Forests in the Anthropocene

Impacts of heat and drought on forest functioning

Friday, 6th October 2023
08:00 – 17:00

Swiss Federal Institute of Technology ETH Zurich
AudiMax (HG F 30)
Rämistrasse 101
8006 Zurich

Keynote Speakers

Prof. Dr. Janneke Hille Ris Lambers
ETH Zurich

Prof. Dr. Jürgen Bauhus
Albert-Ludwigs-University Freiburg

Junior Keynote Speakers

Mauro Hermann
ETH Zurich

Mirela Beloiu Schwenke
ETH Zurich

SFL ScienceDay

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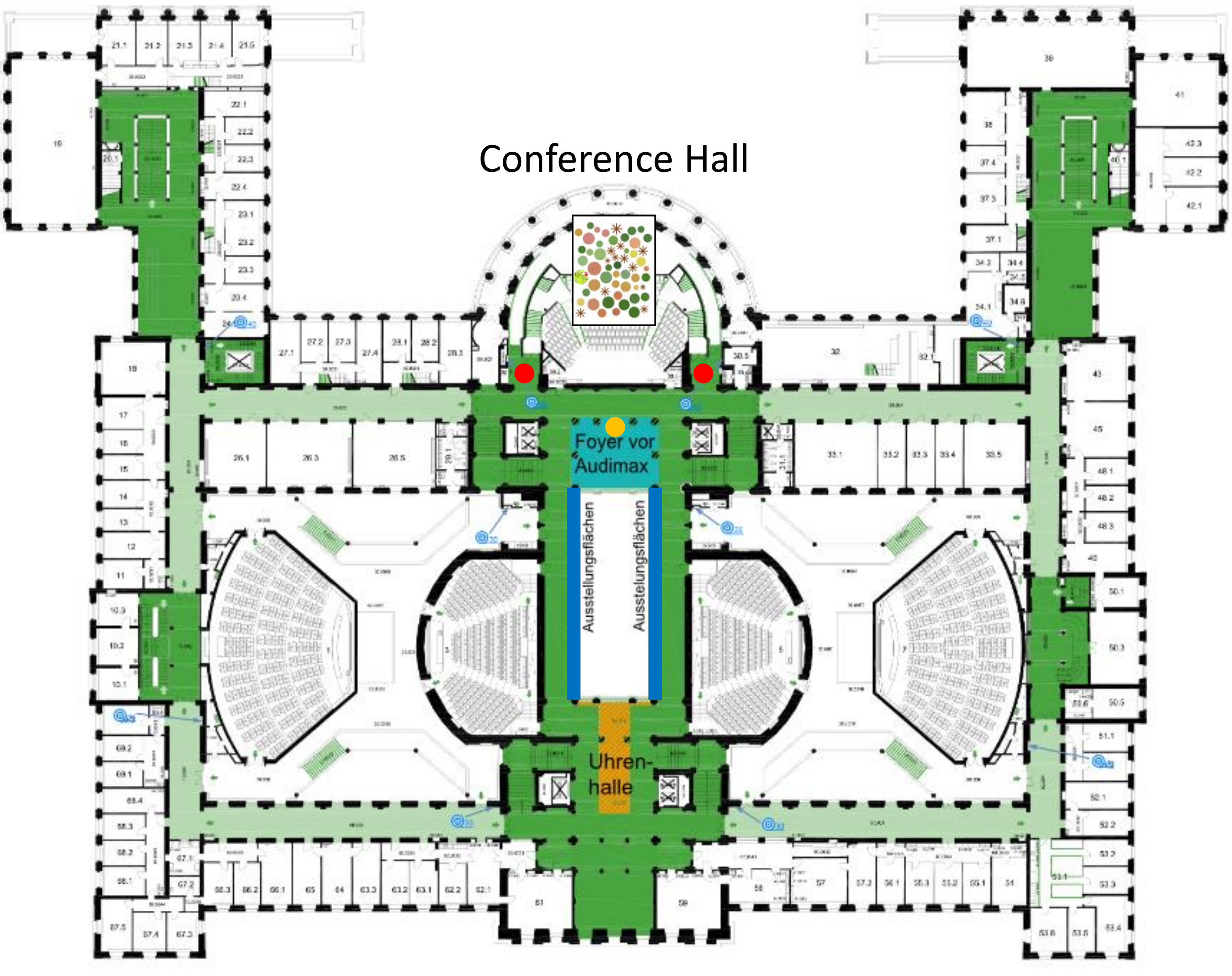
Content

ETH Zürich HG Building F-Floor Floor Plan



- Registration / Apèro
- Entrances
- Poster Sessions

Event Program

08:00 - 09:00	**Registration**		
09:00 - 09:15	**Welcome and opening ceremony**		

Session 1 Chair: Grossiord, Charlotte

09:15 - 09:45	1.0	Hille Ris Lambers, Janneke	**Keynote:** Forest regeneration in a changing world
09:45 - 10:00	1.1	Hermann, Mauro	**Junior Keynote:** Meteorological history of low-forest-greenness events in Europe in 2002-2022
10:00 - 10:15	1.2	Eisenring, Michael	Legacy Effects of an Extreme Drought Event Can Modulate Phytochemical Profile and Leaf Herbivory in European Beech
10:15 - 10:30	1.3	Deluigi, Janisse	The Impact of Tree-tree Interactions on Leaf-level Carbon Exchange Under Heat Vs. Drought Stress
10:30 - 11:00		**Coffee break and poster session** (posters of Session 1 & 2)	
11:00 - 11:15	1.4	Didion-Gency, Margaux	Chronic Warming and Dry Soils Limit Carbon Uptake and Growth Despite a Longer Growing Season in Beech and Oak
11:15 - 11:30	1.5	Marano, Gina	Predisposing and Inciting Stress Factors Leading to Drought-induced Mortality
11:30 - 11:45	1.6	Wang, Songwei	Leaf Minimum Conductance And Residual Water Use In 9 European Tree Species During A Hot Drought
11:45 - 13:15		**Luch Break**	

