soil from the Static Fertilization Experiment was incubated with two heavy metal contents (background and elevated) to test whether the tolerance of the soil microbiome to heavy metal inputs varies with agricultural practices.

Preliminary results indicate that the addition of heavy metals had no effect on the rate of microbial respiration, regardless of the fertilization used. Hydrolytic enzymes activities were slightly increased by heavy metal addition, except for organically fertilized soil where the opposite effect was observed. Additionally, we will provide data on dynamics on bioavailable heavy metals, redox properties, nutrients dynamics, microbial abundance and diversity in soil. By combining geochemical and microbiological techniques, it will be possible to determine how fertilization practices affects the dynamics of soil microbial communities and affiliated ecosystem processes upon heavy metal contamination.

Topic 1: Ecosystem responses to landuse change

Biofortified and climate-resilient food and fodder production on marginal soils

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By 2050 the world's population will exceed 9 billion, so food production needs to increase by 70-85% (Dhankher & Foyer 2018). Available arable land is limited in Europe, thus to include idle and marginal land in agricultural production is crucial (Schröder et al 2018). Another frontier is to supply high quality food and feed to increase the nutrient density, including micronutrients such as sellenium, iodine of staple crops. In line with the decreasing productivity of arable soils and progressing climate change, the BioFoodOnMars projectdevelop new strategies to increase the amount and quality of food and feed crops in Europe leading to sustainable growth of plant production and improved climate change resilience of agroecosystems.

This project aims at mapping potential crop yields and the valorization opportunities on marginal soils under various regional conditions in Europe and trying to optimize the biomass production and valorization with biofertilizers or soil additives, like silicon, or management changes like remote sensing and digitalization.

The BioFoodOnMars plans to activate idle and marginal land for food and non-food crops. High amounts of quality biomass can be produced on marginal soils by improving their physico-chemical properties using amendments made from agricultural by-products and biofortification of food/fodder crops (e.g. Se). In addition, silicon fertilization will increase the resistance of crops to biotic/abiotic stresses and plant resilience to climate change. Improving plant water use efficiency, resilience to disease and pests, and biodiversity will reduce agrochemical use in crop production. The project includes the management of agricultural by-products, e.g. by transformation into biogas and energy recovery, and producing organic amendments usable to improve marginal soil properties. This will contribute to reduce atmospheric CO_2 emissions, promoting lower C footprints.

A toolbox addressing resilient agrosystems allowing sustainable intensification of agriculture under increasing stress of climate change, new pests and disease outbreaks and other environmental pressures and preserving biodiversity and ecosystem services will be the end-product.

Keywords: marginal soil, silicon, selenium, staple crops, soil amendments

Topic 1: Ecosystem responses to landuse change

Heat emission from High Voltage Direct Current (HVDC) underground cables affect soils and crops - Results from an innovative greenhouse trial

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The "energy transition" decided in 2011 towards more renewable energies is forcing an appropriate grid expansion. Electricity produced in northern Germany is mainly consumed in southern Germany. Due to local protests of citizens regarding environmental concerns, visual disruption, expected economic losses e.g., underground cables are increasingly demanded. The German Federal Network Agency (BNetzA) labeled 3.386 km new power line projects as underground cables. However, only little is known about the effect of long-term heat emission from a HVDC underground cable on the water balance and temperature of the overlaying soil, on root growth, plant development and yield. To clarify the questions, a pilot project was initiated at the Martin-Luther-University in Halle-Wittenberg to particularly examen potential heat flow effects from the planned Suedostlink, a 525kV HVDC power line traversing Saxony-Anhalt. 24 soil monoliths (SM) with a diameter of 50 cm and a height of 140 cm were constructed. Natural top- and subsoils extracted on two different sites along the planned HVDC line were installed taking the typical dry bulk density into account. One part of the SMs were heated on the bottom to simulate the heat emission of an HVDC cable the others served as control. Furthermore, three different annual precipitations were simulated with dry, average and wet years. The study was designed as a three-factor experiment with treatment, precipitation and soil as factors and two replications. It was conducted under controlled climate conditions in the greenhouse. A crop rotation consisting of spring barley, sugar beets and spring wheat was cultivated over three cultivation phases. During the trial water content and temperature of the SMs were constantly measured in three depths. Root intensity for each SM was calculated in a range of 22-53 and 71-101 cm below ground. Dry weight of the crop yields was determined and compared. The results show crop-specific differences in yield and root growth, partly dependent on the soil type and the position in the crop rotation.

