



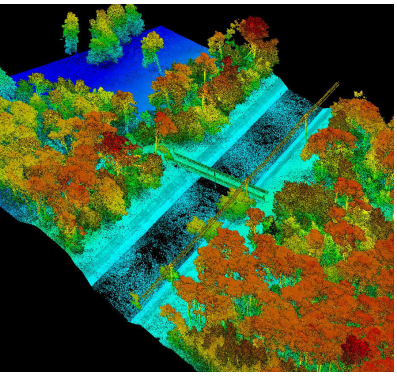


Forest Monitoring to assess Forest Functioning under Air Pollution and Climate Change

FORECOMON 2021 – The 9th Forest Ecosystem Monitoring Conference

7–9 June 2021
WSL, Birmensdorf, Switzerland

Proceedings

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2021 FORECOMON

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Preface

Climate change and air pollution affect forest ecosystems in many different ways. Drought periods, as in 2018, strongly reduce tree growth and increase tree mortality in Europe and elsewhere. At the same time, elevated air pollution levels affect forests from the leaf to ecosystem level. While societies' expectations to forests are increasing and forests have become focal points for local, national and global interests, the provision of ecosystem services such as timber production, water purification, and carbon sequestration is increasingly at risk. To address the impact of global change on forest ecosystems and their resilience, long-term data series are indispensable to evaluate status, trends and processes in forest ecosystems.

Three decades of monitoring effects from air pollution within the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) under the UNECE Convention on Long-range Transboundary Air Pollution (Air Convention) have provided a harmonized and standardized asset of long-term data series. This allows scientists, stakeholders and policy makers to address the status and changes of European forest ecosystems and their functioning also in relation to the more general context of climate change.

The goal of the FORECOMON 2021, the 9th ICP Forests Scientific Conference is to highlight the extensive ICP Forests data series on forest growth, phenology and leaf area index, biodiversity and ground vegetation, foliage and litter fall, ambient air quality, deposition, meteorology, soil and crown condition. We combine novel modeling and assessment approaches and integrate long-term trends to assess air pollution and climate effects on European forests and related ecosystem services. Novel results and conclusions from local to European scale studies will be presented and discussed.
As a special contribution to the scientific scope of the conference, we are delighted to announce the following keynotes, presented by renowned scientists:

- *Forests in transition – learning from current extremes to assess future pathways* by Prof. Andreas Rigling (WSL/ETHZ)
- *Forest soil carbon cycle under drought – linking experiments, monitoring and natural gradients across Switzerland* by Dr. Frank Hagedorn (WSL)
- *Accounting for time: long-term effects of N addition on forest bio-geochemistry and C sequestration* by Prof. Federico Magnani (UNIBO)
- *Responses of Swiss forests to long- and short-term environmental changes* by Prof. Nina Buchmann (ETHZ)

The 9th ICP Forests Scientific Conference takes place on 7–9 June 2021 followed by the 36th Task Force Meeting of ICP Forests, taking place on 10–11 June 2021 at the Swiss Federal Research Institute WSL in Birmensdorf nearby Zurich, Switzerland and by a post-conference excursion from 11–12 June 2021 into the Swiss Alps.

The FORMON 2021 Summer School on the same topic "*Forest Monitoring to assess Forest Functioning under Air Pollution and Climate Change*", takes place on 22–28 August 2021 in Davos, Switzerland and complements the 9th ICP Forests Scientific Conference. The 2021 Summer School is supported by ICP Forests, the

SwissForestLab and the European Network for forest research and higher education NFZ.forest.net. FORMON aims to provide an in-depth understanding of the concepts, approaches, and available data infrastructure of forest long-term monitoring. Novel modelling and assessment approaches will be discussed considering the expectations to future forests from a scientific, forest management, and socio-economic perspective. Students and young scientists are provided an insight into the data treasure of ICP Forests and will take advantage of in-depth lectures by renowned scientists on selected topics concerning long-term forest ecosystem research.

The remaining uncertainties due to the COVID-19 pandemic travel restrictions led us to the decision to postpone the conference from 2020 to 2021. To reach as much flexibility as possible, we are offering a hybrid conference, allowing for virtual and physical attendance.