Session 2 Chair: Gessler, Arthur

13:15 - 13:45	2.0	Bauhus, Jürgen	**Keynote:** Hiking without map and compass? The path to adapting our forests
13:45 - 14:00	2.1	Beliou Schwenke, Mirela	**Junior Keynote:** Tree Species Response to Drought in Temperate Forests: New Monitoring Perspectives
14:00 - 14:15	2.2	Schmidt, Michael	Deep Soil Organic Matter Response to Warming is Depth- and Site-specific
14:15 - 14:30	2.3	Guidi, Claudia	Drought Impacts Soil Carbon Storage Through Changes in Soil Biota – Evidence from a Long-term Irrigation Experiment in a Dry Pine Forest
14:30 - 15:00		**Coffee break**	
15:00 - 15:15	2.4	Mas, Eugenie	Enhanced Water Source Partitioning is Not Enough to Overcome Drought Impacts in Mixed Mediterranean Forests
15:15 - 15:30	2.5	Pistone, Azzura	Unraveling the Demographic History of Abies Spp. By Combining Ancient Pollen Data with Genetic Simulations
15:30 - 15:45	2.6	Diaz-Yanez, Olalla	Tree Migration in Complex Landscapes
16:00 - 17:00		**Apèro and poster session** (posters of Session 1 & 2)	

Oral Presentations

Meteorological history of low-forest-greenness events in Europe in 2002-2022

Mauro Hermann[1)], Matthias Röthlisberger[1)], Arthur Gessler[2), 3)], Andreas Rigling[2), 3)], Cornelius Senf[4)], Thomas Wohlgemuth[2)], Heini Wernli[1)]

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Forest dieback in Europe has recently intensified and become more extensive. This study identifies low-forest-greenness events at the 50-km scale in Europe in June-August 2002-2022 from the 250-m normalized difference vegetation index (NDVI). It quantitatively investigates meteorological precursors (timing and persistence of temperature, T2m, and precipitation, P, anomalies) to these events in the temperate and Mediterranean biome. We quantify the impact of the 2022 event, which, according to our criteria, negatively affected 37% of temperate and Mediterranean forests – more than in any other summer.

The low-NDVI events occurred in particularly hot-dry summers. Another key precursor is the anomalous accumulation of dry periods, i.e., P deficits, over the preceding 26 (34) months in the temperate (Mediterranean) biome. While the persistence of positive T2m anomalies over about the same 26-month period, as well as strong hot-dry conditions in the previous summer were characteristic of temperate low-NDVI events, we find hardly any other meteorological precursors to the Mediterranean events. The significant dry periods went along with reduced cyclone activity in the Mediterranean and positive anticyclone frequency in the temperate biome. In summary, our systematic investigations provided clear evidence of how surface weather over up to 3 years can negatively impact European forest greenness.

Legacy Effects of an Extreme Drought Event Can Modulate Phytochemical Profile and Leaf Herbivory in European Beech

Michael Eisenring[1)], Arthur Gessler[2), 3)], Esther R. Frei[3), 4), 5)], Gaétan Glauser[6)], Bernd Kammerer[7)], Maurice Moor[1)], Anouchka Perret-Gentil[1)], Thomas Wohlgemuth[3)], Martin M. Gossner[1), 2)]

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[4)] WSL Institute for Snow and Avalanche Research SLF, Davos, Switzerland

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Current climate change scenarios anticipate a general increase in extreme drought events in the coming decades. In addition to the immediate consequences for many forest ecosystem processes, extreme-drought events can also have long-lasting effects on forest community dynamics and species interactions. Yet, our understanding of how drought legacy may modulate ecological relationships is just unfolding. Here, we investigated the legacy effects of an extreme drought event on European beech (*Fagus sylvatica* L.) leaf chemistry and tree-herbivore interactions by using a natural experimental setup, in which trees severely impacted by an extreme drought event grew next to apparently unstressed trees. For two consecutive years after the extreme Central European summer drought event in 2018, we collected beech leaves from the sun-exposed and shaded canopy of previously drought stressed and unstressed trees. Beech leaf chemistry was analyzed using targeted and untargeted analytical approaches and leaf damage by different herbivore feeding guilds was quantified. We found that (1) drought stress had long lasting impacts on nitrogen and fiber content as well as on specialized composite phytochemical profiles. However, drought did not affect primary phytochemical profiles. (2) Drought-caused changes in leaf chemistry influenced the likelihood of herbivory, but dependent on herbivore feeding guilds. (3) Drought legacy effects on phytochemistry and beech-herbivore interactions were often weaker than between-year or between-canopy strata variability. Our results demonstrate that a single extreme drought-event bears the potential to affect tree-herbivore interactions in the long term. Drought legacy effects, as described in this study, will likely become more important in modulating tree-herbivore interactions since both drought frequency and severity are projected to globally increase in the coming decades.