Topic 2: Climate change impacts

The TrophinOak - PhytOakmeter platform

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TrophinOak and PhytOakMeter focus on biotic and abiotic interactions with the in vitro propagated clonal Oak tree DF159 (Quercus robur L.) under laboratory and field conditions, respectively.

With the TrophinOak platform, we first studied the impact of detrimental and beneficial interactions using collembola, caterpillars, nematodes, fungal mutualists and parasites. Transcriptomic and metagenomic analyses were coupled with growth traits and C/N allocation analyses in order to better understand how the endogenous rhythmic growth displayed by this major forest tree interplays with its complex multitrophic interactions. Four projects were run on this TrophinOak platform. The DFG project TrophinOak itself was complemented with two iDiv Flexpool projects “Mycorrhizal interactions of different fungi with oak trees” and “PlastOak” and a Marie curie EU grant “OakMykEvo”.

From 2010 on, DF159 clonal saplings were released in the field as phytometers in two time series over 10 Years on sandy and chernozem soils, respectively. The PhytOakmeter platform also includes sites selected along a European climate gradient from Finland to Southern France. To tackle the influence of water relations, they also included a precipitation gradient along the central German TERENO sites in Saxony Anhalt. Modifications in soil microbial community composition under the influence of the oak clone were studied in 2018 using amplicon sequencing. The data were related to oak growth traits, but also to climatic and edaphic variables. The presented Oak platform is an ideal tool to study acclimation and adaptation of a long-lived forest tree to ecological variations and climate changes in the near future.

Topic 2: Climate change impacts

Drought effects on microbial communities: A Mediterranean-forest experiment from Soil For Europe project.

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The Mediterranean forest is predicted to be one of the most affected ecosystems due to future climate conditions. With the temperatures rise, water stress increases, and precipitation decrease, in turn creating multiple responses from the soil Mediterranean-forest ecosystems. The increasing recondition of the microbial communities to support trees under stress conditions, advocate to evaluate the effects of drought in microbial communities associate to Mediterranean forest. Within the project SoilForEurope, the Montpellier European Ecotron facility offered an experimental setup in large mesocosms allowing to simulate realistic conditions in soil monoliths (1m^2, 1m depth) along two years experiment to test recurrent severe droughts on forest understory. Therefore, microbial DNA was extracted from 95 soil samples of the upper 10 cm soil layer. PCR-based amplicon libraries were produced using taxon specific primers sets (16S) and pair-end sequenced utilizing the Illumina MiSeq NGS platform. Sequence datasets were then analyzed by Dadasnake pipeline, and the respective taxonomic and functional groups were determined with reference databases. Results do not suggest a significant difference at bacterial diversity level between the drought and control treatments. However, diversity differ across the time, between the before and after drought periods. Bacterial community composition reveal that at the second year of the experiment, the bacterial communities are more homogenous among them and significant different from the first year communities. We found abundances varies mainly in the phyla Proteobacteria, Chloroflexi and Actinobacteriota. This results showing changes in the structure and composition of bacterial-tree related communities shows the responsible microorganism to held Mediterranean forest to face future stress conditions.

Topic 2: Climate change impacts

Functional traits in a reciprocal translocation experiment

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Warming of mountain regions is projected to be three times faster than the global average likely affecting ecosystem resilience and functioning. In recent years, plant functional traits have become the common currency to measure functional diversity. Yet, little is known how functional traits of grassland communities will change under altered climatic conditions. Here, we have translocated intact plant soil mesocosms from two mountain habitats downslope to simulate their potential local future climate (warming and drought). Moreover, we have translocated mesocosms of low land plant communities upslope to simulate the upward expansion of species distribution. Preliminary results indicate an increase in functional richness, no matter if plant communities have been moved down- or upslope. Underlying drivers of increasing functional richness (occupied traitspace) are likely species turnover under warming and species plasticity under cooling.