Despite all challenges, we are confident that we will enjoy an inspiring conference with new insights from 23 oral and 61 poster presentations with authors and co-authors from 36 countries allowing enlightening discussions to shape the future science in *Forest Monitoring to assess Forest Functioning under Air Pollution and Climate Change.*

On behalf of the conference committees,

Marcus Schaub

Session 1:

The Classics – Long-term trends in forest ecosystem processes as affected by air pollution, drought or other extreme weather events

Oral presentations

Accounting for time: long-term effects of N addition on forest biogeochemistry and C sequestration

ID: 187

Magnani, Federico

Alma Mater Studiorum – Università di Bologna, Italy

Human activities have resulted in a sustained increase in atmospheric N deposition onto terrestrial ecosystems over the last century, with potential effects on plant health, soil processes, ecosystem productivity and C sequestration. Temperate and boreal forests are particularly sensitive to the alteration of the natural N cycle, due to widespread N limitations but also to their location in hotspots of N pollution in Europe, North America and, more recently, China. The effects of N deposition have been explored through a combination of approaches, both observational and experimental, yielding sometimes contradictory results about the sensitivity of the forest C cycle to N inputs, as well as the critical loads for ecosystem N saturation. The hypothesis is presented here that the prevailing mechanism of N deposition is through its accumulation in the soil, resulting in a slow change in N capital and turnover rates, possibly mediated by soil organic matter C/N. The hypothesis has been tested through a re-analysis of long-term N fertilization experiments. N addition resulted in a significant increase in soil N and C contents and a decline in C/N ratios, consistent with the regional pattern observed in ICP Forests plots. This was associated with a substantial increase in soil net N mineralization, which over time is expected to exceed the direct effects of annual atmospheric N deposition. After taking into account this hidden long- term contribution, a rather coherent picture emerges of the response of gross forest C sequestration to N deposition, with an initial positive effect followed by saturation and a steady decline as further N is added, which is associated with N leaching and is compounded with the onset of tree mortality. The proposed hypothesis helps reconcile the results from N fertilization experiments with the evidence coming from forest regional monitoring in the ICP Forests network.

Nitrogen deposition is the most important environmental driver of continental-scale forest growth in Europe

ID: 183

Etzold, Sophia (1); Ferretti, Marco (1); Gessler, Arthur (1); Waldner, Peter (1); Schaub, Marcus (1); David, Simpson (2,3); Thimonier, Anne (1); De Vries, Wim (4)

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Understanding which factors drive forest growth is critical to predict how forests might respond to climate change. However, uncertainty exists on the role of altered environmental drivers, such as climate and air pollution, in affecting forest production at the continental scale, especially in interaction with site- and stand characteristics.

We conducted a continental-scale analysis of ICP Forests growth data obtained over the period 1995–2010 from nearly 100,000 trees distributed in 442 permanent observation plots located in even-aged, managed, and almost pure forest stands across 23 countries in Europe.

Multivariate statistics provided evidence that stand characteristics like stand density index and stand age are key to explain forest increment. For most species a clear relationship of growth with atmospheric N deposition appeared, with an overall positive, but in some cases non-linear response with a tipping point at 24–34 kg N ha^{-1} yr^{-1}.

Additionally, N deposition had indirect negative effects on stem increment by altering soil pH and foliar nutrient concentrations. With the exception of a consistent temperature signal for Norway spruce, climate-related predictors and ground-level ozone showed less generalized relationships with stem increment. Our results indicate that, together with the driving forces exerted by stand density and age, N deposition is at least as important as climate to modulate forest growth at continental scale in Europe, with a potential negative effect at sits with high N deposition.