The Impact of Tree-tree Interactions on Leaf-level Carbon Exchange Under Heat Vs. Drought Stress

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With rising global surface temperatures, extreme climatic events such as heatwaves associated with droughts are becoming increasingly frequent and severe. During these so-called “hot droughts”, higher air temperatures are combined with reduced soil moisture, potentially exacerbating their individual effects. In forest ecosystems, they have been associated with large-scale tree mortality, reduced forest productivity, increasing wildfires and pest outbreaks. One main challenge for trees during these extreme climatic events is to maintain optimal performance, including carbon (C) exchange (e.g., maintain C uptake through photosynthesis and limit C losses through respiration). Even though trees can acclimate to a certain extent to hotter and drier conditions, their response is further modulated by species interactions, which can increase or decrease resource access. Understanding how heat and drought individually but also concurrently affect trees C exchange and the role of species interactions is therefore necessary to predict forest dynamics under future climate.
Using an experimental climatic manipulation in open-top chambers, we assessed how heat, drought and their combination impacted the acclimation of leaf- photosynthesis and respiration (i.e., temperature response curves) of downy oak and European beech and whether species interactions (monocultures vs. mixtures) modulated these effects. Our results show that drought had the strongest adverse impact on the photosynthetic rate and optimum temperature of both species, especially during the warmest period of the season. However, this effect was not exacerbated by co-occurring high air temperature. Warming resulted in a higher thermal optimum of photosynthesis (but no higher assimilation rate), especially in beech. Respiration was less affected by warmer and drier conditions than photosynthesis, suggesting that the balance between C uptake and C loss might be off during extreme climatic events. Inter-specific interactions generally had a positive effect on oak and a negative one on beech. However, those varied with climatic conditions and during the season.

Chronic Warming and Dry Soils Limit Carbon Uptake and Growth Despite a Longer Growing Season in Beech and Oak

Margaux Didion-Gency[1)], Yann Vitasse[2)], Nina Buchmann[3)], Arthur Gessler[2), 4)], Jonas Gisler[2)], Marcus Schaub[2)], Charlotte Grossiord[1), 5)]

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Progressively warmer and drier conditions impact tree phenology and carbon cycling with large consequences for forest carbon balance. However, it remains unclear how individual impacts of warming and drier soils differ from their combined one and how species interactions modulate tree responses. Using mesocosms, we assessed the multi-year impact of continuous air warming and lower soil moisture acting alone or combined on phenology, leaf-level photosynthesis, non-structural carbohydrate concentrations, and aboveground growth of young European beech and Downy oak trees. Warming prolonged the growing season of both species but reduced growth for oak. In contrast, lower moisture did not impact phenology but reduced trees' assimilation and growth for both species. Combined impacts of warming and drier soils did not differ from single ones. Our work revealed that higher temperature and lower soil moisture have contrasting impacts on phenology vs. leaf-level assimilation and growth, with the former being driven by temperature and the latter by moisture.

Predisposing and Inciting Stress Factors Leading to Drought-induced Mortality

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In recent years, an unprecedented increase in both the frequency and intensity of extreme drought events severely affected low-elevation forests in Central Europe. Existing empirical and dynamic models often fail to capture mortality patterns resulting from the combined impacts of climatic extremes. To address this issue, we developed a modeling framework to analyze the main factors leading to mortality during the drought years of 2018-2019 in even-aged beech stands in Switzerland. First, we assessed drought indices of differing complexities to capture stand-level growth responses during extreme drought events. Subsequently, we simulated stand development over time using a new feature of the forest gap model ForClim based on the Decline-Disease theory (Manion, 1981). This novel framework includes a carbon and drought memory terms as a predisposing factors and a drought duration term coupled to for spring and autumn soil water deficits as an inciting factors. We also improved the model's sensitivity to environmental extremes (temperature and soil). Lastly, we applied a pattern-oriented modeling approach across sites representing a climatic gradient from cold-wet to warm-dry conditions in Central Europe, simulating potential natural vegetation. Our findings revealed that even the most accurate index alone could not fully explain mortality patterns, as it primarily reflected carbon starvation. We contend that isolated growth decline is not the primary driver of mortality in low-elevation stands. Our stress-based approach to modeling drought-induced mortality successfully replicated mortality events resulting from drought extremes across all studied stands. Notably, towards the drier end of the selected sites, drought-tolerant species dominated, accompanied by an increased frequency of mortality events. In a changing climate, our novel modeling approach helps identify drought trajectories and their effects on stand dynamics. Moreover, it underscores the critical role of site-specific conditions, particularly soil water availability, in shaping stand-level dynamics and species responses to drought events.

Leaf Minimum Conductance And Residual Water Use In 9 European Tree Species During A Hot Drought

Songwei Wang[1)], Günter Hoch[1)], Georges Grun[1)], Ansgar Kahmen[1)]

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Residual canopy transpiration (E_{min_canop}) is a key physiological trait that determines a trees' survival time under drought after stomatal closure and after trees have lost access to soil water. E_{min_canop} mainly depends on leaf minimum conductance (g_{min}) and vapor pressure deficit. Here we determined the seasonal variation of g_{min} and how leaf cuticular and stomatal traits are related to the interspecies variation in g_{min} for nine European tree species in a mature forest. In addition, we determined the species-specific temperature responses of g_{min}. With this newly obtained insight into the variability of g_{min} in temperate tree species, we calculated daily E_{min_canop} for the nine species using climate data of the hot drought that occurred at our research site in 2022. Our results show that g_{min} ranged from 0.9 to 5.1 mmol m^{-2} s^{-1} across the nine species and was stable in most species throughout the growing season. The interspecies variation of g_{min} was associated with leaf cuticular and stomatal traits. Additionally, g_{min} exhibited strong temperature responses and increased, depending on species, by a factor of two to four from 25 to 50 °C. Based on our estimation and standardized by tree size (stem basal area), daily E_{min_canop} ranged from 1.6 to 33.2 L m^{-2} for the studies species at the site and exhibited species-specific rapid increases under hotter temperatures. Our results suggest that trees, depending on species, need substantial amounts of water during a drought, even when stomates are fully closed. Species differences in g_{min} and ultimately E_{min_canop} can contribute, together with other traits, to the ability of a tree to keep its tissue hydrated during a drought and explain species-specific differences in drought vulnerability.