Topic 2: Climate change impacts

Water deficit impaires growth and carbon uptake but the proportion of newly assimilated carbon transferred to the rhizosphere is sustained

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Tree species are suffering worldwide from extended periods of drought due to, for example, warmer temperatures which increase soil evaporation and plant transpiration. These conditions do not only affect growth and vitality of trees but also feed back on the cycling of carbon at the plant-soil interface.

In September 2019, we established a mesocosm experiment to mechanistically understand how interactions between plants and soil biotic and abiotic resources are altered on a seasonal basis due to prolonged water deficit. The mesocosms consist of young Scots pine (*Pinus sylvestris* L.) trees established in soil collected from a naturally dry forest in the Rhone valley of Switzerland; and were exposed to three different levels of water limitation, i.e., control (sufficient water), intermediate water deficit (40% reduction), and severe water deficit (75% reduction). One year after the start of the experiment a $^{13}CO_2$ pulse labelling was conducted to trace photosynthetic assimilates into above- and belowground carbon pools (including needles, roots, soil pore CO_2, phospholipid fatty acids of soil microbial groups).

We observed that the aboveground growth of trees was more strongly and rapidly impaired by water limiting conditions as compared to belowground growth, increasing the partitioning of plant biomass towards fine roots. Severe soil moisture deficit decreased plant carbon uptake and the velocity of carbon allocation from needles to fine roots. Yet, more ^{13}C was allocated to the root systems of trees exposed to water limiting conditions, and the proportion of recently assimilated carbon translocated to fungi remained sustained under both drought treatments. These findings indicate that even when plant growth is constrained by lack of water, newly assimilated carbon continues to be transferred to roots and the rhizosphere.

Topic 4: Context dependencies and interactions among drivers

Water deficit history selects plant beneficial bacteria under conventional farming

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Water deficit is critical for plant fitness and survival, especially when successive drought events happen. Specific soil microorganisms are able to improve plant tolerance to stress. Microorganisms adapted to dry conditions can be selected by plants over time because of properties such as sporulation, substrate preference or cell-wall thickness. However, the complexity and interconnection between abiotic factors, like drought or soil management, and biotic factors, like plant species identity, make it difficult to elucidate general selection processes of such microorganisms. Using a pot experiment in which wheat and barley were grown on conventional and organic farming soils from the experimental platform Global Change Experimental Facility (GCEF), we determined the effect of water deficit history on soil microorganisms by comparing single and successive events of water limitation. We analyzed the total microbial community (16S rRNA genes) as well as the 1-aminocyclopropane-1-carboxylate (ACC) deaminase positive (acdS+) microorganisms, known for their beneficial effect on plants under drought stress. Rhizosphere and in bare soil were analyzed using Illumina sequencing and qPCR. The analysis showed that plant presence or identity, farming practices and water deficit strongly impact the composition of both the total microbial community and the acdS+ microorganisms. In contrast, recurrent dry conditions only moderately influence the abundance and diversity of both communities compared to a single dry event. Finally, we identified an interactive effect of the farming system and the soil conditioning to water deficit. Indeed, possibly due to a better nutrient status, plants grown on soils from conventional farming showed a higher growth and were able to select more adapted microbial taxa. Some of them were already known for their plant-beneficial properties like the Actinobacteria Streptomyces, but interestingly, some Proteobacteria were also enriched after successive water deficit events in soils from conventional farming. Our approach allowed us to identify key microbial taxa promoting drought adaptation, thus improving our understanding of drought effects on plant-microbe interactions.