Chronic nitrogen deposition effects under climate change in an Austrian karst catchment

ID: 202

Dirnböck, Thomas (1); Kobler, Johannes (1); Geiger, Sarah (1); Pröll, Gisela (1); Djukic, Ika (1); Brielmann, Heike (1); Hartmann, Andreas (2); Liu, Jan (2)

(1) Environment Agency Austria, Austria; (2) University of Freiburg, Germany

Excess nitrogen (N) deposition and gaseous N emissions from industrial, domestic, and agricultural sources have led to increased nitrate leaching, the loss of biological diversity, and has affected carbon (C) sequestration in forest ecosystems. Nitrate leaching affects the purity of karst water resources, which contribute around 50% to Austria's drinking water supply. Here we present an evaluation of the drivers of dissolved inorganic N (DIN) concentrations and fluxes from a karst catchment in the Austrian Alps (LTER Zöbelboden) from 27 years of records. In addition, a hydrological model was used together with climatic scenario data to predict expected future runoff dynamics. The study area was exposed to increasing N deposition during the 20th century (up to 30 to 35 kg N ha^{-1} y^{-1}), which are still at levels of 25.5 ± 3.6 and 19.9 ± 4.2 kg N ha^{-1} y^{-1} in the spruce and the mixed deciduous forests, respectively. Albeit N deposition was close to or exceeded critical loads for several decades, 70%–83% of the inorganic N retained in the catchment from 2000 to 2018, and NO_3-N concentrations in the runoff stayed < 10 mg L^{-1} unless high-flow events occurred or forest stand-replacing disturbances. We identified tree growth as the main sink for inorganic N and expect higher retention in future as a result of warming. Expected climatic changes will also cause lower runoff. Together these effects will likely result in increased retention of N deposition in the future.

Acidification and recovery of forest ecosystems in central Japan during the past few decades

ID: 159

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(1) Asia Center for Air Pollution Research (ACAP), Japan; (2) Forestry and Forest Products Research Institute, Japan; (3) Tokyo University of Agicultural and Technology, Japan

Central Japan has historically experienced large-scale deposition of sulfur (S) and nitrogen (N) from the atmosphere due to the domestic air pollution in the 1960s/1970s and trans-boundary air pollution since the 1980s. After these high deposition periods, the emissions started declining since the late 2000s. In this study, based on two papers including Sase *et al.* (2019), and relevant monitoring data, we overview changes in conditions of forest ecosystems in central Japan during the past few decades to discuss the future of forest ecosystems in Japan. At Lake Ijira catchment (IJR), Gifu Prefecture, in which the acid deposition was the highest in Japan, atmospheric deposition, soil chemical properties, forest growth, and river water chemistry have been monitored since the 1980s. Soil acidification and river water acidification with high concentrations of SO_4^{2-} and NO_3^- were observed at IJR in the mid-1990s. It was suggested that climatic anomalies, such as cold summer in 1993 and drought summer in 1994, altered biogeochemical processes, resulting in acidification and N saturation of IJR. The NO_3^- concentration in the river increased continuously until the early 2000s.

Thereafter, the river water chemistry started recovering due to reductions in atmospheric deposition, diminished effects of climatic anomalies, and forest management practices. However, the isotopic data suggest that most of atmospheric S is still retained in soil.

Possible climatic anomalies may alter biogeochemical processes in the future, again. Other relevant monitoring data will be assessed, too.

What is the current carbon storage and future carbon sequestration potential of forest soils in the UK?

ID: 186

Vanguelova, Elena.

Forest Research, Farnham, United Kingdom

Afforestation results in sequestration of atmospheric CO_2 as trees grow. More than half of the carbon in forests is stored in the soil. Different tree species have profound effect on soil functions and the potential for carbon storage. Forests planted on mineral soils are generally accepted to result in increased soil carbon content. However, in some circumstances afforestation on organo-mineral or organic soils may result in substantial loss of soil carbon due to soil disturbance during forest planting. Climate and pollution changes as well as forest management practices can change the storage and dynamics of forest soil carbon.

This presentation will include quantification of forest soil carbon stocks, pools and change from past and present forest soil carbon surveys, resurveys and studies carried out within the UK. Forest soil and deadwood stocks and stability under main tree species and forest soil types from the UK BioSoil survey plots will be summarized.

Changes of shallow and deep soil carbon during forest lifecycle assessed from long term monitoring networks will also be discussed. Finally, likely changes of forest soil carbon under future climatic and environmental conditions will be demonstrated with results from a few case studies.

Trends in water chemistry in Europe and North America

ID: 189

De Wit, Heleen A; Austnes, Kari

Norwegian Institute for Water Research, Norway

I will present the ICP Waters program, a sister program of ICP Forests under the Working Group of Effects, and show some key results from recent publications. I will highlight issues of interest to the ICP Forests community such as trend analysis of water chemistry records and nitrogen and nutrient limitation.