Hiking without map and compass? The path to adapting our forests

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Adapting forests to global change presents us with enormous challenges. Changes in climate as well as in the biotic environment (diseases, pests, invasive species) are proceeding at a rate we could not have imagined until recently. In most cases, this requires active adaptation of forests, as natural acclimation and adaptation processes are not rapid or effective enough to sustain the provision of many forest ecosystem services. Even with widely accepted active adaptation measures (e.g., mixed stands, structural diversity, changes in tree species composition, thinning), we do not know to what degree of change in the climatic and biotic regime they will be effective. Therefore, one of the great challenges of adaptation is to identify such measures and steps that can be called "no regret". In this context, it is necessary to think not only about the forests themselves, but also about the capacity of forest enterprises. The presentation should be understood as a contribution to the discussion on forest adaptation.

Tree Species Response to Drought in Temperate Forests: New Monitoring Perspectives

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Forests cover about 31 % of the global land area and are home to 80 % of the Earth's terrestrial biodiversity. They provide a myriad of ecological, economic, and climatic benefits, yet they are highly vulnerable to climate extremes. The frequency and intensity of extreme weather events, such as drought or heavy rain, are expected to increase in the 21st century. The effects of climate-induced shifts, as well as tree mortality, have already been observed. Nevertheless, it is questionable whether native tree species will manage to keep up with climate change.

Here, I will present recent efforts that bring together field and remote sensing monitoring approaches to assess the response of more than 10 tree species to drought. Forest monitoring and in particular tree species health assessment, is a fundamental building block to enabling sustainable forest management. Yet species monitoring is a challenging task that typically requires extensive field surveys that are time-consuming and costly. In addressing these challenges, remote sensing can contribute significantly. Thus, recent applications of deep learning approaches for tree species identification and tree health assessment will also be presented.

Deep Soil Organic Matter Response to Warming is Depth- and Site-specific

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In an increasingly warmer world, soil will warm in near synchrony with air temperatures. Consequently, heterotrophic respiration accelerates, but is unclear how this will affect soil organic matter (SOM) stocks, the Earth's largest terrestrial stock of reactive carbon. And half of that SOM stock resides in deep soil (below 30 cm). Meta-analyses of how SOM responds to warming exist, but so far did not cover the deep SOM. Despite their large stock size, subsoils remain largely underrepresented in warming studies. But what becomes increasingly clear, is that deep SOM can respond very differently to warming than surface soils, and may show even stronger response than surface soil to changing environmental conditions.
Sources of uncertainty in predictions of how global SOM will respond to a warmer world is the lack of (1) process understanding of deep SOM dynamics, and (2) the lack of multitemporal, especially decadal, observations. (3) We still cannot synthesize and analyze data stemming from the increasing number of field experiments, because experiments were made using different methodologies, or results are reported in different units.
The aim of this presentation is to summarize the latest research insights on belowground carbon cycling, and ultimately to contribute to the answer the question: What will be the role of deep soil organic matter in terrestrial carbon cycle feedback to warming over the next century?

Drought Impacts Soil Carbon Storage Through Changes in Soil Biota – Evidence from a Long-term Irrigation Experiment in a Dry Pine Forest

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Severe droughts alter soil organic carbon (SOC) cycling, but net effects on SOC storage are unclear as drought affects both C inputs and outputs from soils. Here, we explored the overlooked role of soil fauna on SOC storage in forests, hypothesizing that soil faunal activity is particularly drought-sensitive, thereby reducing litter incorporation into the mineral soil and, eventually, long-term SOC storage.

In a drought-prone pine forest (Pfynwald, Switzerland), we performed a large-scale irrigation experiment for 17 years and assessed its impact on vertical SOC distribution and composition. We also examined litter decomposition of dominant tree species and determined soil fauna abundance and community composition.

In the first decade, summer irrigation induced C losses from organic layers (-1.0 kg C m^{-2}) and comparable C gains in the uppermost mineral soil (+0.8 kg C m^{-2}). The vertical SOC redistribution can be attributed to increased root-C inputs under irrigation, doubling pine fine-root production and rhizodeposits, and to greater litter incorporation into the mineral soil by soil fauna. Irrigation strongly increased litter mass loss especially when meso- and macrofauna were included (+215 %) than when excluded (+44 %). There was also a many-fold increase in soil fauna abundance during the dry summer months, together with long-lasting shifts in mesofauna community composition under irrigation.

Overall, our study shows that soil fauna is highly sensitive to natural drought, which leads to a reduced C transfer from organic layers to the mineral soil. The decreased C supply for belowground communities under dry conditions potentially reduces the microbial processing of organic matter, and eventually the long-term C stabilization in the mineral soil.

Enhanced Water Source Partitioning is Not Enough to Overcome Drought Impacts in Mixed Mediterranean Forests

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High species diversity in forest ecosystems could reduce their vulnerability to extreme droughts through increased belowground water source partitioning. Yet, the dynamic of belowground water uptake mechanisms driving beneficial diversity effects on tree water use remains unclear. Using 30 long-term permanent plots in Mediterranean forests with increasing tree species diversity, we examined the seasonal patterns of *in-situ* aboveground and belowground water relations on 260 trees from four pine and oak species over two years. We found that increasing species diversity (from monospecific to four-species mixtures) induced strong water source partitioning between oak and pine species. However, despite a strong belowground moisture partitioning in mixtures, reductions in photosynthesis, stomatal conductance, leaf water potential, and stomatal regulation were enhanced compared to monospecific during dry periods for pines but not oaks. Our findings reveal that reduced competition for soil water in diverse forests is insufficient to buffer the adverse impacts of severe droughts on aboveground water relations.