Topic 4: Context dependencies and interactions among drivers

Climate change impacts on agroclimatic indicators for Long-Term Field Experiment sites

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Long-Term Field Experiments (LTEs) are critical agricultural infrastructures implemented to evaluate the long-term effects of various management practices (tillage, fertilization and crop rotation) under stable conditions. Since the proposed climate change is expected to affect existing conditions, the impacts of these changes on these experiments are largely unknown. Our study aimed to examine the effects of climate change on LTEs in Germany by utilizing the climate variables (temperature, precipitation) and agroclimatic indicators (drought, consecutive dry days, growing degree days, etc.) to compare a baseline (1971-2000) with future periods (2021-2100). A framework is presented to combine spatially distributed climate data, LTE locations and metadata acquired from a web-based repository to identify the possible climatic changes at German LTE sites with >20 years of duration under the IPCC's Shared Socio-economic Pathway (SSP) scenarios. The LTEs (n=247) were classified into two main categories as management (fertilization, tillage, crop rotation) and land use (field crops, grassland). Over 140 LTEs were predicted to shift from humid to semi-arid conditions in Germany. Frost days in LTE showed a decrease by up to -60 days, whereas the length of growing days in the vegetation period is expected to increase by 90% under the SSP5 scenario by 2100. The outputs of our study are expected to provide an understanding of LTEs to assist the use of experimental data for the continuum of agricultural productivity under climate change.

Topic 4: Context dependencies and interactions among drivers

Soil organic matter composition and CO_2 emissions change seasonally along a gradient of land use intensity and climate

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Ongoing shifts in land use, and the magnitude to which these changes occur, especially the conversion from natural to agricultural areas and land use intensification, may have far reaching consequences for ecosystem processes and functions including changes in the retention and cycling of nutrients and soil organic matter (SOM) turnover within soils. Here we investigate whether seasonal CO_2 evasion flux dynamics are impacted by the changes in SOM content and composition considering a future climatic scenario. We analyzed SOM composition, microbial respiration and CO_2 emission fluxes in five specific land-use types (organic cropland, conventional cropland, intensive meadow, extensive meadow and extensive pasture) under ambient and future climate scenarios across seasons in the Global Change Experimental Facility. Fourier-transformed Infrared (FTIR) analyser was used to assess SOM composition. Additionally, soil CO_2 fluxes and enzyme activities were measured, as indicators of microbial activity and SOM degradation. Distinct changes in SOM composition occurred during the year with more labile compounds like amides in winter and summer towards more stable compounds, like lignin and carboxylic acids, at the end of vegetation season. While SOM composition remained similar between land uses total organic carbon (TOC) content differed between land uses. Shifts in the composition of SOM may be attributed to changes in microbial processing throughout the year and climate treatments. CO_2 fluxes differed between the land uses and climate treatments with highest emissions found in extensive meadow and pasture in future climatic treatments. Finally, soil CO_2 emissions and enzymes were related to soil organic matter content and composition, soil moisture and nutrients which higher emissions related to higher NH_4 concentrations. This study highlights the importance of nutrients along with climatic conditions for soil CO_2 fluxes.

Sensitivity of eco-physiological indicators to seasonal changes as affected by land use

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The activity of microorganisms mediates soil-plant interactions that contribute to soil development through organic matter transformation and nutrient cycling. In turn, soil environment and resources control microbial physiology. Eco-physiological indices such as respiratory-activation quotient (QR) and microbial coefficient (Cmic/Corg) are used as indicators of soil quality because they mirror microbial activity state and quickly respond to soil environmental alterations.

In this study, we aimed to compare the sensitivity of eco-physiological indices to land use and moderate climate (ambient and future) impacts in a long-term field experiment in Bad Lauchstädt, UFZ, Halle, Germany. For this purpose, we monitored the seasonal changes in soil biochemical properties on the plots under contrast land use (Organic Farming, Conventional Farming, Intensive Meadow, Extensive Meadow, and Extensive Pasture) of the Global Change Experimental Facility (GCEF). We determined basal and substrate-induced (SIR) respiration by CO_2 emission, microbial growth parameters by substrate-induced growth respiration (SIGR).

In the wet winter season following the relatively dry summer and autumn, the microbial metabolic coefficient QR was 40% greater in grasslands than in croplands, possibly due to intensive decomposition of plant residues in the former. This was confirmed by a 3 times greater fraction of active microorganisms in the grasslands vs croplands. In contrast, total microbial biomass gradually increased from the winter to the summer season. In general, the QR sensitively mirrored the drought consequences, while total microbial C better indicated seasonal changes, and a distinct land use effect was detected by specific growth rates of soil microorganisms.