Session 1:

The Classics – Long-term trends in forest ecosystem processes as affected by air pollution, drought or other extreme weather events

Poster presentations

Impact of drought on soil CO_2 efflux and vertical partitioning of soil CO_2 production at a beech and a pine forest site in north-east Germany

ID: 110

Jochheim, Hubert (1); Wirth, Stephan (1); Paulus, Sinikka (2); Martin, Maier (3); Haas, Christoph (1); Gerke, Horst H. (1)

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Soil respiration is one of the most important carbon fluxes in forest ecosystems. The analysis and quantification of the fluxes and its influencing factors play a crucial role in the understanding of the global carbon budget.

We present results of six years measurements of soil respiration at two German ICP Forests Level II sites with Scots pine and European beech on sandy soils. CO_2 efflux and vertical partitioning of CO_2 production in soils were calculated using the flux-gradient approach based on measured CO_2 concentrations at the soil surface and different soil depths up to 1 m. CO_2 concentrations were measured every 30 minutes using NDIR sensors, connected to gas permeable soil gas probes. Soil moisture and temperature were measured at identical time steps and soil depths. Site-specific diffusion models were used to calculate the time series of soil gas diffusivity.

The central aim was to resolve trends CO_2 production and efflux from both forest sites. The results show on average similar CO_2 effluxes at both forest sites. In the year 2017 with high precipitation rates, the CO_2 efflux increased especially at the beech forest site. Two years of drought (2018 and 2019) resulted in a decline of 49% in CO_2 efflux at the beech and of 28% at the pine forest site, as compared to the previous, wetter year (2017).

The flux gradient approach enabled vertical partitioning of CO_2 production, showing that the vertical distribution of soil CO_2 production differed between both locations. In the case of beech, its maximum was in the organic layer, while it reached its maximum in the upper mineral soil at the pine forest site. The climate may affect the vertical distribution of CO_2 production. The CO_2 production of the beech site was concentrated at the upper soil layers during the wet year (2017), whereas the maximum of CO_2 production in the dry year (2018) shifted to lower soil layers. Slight differences in the vertical distribution were detected at the pine forest site.

European beech and oak show different resource dynamics in mast years

ID: 112

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During mast years, i.e. years with high fruit production, a change in resource allocation to vegetative and generative compartments is expected. We investigated the influence of mast years on fruit and leaf production, basal area increment (BAI), and leaf carbon and macronutrient concentrations. Our target species were European beech (*Fagus sylvatica*) and two oak species (*Quercus petraea* and *Quercus robur*). We used measurements from four surveys of the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests). We applied superposed epoch analyses to investigate the resource dynamics between high fruit production and vegetative compartments, before, during, and after mast years. We further explored the direct effect of high fruit production on BAI in single trees and on leaf carbon and macronutrient concentrations.

In beech BAI was reduced during mast years, i.e. beech showed resource switching. In oaks we found that high fruit production did not lead to a decrease of BAI, i.e. resource matching occurred. However, in the year after the mast year, oaks showed resource depletion with a reduction in BAI. In the year prior to the mast year, we found resource accumulation in all species: beech showed increased leaf biomass, and oaks showed increased BAI. In beech foliar carbon concentrations, foliar C/N ratio and mass of 100 fresh leaves were reduced, and all foliar macronutrients were enhanced during mast years. In oaks, foliar carbon concentration was higher, and foliar phosphorus concentration was lower during mast years.