Unraveling the Demographic History of *Abies Spp* by Combining Ancient Pollen Data with Genetic Simulations

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Climate change triggered tree decline is a major concern for European forests. Identifying species and provenances that will be able to cope with climate change is of paramount importance. In this context, silver fir (*Abies alba*) is a prominent species thanks to its relatively high drought resistance, shade tolerance, frost hardiness and its capacity to promote biodiversity by forming mixed forests. Thereby, silver fir provides a promising alternative to Norway spruce that suffer from massive climate induced die-back in some parts of Europe or to the introduced Douglas fir. Silver fir grows under a large variety of climates, suggesting a large ecological niche and potentially high genetic diversity. Understanding the demographic history of the species and its consequences on the distribution of genetic diversity would be necessary to exploit the full potential of this species for climate change adaptation. We used a combination of pollen records from 174 sites across Europe and a vegetation reconstruction model (REVEALS) to infer past population size fluctuations of the species from the Last Glacial Maximum to today. Subsequently, we supplied this information to a spatially explicit population coalescent simulation model to predict the spatial distribution of genetic diversity across the entire species range. Contrasting the simulation results with observed genetic diversity data revealed that contemporary patterns of genetic diversity are mainly driven by past demographic history, yet deviations were also detected that may suggest ascertainment bias both in genetic and pollen data. Most importantly, our results help identify areas of potentially high genetic diversity, which could be of great value for climate-smart forest management practice.

Tree Migration in Complex Landscapes

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[1)] Forest Ecology, Department of Environmental Systems Science, ETH Zurich, Switzerland

Tree migration rates and spatial patterns can be strongly influenced by the types of arrangements of habitat patches in a landscape. Complex landscapes have higher topographical variability, and changes in slope-aspect relationships have an influence on local climatic conditions. Tree migration can also be influenced by local weather changes and bigger climate shifts. However, it is not clear how their combined effect influences tree migration dynamics and what the combined role of alternative spatial patterns, such as those caused by landscape

In this study, we want to understand: How does climate change affect how tree migration rates in landscapes with different levels of complexity? What role does landscape fragmentation play in complex landscapes? We selected catchments in Switzerland that represent different levels of landscape complexity and simulate tree migration dynamics under the influence of different climate scenarios and alternative levels of landscape fragmentation. The forest landscape model LandClim is used to simulate migration processes. This model has been updated to an annual time scale with a new formulation for tree dispersal.

In our presentation, we would like to share the preliminary results on migration rates and talk about the computational challenges we faced. We'll also share what we learned about migration rates on complex landscapes, under different climate situations, and at various levels of landscape fragmentation.

Poster Presentations

Managing European Alpine Forests with Close-to-nature Forestry to Improve Climate Change Mitigation and Multifunctionality

Simon Mutterer[1),3)], Clemens Blattert[1)], Timothy Thrippleton[1)], Jurij Diaci[2)], Gal Fidej[2)], Leo G. Bont[1)], Janine Schweier[1)]

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Close-to-nature forestry (CNF) has a long tradition in the management of European Alpine forests and contributes to the continuous provision of forest ecosystem services, such as protection against natural hazards. Climate change poses new challenges, however, and raises questions about the future applicability of CNF in Alpine forests: Is CNF an appropriate management approach for adaptation to climate change impacts? Can CNF meet the increasing societal demands, including potentials for climate change mitigation? We simulated forest development at two Alpine study sites with a long CNF history, together representing a large biogeographic gradient from high-elevation inner (Switzerland) and lower-elevation south-eastern Alpine forests (Slovenia). The simulations considered different climate scenarios and management strategies that represented current CNF variants of Alpine forest management and adapted versions. We assessed the impacts of management on the provision of biodiversity and forest ecosystem services (BES) using an indicator framework covering key BES of the investigated regions, including carbon sequestration (CS). CNF performed well in ensuring multiple BES in the long-term simulations. However, none of the strategies met all objectives equally well; while biodiversity indicators benefited from low intensity and no management, protection from gravitations hazards and timber production benefited from the adaptation strategy. The effects of climate change differed both between and within the study sites along environmental gradients. In the inner Alpine study site, ecosystem services were more sensitive to climate change. Under the extreme climate change scenario, CS potentials even decreased at lower elevations. This negative effect could be compensated to a certain degree by fostering climate-adapted species. To conclude, sustaining multiple ecosystem services and CS potentials under the uncertainties of climate change requires an adaptation of CNF by fostering a high tree diversity, including climate-adapted species. Diversified management, including unmanaged forest areas, is central for the enhancement of biodiversity in Alpine forests.

Mature Trees Face Stronger Drought Effects Than Conspecific Saplings During the 2023 Growing Season

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Temperate forests are increasingly affected by climate change induced droughts. Following hydraulic models, drought stress and vulnerability to drought increase with tree height. Currently, there is limited empirical data available to test if mature trees respond differently to drought stress than conspecific saplings under natural conditions. Addressing this question is crucial for anticipating future forest composition and structure.

We compared predawn and midday leaf water potentials (LWP) of conspecific saplings and mature trees of nine species (six broadleaves, three conifers) at five dates from May to August 2023 at the Swiss Canopy Crane II (SCC II) site.