Topic 4: Context dependencies and interactions among drivers

Impact of soil microbial diversity on crop productivity and mitigation of drought stress

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Microbial diversity in soil contributes to various ecosystem functions services. Mounting evidence also suggests that soil microbial diversity may contribute to the resistance of ecosystem's functioning to environmental perturbations where soils rich in microbial diversity are expected to be less affected by environmental perturbations than soils which are harboring lesser microbial diversity. However, most of these pieces of evidence originate from non-cropping ecosystems and, therefore, we lack knowledge of how the cropping systems would respond to environmental perturbations. This knowledge gap is particularly important to be filled because cropping systems have distinct intrinsic properties as compared to other terrestrial ecosystems. For this, we investigated how soil microbial diversity will interact with one of the major global climate change factors, that is, drought, in shaping plant fitness with consequences for agricultural productivity. We found a strong negative relationship between soil microbial diversity and plant biomass production indicating a net negative effect of soil microbial diversity on plant fitness, and therefore, crop production. Our results indicate that we cannot simply translate the knowledge gained from other terrestrial ecosystems to cropping systems and pave the foundation for future research to disentangle the feedback mechanisms between crops and soil microbes.

Topic 4: Context dependencies and interactions among drivers

JENATRON: Do shared plant and soil history alter the strength of biodiversity ecosystem functioning relationships?

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Over the last three decades, concern about species loss has motivated many studies that experimentally reduce species richness and examine the consequences for ecosystem functioning. So far, results have shown that there is generally a positive association between plants species richness and ecosystem functioning (BEF). Moreover, the strength of this relationship typically gets stronger over time, which can be seen as enhanced functioning in diverse plots, and reduced functioning in monocultures. In Spring and Summer 2022 the JENATRON experiment will test whether the strengthening BEF relationship over time is driven by soil community assembly, shared plant history, or a combined effect of both factors. JENATRON will be established in the iDiv Ecotron facility using a plant diversity gradient from 1 to 3 species (plus a 6 species-level as high-diversity control) from the Trait Based Experiment of the Jena Experiment factorially crossed with soil history and plant history. Soil History (+/- SH) will be established by excavating intact monoliths from the Trait Based Experiment (+SH) or from bare ground plots (-SH). Plant History (+/- PH) will be established using two seed sources: seeds harvested from plants growing in the Trait Based Experiment for 12 years (+ PH), and original seed material used to set up the Trait Based Experiment (-PH). The independent crossing of soil history and plant history for each level of plant species richness results in the following four treatments in each EcoUnit: (1) "with plant history, with soil history"; (2) "without plant history, with soil history"; (3) "with plant history, without soil history"; and (4) "without plant history, without soil history". Eleven sub-projects of the Jena Experiment Research Unit will work closely together to investigate the independent and interactive effects of plant history and soil history on BEF relationships. Response variables will be measured from many research areas including microbiology, chemical ecology, phenology, proximal sensing, genomics and food web modelling. If soil or plant history alter BEF relationships, an important implication of the results is that novel communities without shared history could be a poor surrogate for long-term conservation.

Topic 4: Context dependencies and interactions among drivers

Climate change and land use influence the phylogenetic and functional diversity of soil nematode

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A large number of studies has shown that both shifts in the number of soil fauna species and the diversity of functions induced by the patterns of climate change and land use are of primary importance for the regulation of ecosystem functioning and services. These research projects have provided considerable insights into the mechanisms underlying the effects on changes in community structure and functions of soil fauna. However, investigations of how the phylogenetic and functional dissimilarity of soil fauna communities are influenced by climate change and the types of land use have been far less numerous, but these dissimilarity analyses have the potential to infer the dynamics of community structure and assembly. Here, we studied the nematodes which are the most abundant metazoa in the soil to examine the effects of interactions between simulated climate change and different types of land use on the phylogenetic and functional alpha and beta diversity in the nematode community across the long term. We currently revealed that especially land-use induced shifts in the diversity and community composition of nematode while the effects of climate effects were weak. Results are also expected to assess the effect of land use on the phylogenetic diversity of nematodes.