Monitoring of mercury in tree foliage in Austria

ID: 121

Tatzber, Michael; Fürst, Alfred

Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW)

In forest ecosystems, tree foliage is a key parameter for estimations of mercury inputs to soil and water. The Austrian Bio-Indicator Grid took place in 1983 and in 1995 20 sites were chosen for intensive monitoring (Level II; reduced to 16 sites in 2010). For six of these Level II plots, mercury in tree foliage (needles/leaves, seeds or fruits, twigs and other biomass) is monitored since 2016. Even though these six sites were not polluted with mercury, the resulting data are valuable for estimations of the range of mercury inputs. Mercury contents in spruce needles from 709 sites of the Austrian Bio-Indicator Grid are determined every year and include sites where mercury pollutions are higher than in the six Level II plots. Together, these data can give a rough idea in which range the mercury inputs into soil and water could be in such sites. The quick and easy analytical method (Altec-AMA 254) and the stored retain samples allowed for the evaluation of the impact of mercury emissions on contents in spruce needles before 2000 in 709 samples plots for each year for the first time. This analytical method is contamination-free and sensitive enough to determine even naturally occurring mercury concentrations in tree foliage. The intended poster presentation will include data of mercury contents from the non-polluted forest foliage of six Level II plots and mercury data of 709 sites of the Austrian Bio-Indicator Grid. The latter data showed that mercury contents in spruce needles from polluted areas were distinctly higher compared to materials from Level II.

Fluxes and stocks of nitrogen in the litterfall and soil in evergreen broadleaves and fir forests

ID: 123

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In this work, the nitrogen fluxes in litterfall as well as the stocks and available nitrogen in the soils of two experimental plots representing evergreen broadleaves and Bulgarian fir forests, respectively, were calculated. It was found that only the woody litterfall flux of nitrogen was significantly higher in the fir forest than that of the evergreen broadleaves one. The total nitrogen stock was higher in the soil under fir but the percentage of the available nitrogen (ammonium + nitrates) was significantly higher in the soil of the evergreen broadleaves up to the depth of 20 cm despite the non-significant difference of the C/N ratio in all soil layers. The microclimatc conditions (higher soil temperature in the soil of the evergreen broadleaves forest) is the most probable cause for that difference.

Identifying effects of climate conditions on foliar nutrition

ID: 128

Krüger, Inken; Schmitz, Andreas; Sanders, Tanja

Thünen Institute, Germany

Foliar nutrition depends on the nutrient availability and uptake capacities of the tree, which at a longer time scale are influenced by soils and deposition and at shorter time frames by temperature and precipitations. Taking climate conditions into consideration is thus important when interpreting data on foliar nutrition.

To identify the intra- and interannual effects of climate conditions, we used a moving-window approach on data collected by institutions of the German Federal States within the ICP Forest Level II network. Climate effects on nutrients (N, P, K, Ca, Mg) as well as foliar mass were analyzed for five temperate tree species (European beech, temperate oaks, Norway spruce, Scots pine).

N, P and K are generally less sensitive to climate variations than Mg and Ca. In beech, no significant effects on nutrient ratios were found, thus allowing their analyses without including climate conditions. For the other tree species, significant effects of current or lagged climate conditions were found for both nutrient ratios and concentrations. Still, they are generally less sensitive to climate conditions than nutrient contents and foliar mass. When opposing effects on nutrient concentration and foliar mass were found, effects on the corresponding nutrient content overwhelmingly follow similar patterns as the effects on foliar mass.

Short time periods (less than three months) are often more informative than means over several months. The best suited time periods to assess the favorability of a given sampling year depend on the tree species and nutrient.

Site types revisited: comparison of traditional Russian and Finnish classification systems for European Boreal forests

ID: 135

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Forest site type (ST) classifications are tools used in research, monitoring, and management. Ideally, they provide information on the properties of a forest site independent of its development stage and management history. In Finland, the Cajanderian (C) forest ST classification is based on the composition of understory (US) vegetation assuming that it reflects the site's productivity. In Russia, the Sukachevian (S) forest classification is similarly based on US vegetation but also accounts for tree species and soil wetness and paludification. The systems differ in the rules of their determination. Both systems are ca. 100 years old, thus the vegetation they were created to describe has been modified by multiple factors.

BioSoil vegetation and soil survey data from Finland and the respective data set from NW Russia enabled us to compare C and S systems in terms of the US community composition (that is supposed to define them), soil fertility and tree productivity (that they are supposed to indicate), and US biodiversity (that is of interest for conservation purposes). We create and employ models to classify forest sites into C and S types based on vegetation composition to enable their cross-comparisons.

Within both systems the STs form similar, meaningful gradients in terms of the studied variables. Certain STs from the two systems are largely overlapping in community composition and arranged similarly along a fertility gradient and may thus be considered comparable. The results aid information transfer between Finland and Russia in basic and applied ecological research.