Our results show significantly decreasing predawn and midday leaf water potentials of saplings and mature trees along the observation period that included an extensive heat and drought event in mid-August. Across the season, saplings had significantly less negative predawn and midday LWP than mature trees. However, after correcting the LWP values for the hydrostatic effects of tree height, we found no differences in predawn LWP between saplings and conspecific mature trees in most cases, indicating similar soil water access between saplings and mature trees at our site. Contrastingly, there was a trend towards less negative midday LWP for saplings compared to mature trees even after removing the hydrostatic contribution to LWP in most species, that increased over the observation period with some mature individuals experiencing LWP close to their species-specific P50 value. This differences likely result from combined effects of increasing friction resistance to water flow with tree height and microclimatic differences in VPD between the upper canopy and the forest understory.

These results suggest that tall trees at the SCC II site face stronger drought effects than conspecific saplings and emphasize the importance of additional factors besides hydrostatic effects (e.g., microclimatic gradients) that lead to the observed differences between tree sizes.

Drought-induced Crown Damage in Beech: do Tree Rings Reveal Predisposing Factors

Anna Neycken[1)], Thomas Wohlgemuth[2)], Esther R. Frei[2)], Christof Bigler[3)], Marco Lehmann[2)], Matthias Saurer[2)], Stefan Klesse[2)], Andri Baltensweiler[2)], Michel Scheggia[4)], Mathieu Lévesque[1)]

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The record-breaking drought in 2018 caused premature leaf discoloration and shedding (early browning) in many beech (*Fagus sylvatica* L.) dominated forests in Central Europe. Yet, a high degree of variability in drought response among individual beech trees within the same forest was observed. While the prolonged precipitation deficits and elevated temperatures severely impacted some trees, others remained vital with no or only minor signs of crown damage. Why some beech trees were more susceptible to drought-induced crown damage than others and whether growth recovery is possible are poorly understood.

To address whether there were predisposing factors that could predict the weakening of individual beech trees, a total of over 1000 increment cores were analyzed. The cores were taken from beech trees that showed early browning or crown damage caused by the 2018 drought and from neighboring beech trees that remained vital. We compared the growth between the two vigor classes from different perspectives: long-term growth, response to water balance, climate extremes, and mast years. In addition, we investigated if competition and species diversity could explain the differences in vitality. In a smaller selection of trees, we studied whether a diverging functional behavior could explain the vitality differences using the "triple isotope analysis" of carbon ($\delta^{13}C$), oxygen ($\delta^{18}O$), and hydrogen ($\delta^{2}H$) in tree ring samples from the last 61 years (1960 – 2020).

The results demonstrate a slower growth of beech trees with drought-induced crown damage compared to the vital beech trees for more than 50 years. In addition, beech trees with early browning showed a greater response to the current and previous summer’s climatic water balance than the vital beech trees. The isotopic results suggest differences in stomatal regulation and carbon utilization, potentially explaining the diverging responses to the 2018 drought.

Forest-floor Greenhouse Gas Fluxes In A Subalpine Spruce Forest: Continuous Multi-year Measurements, Drivers, And Budgets

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Forest ecosystems play an important role in the global carbon (C) budget by sequestering a large fraction of anthropogenic carbon dioxide (CO_2) emissions and by acting as important methane (CH_4) sinks. The forest-floor greenhouse gas (GHG; CO_2, CH_4 and nitrous oxide N_2O) flux, i.e., from soil and understory vegetation, is one of the major components to consider when determining the C budget of forests. Although winter fluxes are essential to determine the annual C budget, only very few studies have examined long-term, year-round forest-floor GHG fluxes. Thus, we aimed to i) quantify the seasonal and annual variations of forest-floor GHG fluxes; ii) evaluate their drivers, including the effects of snow cover, timing, and amount of snow melt, and iii) calculate annual budgets of forest-floor GHG fluxes for a subalpine spruce forest in Switzerland. We measured GHG fluxes year-round during four years with four automatic large chambers at the ICOS Class 1 Ecosystem station Davos (CH-Dav). We applied random forest models to investigate environmental drivers and to gap-fill the flux time series. Annual and seasonal forest-floor CO_2 emissions responded most strongly to soil temperature and snow depth (2.34±0.20 kg CO_2 m^{-2} yr^{-1}). Furthermore, the forest-floor was a consistent CH_4 sink (-19.1±1.8 g CO_2-eq m^{-2} yr^{-1}), with annual fluxes driven mainly by snow depth. N_2O fluxes were very low, negligible for the forest-floor GHG budget at our site. In 2022, the warmest year on record with also below-average precipitation at the Davos site, we observed a substantial increase in forest-floor CO_2 emissions compared to other years. Due to the relevance of snow cover, we recommend year-round measurements of GHG fluxes with high temporal resolution. With increasing temperatures and less snow cover due to climate change, we expect increased forest-floor CO_2 emissions, with negative effects on its carbon sink behaviour.

Are Temperate Tree Species Able to Adjust Root-water Uptake Depth in Response to Drought?

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Temperate trees are facing a growing challenge due to limited water supply and increased atmospheric demand resulting from an extreme trend in drought events. Traits such as root-water uptake depth (RWUD) are crucial for determining a species' performance during drought. The objective of this research is to determine the ability of species to adjust their RWUD during drought. For this purpose, we analyzed δ^2H and δ^{18}O isotope data from xylem water samples obtained from nine co-occurring temperate tree species over three growing seasons (2020-2022) at the Swiss Canopy Crane II site in Switzerland. Additionally, we analyzed bi-weekly water samples collected from precipitation, throughfall, and soil water at different depths. The years 2020 and 2022 were comparatively dry when compared to the reference period of 1991-2021, whereas 2021 experienced a wet summer. This provides an opportunity to observe the dynamics of RWUD across a broad range of soil water supply.