Phosphorus leaching in beech forest soils as affected by fertilization and seasons

ID: 137

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Leaching represents a key pathway of phosphorus (P) depletion of forest ecosystems: However, the relative importance of influencing factors is largely unknown. Our aim was to quantify seasonal patterns of dissolved organic and inorganic P (DOP and DIP) and nitrogen (N) leaching in a P-poorer sandy soil and P-richer loamy beech forest soil and test their response to fertilization with N and P. Leachates were sampled by zero-tension lysimeters in surface soils during the four seasons. Although total soil P stocks differ five-fold between the two sites, results show only slightly higher P concentrations in leachates (~25%) at the site with greater P stocks, probably due to differences in organic horizon thickness and reactive mineral surfaces. Responses of P leaching to N x P fertilization depended also on the inherent soil P stock. While responses of DIP leaching to fertilization remained small at the P-richer site, it increased most strongly under N fertilization at the P-poorer site, which we relate to a removal of N-limitation of phosphatase activity in soils and to an increased degradation of soil organic matter.

Leaching shows pronounced seasonal patterns at both sites, with a three-fold higher P leaching in summer than in spring. The differences in leached total P during the year are mainly caused by varying PO43- concentrations, while DOP remains rather constant and did hardly differ between sites. Thus, DOP leaching is independent of fertilization treatments and seasons, supporting the theory that DOP is a byproduct of dissolved organic matter mobilization.

Comparison of soil profile in natural beech/mixed and managed spruce forests

ID: 139

Fadrhosnová, Věra; Novotný, Radek; Šrámek, Vít

Forestry and Game Management Research Institute, Czech Republic

The contribution is to evaluates elements concentration in soil profiles under natural beech or mixed stands comparing to managed spruce monocultures in two mountain regions of the Czech Republic.

Nature reserves with original old beech or mixed stands were selected by the nature conservation authorities and for these paired mature spruce stands were found in the neighborhood. The soil pits were dug at least to 80 cm depth and soil samples were taken from FH layer and from mineral soil (0–10 cm, 10–20 cm, 20–40 cm and 40–80 cm depth). The sampling procedure and laboratory analyses were performed according to the ICP Forests methodology.

The bedrock of both regions consists of gneiss, para-gneiss or granite, prevailing soil types are mostly dystric cambisols or podzols. It constitutes naturally poor and acid sites which were moreover loaded by acid deposition in the past. In general, no significant differences were found in pedochemical properties between beech and spruce stands. We have detected low or very low concentration of base cations, especially in exchangeable form. In some cases, soil profiles in beech stand have lower nutrition content and very low base saturation in the whole profile up to 80 cm depth in comparison with spruce stand. Differences were found in deeper part of soil, where slightly higher concentrations of base cations in spruce stands were found. Spruce has a shallow root system. This means it can usually uptakes nutrients from the depth 0–40 cm. Especially on acid and nutrient poor sites nutrients in deeper soil layers cannot be utilized in comparison with beech trees.

We can conclude, that nutritional level in studied areas is not favorable; even addition of base cations by weathering is rather limited – especially in case of calcium. On the other hand, nitrogen concentration in soil can be classified as good or high. This nutritional misbalance can negatively influence the health condition of trees.

Leaf morphological traits and leaf nutrient concentrations in European beech stands across a water availability gradient in ICP Forests Level II plots

ID: 148

Salehi, Maryam (1); Thimonier, Anne (1); Braun, Sabine (2); Potočić, Nenad (3); Vejpustková, Monika (4); Iacoban, Carmen (5); Meesenburg, Henning (6); Calatayud, Vicent (7); Pavlenda, Pavel (8); González, Rosario (9); Roskams, Peter (10); Canullo, Roberto (11); Raspe, Stephan (12); Krüger, Inken (13); Bertini, Giada (14); Andreetta, Anna (15); Vanguelova, Elena (16); De Cinti, Bruno (17); Waldner, Peter (1)