The initial results show species-specific differences in the summer δ^2H and δ^{18}O isotopic signals. While xylem-water δ^2H and δ^{18}O values for *Quercus sp.*, *Fraxinus excelsior*, and *Sorbus torminalis* suggest RWU in deeper soil, *Carpinus betulus*, *Picea abies*, and *Abies alba* signal a predominant RWU in the top soil. *Fagus sylvatica* exhibits variability in their values, indicating RWUD adjustment. These initial findings reveal different rooting strategies and resource partitioning within the rhizosphere. The final results of this study are expected to have significant implications for understanding the mechanisms behind drought vulnerability of temperate trees and improving the prediction of tree species' responses to an altered hydrological regime.

Process-based Assessment of Tree Stress and Risk Under Drought Conditions

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Droughts impose significant risks to forest ecosystems, as they affect tree stress and induce mortality. However, high uncertainties persist in how forests respond to extreme events, such as drought. In this paper, we further investigate these processes and the connected risks. Process-based models are based on explicit physical and physiological processes and interactions. They are a powerful tool when assessing long-term impacts on environmental systems over empirical models, especially in climate change conditions. We applied the process-based forest growth model 3-PG to 13 test sites across Switzerland. We simulated the growth of three species, namely *Quercus robur*, *Abies alba* and *Fagus sylvatica*, over two periods: between 1980 and 2018 and between 2013 and 2018. We aim to assess the risk imposed by drought conditions on the test sites and understand how different tree species respond to drought across varying site conditions. We evaluated tree stress through four indicators, depending on temperature, vapor pressure deficit, soil water availability and frost days. We then tested a risk metric based on the stress indicators and the output of 3-PG to assess the risk imposed by climatic conditions. Results show that temperature and vapor pressure deficit are the main drivers of tree stress during both winter and summer. Frost and soil water, on the other hand, impose significant stress less frequently. Vapor pressure deficit consistently influences tree stress during the summer months. Soil water, on the other hand, can lead to higher stress with a lower frequency. The risk metric shows that soil water and vapor pressure deficit are the main drivers of risk during the summer months. These results demonstrate that 3-PG can be used to assess species response and the related risk imposed by drought conditions.

Response of Beech (*Fagus Sylvatica*) Seedlings from Across the Species' Range Exposed to Simulated Drought

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Intraspecific diversity is the basis for adaptation to a changing climate, but how genotypic contributions and plasticity contribute to intraspecific trait diversity ais still largely unknown. Beech (*Fagus sylvatica* L.) is common in Europe and commercially and culturally important. However, it is a drought-sensitive tree species and particularly vulnerable in the seedling and young growth phase. Climate change, including droughts and heatwaves, is likely to change the distribution of beech in Europe and lead to local population declines.

We conducted a common garden experiment with 187 2-year-old beech seedlings originating from 16 populations across the species range in Europe and with a known population genetic structure. We furthermore asked whether and how beech tree seedlings can acclimate to drought via phenotypic plasticity within one season. Toward this aim, we exposed half of the potted seedlings to a simulated drought (i.e., rain-free days) in June and again in July 2023. The two drought periods were intermitted by a recovery period. To assess plant responses to drought, we measured leaf physiological traits such as chlorophyll content, stomatal conductance, and growth. Using leaf spectroscopy, we derive additional traits based on spectral indices such as the Photochemical Reflection Index (PRI), which correlates with the efficiency of photosynthesis. Furthermore, we will use an inversion of the validated PROSPECT-D radiative transfer model to derive plant parameters such as chlorophyll and carotenoids. This enables us to capture relevant physiological drought stress responses across beech tree genotypes. Preliminary results reveal that the different provenances show similar response to the induced drought treatment and that shoot length (plant height) is a strong determinant of drought stress. Knowledge about intraspecific diversity in the species' drought stress response will aid foresters in management and support efforts to help beech persist.

Prediction Of European Spruce Bark Beetle Mortality Based On Tree Radial Growth And Response To Past Drought In Mountain Forests Of South-Eastern Switzerland

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Drought and European spruce bark beetle often interact in forests, causing widespread mortality of trees. However, the processes leading to bark beetle-associated tree mortality are poorly understood, particularly predisposing factors and memory effects of past droughts.

Here, we used tree rings from three sites to investigate Picea abies mortality following European spruce bark beetle infestations in spruce-dominated mountain forests in south-eastern Switzerland. We recorded individual tree and forest structural characteristics and collected increments cores at breast height (1.3 m height, two samples per tree) in circular plots with a radius of 12.62 meters. These plots were situated within two contrasting zones (categories), the first influenced by bark beetle disturbance, the second in a neighbouring undisturbed area. Each category of plot encompassed a comparable number of trees, with no less than 10-12 trees sampled for each. We determined the influence of climate and competition on growth in trees that died and that were not affected by the insect attacks and examined the growth resistance and resilience to past droughts (in particular, drought 2003, 2018, and 2022), to derive regression models of growth-mortality risk. Here, we show preliminary results of the study.

Our results show that trees in an early stage of the bark beetle infestation (green stage) were larger than healthy trees (median diameter at breast height 49 and 31 cm, respectively). Similarly, affected trees were also taller than unaffected trees (median tree height 33 and 23 m, respectively). Crown ratio and slenderness did not significantly differ between these two categories of trees. Recent radial growth was higher in healthy trees compared with infested trees but with differences between sites.

Although still preliminary, our results suggest that accounting for individual tree characteristics and past growth patterns may be important for improving predictions of bark beetle-associated mortality.

Does Increasing Tree Species Diversity Reduce the Drought Sensitivity of Silver Fir, Larch and Douglas Fir?

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With climate change, the frequency and duration of droughts are increasing, strongly impacting forest ecosystems. Therefore, a thorough understanding of the factors influencing tree response to drought is needed. Particularly, it is still unclear how species diversity influences the drought sensitivity of tree species. To assess the influence of tree species diversity on the growth response of silver fir, European larch and Douglas fir to drought, we measured the tree-ring widths of 401 trees with a wide range of species diversity in their neighborhoods at eight sites covering a bioclimatic gradient in Switzerland. We also analyzed the stable isotope ratios of carbon ($\delta^{13}C$), oxygen ($\delta^{18}O$) and hydrogen ($\delta^{2}H$) in tree-ring cellulose for a subset of 24 silver fir and 24 Douglas fir trees at three sites to infer their physiological responses to drought. We used a growth resilience index, corresponding to the ratio between post- and pre-drought growth, mixed-effects models, correlations and superposed epoch analyses to test how species diversity influences species-specific responses to drought. We found that a more diverse neighborhood only significantly enhanced the growth resilience of Douglas fir to drought. We observed similar correlations between stable isotope ratios in tree rings and climate variables for trees in pure and mixed conditions. This suggested that tree species diversity had a limited effect on the physiological responses of silver fir and Douglas fir to moisture availability. Additionally, the superposed epoch analysis did not reveal clear differences in growth and isotopic responses to the 2003, 2015 and 2018 severe droughts between trees growing in pure and mixed conditions. Overall, our results suggest that tree species diversity has minor effects on the drought resilience of silver fir, larch and Douglas fir in Central European temperate forests.

Effect of European Spruce Bark Beetle Disturbance on Tree-Related Microhabitats in Mountain Forests of South-Eastern Switzerland

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Forest ecosystems play a pivotal role in hosting a substantial portion of the Earth's terrestrial biodiversity. Nevertheless, these ecosystems have been subject to an escalating array of disturbances, which are expected to increase in both frequency and severity. The amplification and possible interconnectedness of forthcoming disturbance processes underscore a fundamental requirement to better understand the repercussions of disturbances on the provision of suitable habitats for forest biodiversity.

In this study, we examined the impact of European spruce bark beetle (*Ips typographus* L.) disturbance on the occurrence and diversity of tree-related microhabitats in spruce-dominated mountain forests. This study was conducted across four sites located within the canton of the Grisons in south-eastern Switzerland. Tree-related microhabitats were documented through visual assessments conducted in circular plots with a radius of 12.62 meters. These plots were situated within areas influenced by bark beetle disturbance, as well as in neighboring undisturbed areas. Each category of plot (affected, undisturbed) encompassed a comparable number of trees, with no less than 10-12 trees scrutinized for each.

Our results indicate a higher prevalence of tree-related microhabitats within areas impacted by bark beetle disturbance in comparison to undisturbed sites (with average counts of 82 and 42 microhabitats, respectively). Among the most frequently encountered microhabitats at both locations were CV21, CV51, CV52, GR11, GR12, IN12, and OT12. However, the CV51, CV52 and IN12 microhabitats were predominantly observed within areas affected by bark beetle disturbance. A specific example is provided by the microhabitat BA11 “bark shelter” exclusive to dead trees. Notably, this microhabitat holds substantial importance for bats, providing them a place to rest and mate. The disturbance caused by bark beetle generated tree-related microhabitats, consequently enhancing the availability of habitats. This phenomenon was primarily attributed to the presence of dead trees following bark beetle infestations.

Auswirkungen von Trockenheit in Flächen der interkantonalen Walddauerbeobachtung 2018-2023

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Die interkantonale Walddauerbeobachtung umfasst 2023 eine 40-jährigen Datenreihe mit 200'673 Einzelbeobachtungen von Buchen, 143'883 Beobachtungen von Fichten und 37’170 Beobachtungen von Eichen auf insgesamt 235 Beobachtungsflächen. Nach 2018 stieg der Anteil Buchen mit Kronenverlichtung >60 %, stark an und blieb seither auf hohem Niveau. Die regionale Verteilung der Flächen mit einem hohen Anteil stark geschädigter Buchen widerspiegelt die Niederschlagsverteilung, mit den trockenen Gebieten in der Nordwestschweiz.

Ein wichtiger Grund für die starke Schädigung nach 2018 ist die rasche Aufeinanderfolge von trockenen Jahren. Die Kronenverlichtung >60 % wird durch die Trockenheit von bis zu fünf Vorjahren erklärt. Wenn das Schädigungsrisiko aufgrund dieser Beziehung für die Einzeljahre berechnet wird, ist das Risiko für die Jahre nach 2018 deutlich höher als nach 2003. Eine Erklärung für die Bedeutung der Trockenheit mehrerer Jahre ist die Reduktion der Wasserleitfähigkeit der Gefässe durch Eindringen von Luft, die Kavitation. Diese bleibt über den Winter erhalten und kann sich so akkumulieren.

Auch die Mortalität bei den Buchen stieg 2019 an und blieb seither erhöht. 2023 erreichte sie ein neues Maximum. Bei den Fichten war die Mortalität 2019, 2020 und 2022 stark erhöht. Insgesamt sind seit 2018 15 % der beobachteten Fichten gestorben.

Bei den Eichen ist die Mortalität bei den Flaumeichen seit 2020 deutlich erhöht. Auch bei der Beurteilung der Kronenverlichtung schneidet die Flaumeiche deutlich schlechter ab als die beiden anderen Eichenarten, was die Eignung dieser als bisher sehr trockentoleranten eingestuften Eichenart für zukünftige Pflanzen in Frage stellt.