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Forest productivity is negatively affected by climate change, especially by severe drought. European beech (*Fagus sylvatica* L.) is one of the most important tree species in Europe, with a significant ecological role in sustainable forest management (Hlásny *et al.*, 2014) and a known sensitivity to drought (Van der Maaten, 2012). Here, we aim to investigate the response of morphological traits and nutrient concentrations in beech foliage to changes in water availability, deposition of nitrogen and soil properties, based on data from selected European beech stands in the ICP Forests Level II plots network (foliage chemistry, meteorology, soil chemistry, nitrogen deposition, leaf area index and crown condition surveys), complemented by gridded data (gap filling) and derived drought indices. First results show a general positive correlation between average leaf dry mass and mean annual temperature (MAT). With respect to the macronutrients, a positive correlation was found between foliar N concentration and mean annual precipitation (MAP), albeit a similar correlation was found for MAT. Further results on the relations between leaf nutrients and environmental factors (correlations and linear mixed effect regressions) will be presented.

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Long-term changes in leaf morphological traits of European beech and Norway spruce along multiple gradients in Switzerland

ID: 157

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Leaf morphological traits (LMT) of tree species have been observed to vary spatially across forest sites. However, longer-term records of LMT are often not easily available due to the missing measurements or systematic leaf archives. We thus lack an understanding on the temporal dynamics and drivers of LMT on tree and stand level. Here we make use of long-term LMT measurements and foliar material collections, which were performed within the Swiss Long-term Forest Ecosystem Research Program LWF from 1995 to 2019. The collection of leaves and needles followed the ICP Forests protocol for foliar chemistry and was conducted generally every second year. We focused on European beech (*Fagus sylvatica*) and Norway spruce (*Picea abies*) trees from 11 sites (with 6 beech, 4 spruce and 1 mixed stands). These sites are distributed along wide elevation (485 – 1650 m a.s.l.), precipitation (MAP 940 – 2146 mm) and temperature (MAT 3.2 – 9.8 °C) gradients. The selection of the sites was based on the prominence of the selected tree species and the amount of available measurements from the LWF network. The investigated LMT are i) needle or leaf mass, ii) needle length or leaf area, and iii) the ratios leaf mass per area or needle mass per length. The main aim of the study was to identify the temporal and spatial LMT drivers, including climate (e.g. drought indices, precipitation, temperature, vapor pressure deficit), physiology (via cellulose stable isotopes), leaf chemistry (e.g. micro- and macronutrients), and other stand factors such as fruit production (e.g. mast years) and crown transparency. This study will allow unique insights into LMT drivers and improve the interpretation of leaf functional traits responses to recent climatic changes across Europe.

Forest monitoring from the cloud – Soil water content case study

ID: 158

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While growing efforts have been invested in monitoring environmental changes impact on the forest ecosystems, anomalies increased in intensity and frequency. We are at the point of seeing them as one of the highest risks facing forests.

ICP initiative stands proof that intensive monitoring is key in providing insight into the state of the forest ecosystems. Covering all major forest types in Europe in support of a centralized analysis, we still ask: is it enough? We tried answering this question with a case study focusing on Soil Water Content (SWC) in Romanian Level II plots. As main drought indicator, remote sensing (RS) has previously facilitated the evaluation of SWC on large scale. Resulting products are often low resolution inapplicable in detailed studies.

Using Spectral Mixing Analysis by means of the data collections and processing tools implemented in EarthEngine (GEE), we reached sub-pixel values best fitting pure spectra. Definition of accurate classes led to the extraction of percentages in which water, vegetation and bare land combine to make each Digital Number (pixel value). RS values were matched to the in-situ measurements for all analyzed sample areas.

Converting percentages to concentrations, allowed us to take advantage of the high accuracy of field values as well as the high coverage of satellite imagery. The resulting SWC map is a product unattainable through field measurements alone, and can support the monitoring efforts in an unpredictable environmental context. Extending the study to Level I plots where we lack SWC measurements, can be a useful tool, especially in the light of the high automation capabilities that come with GEE.

The potential of throughfall measurements for the derivation of canopy attributes

ID: 170

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Canopy attributes such as Leaf Area Index (LAI) are highly sensitive and urgently needed parameters for water budget modelling, but they are still rarely available, even on plots with intensive throughfall monitoring. However, similar to differential light measurements above and below the canopy, differential precipitation measurements above (open field) and below a forest canopy (throughfall) are expected to be indicative for the canopy structure at that specific location. To test the potential of such observations for the derivation of canopy attributes, throughfall measurements on 17 Level II plots, each comprising 15 or more locations of throughfall collectors were evaluated in relation to canopy structure resulting from LAI measurement. Next to the bi-weekly collector values, the data also comprised high temporal resolution measurements of throughfall in the plot and of open field precipitation in a nearby clearing.

Gap fraction and LAI were measured with a LAI-2200 sensor in two spatial resolutions: The stand representative values for different opening angles were assessed along a grid of 16 observation points and additionally, local measurements were performed on top of each throughfall collector and repeated over several years. Next to canopy structure, the evaluation highlights ways to use throughfall data for the derivation of interception parameters for the water budget model LWF-Brook90.

Trends and fluxes of soil solution chemistry focusing on nitrate leaching responses to air pollution in Italian forest soils

ID: 175

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Acidification is a natural soil formation process; however, atmospheric emissions of nitrogen and sulphur have exposed forest ecosystems to accelerated anthropogenic acidification for many decades. Since the 1990s, emission reduction has been followed by the decline of related soil deposition. Despite the positive effect of nitrogen deposition on tree growth, and consequently on organic carbon sequestration, the accumulation of nitrogen in the ecosystem could cause nutrient imbalances for plants and contribute to soil acidification. We aimed to investigate within the CONECOFOR (the Italian ICP Forests) sites, temporal changes of atmospheric deposition and soil solution concentration. We, further, applied simple input-output models, in order to evaluate the capabilities of the soil-forest system to retain nitrogen deposition and thus protect underground waters. The positive effect of sulphate deposition decrease was observed with a concomitant high and stable natural exchangeable base (BCE) deposition in most of the sites. However, high levels of nitrogen deposition prevent soil recovery from acidification in the sites around the Po plain. Generally, the retention of nitrogen deposition in the soil-forest system was effective since the observed nitrate fluxes in mineral soil were strongly reduced compared to N input. Nevertheless, significant nitrate fluxes from the subsoil were observed not only in sites with particularly high deposition, but also in the southernmost site which has been exposed to relative low mineral N loads. Drivers other than pollution should be considered as likely causes of nitrogen leaching, and different nitrogen retention efficiency could be also ascribed to differences in forest age and activity.

Ground-level ozone and nitrogen deposition in the Czech Republic: assessment of long-time trends and spatial changes

ID: 176

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Apart from the recently extensively discussed ongoing climate change, ground-level ozone exposure and nitrogen atmospheric deposition remain among the main abiotic threats for ecosystems in rural areas. The aim of our contribution is to present a summarizing assessment of ground-level ozone exposure and nitrogen deposition over the Czech Republic. The long-term trends and changes in spatial patterns for sites representing different environments, geographical regions and altitudes are revealed. Furthermore, the areas under the highest pressure due to high ozone and nitrogen loads in Czech forests are indicated. For our analysis we use data from nation-wide monitoring network measured by CHMI. An increase in daily mean O_3 concentrations is apparent at all sites from 2014 onwards. In parallel with the O_3 changes over the years, the deformation of seasonality profiles over a long period of time occurs, resulting in a shift of the peak O_3 concentrations towards later days in the year. The above is evident at all sites though to a different extent, with the maximum shift of one month over the period of 23 years. This shift is most pronounced for mountain sites, whereas it is much smaller for urban sites.

Assessing the risk of elevated nitrate leaching from Swiss forests

ID: 180

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Water percolating from forests soil is an important source of drinking water. However, excess atmospheric deposition of plant available nitrogen (N) can result in elevated leaching of nitrate impairing the quality of drinking water. In this study, we used chemical analyses were carried out for samples of soil and soil solution and of foliage collected on 68 intensive long-term forests monitoring plots of the Swiss Inter-Cantonal plot network (IAP) and of the ICP Forests Level II plot network in Switzerland, Belgium, France, Denmark, Germany, Italy, and Ireland. Nitrogen leaching was calculated by multiplying mineral N concentrations in soil solution with water fluxes derived from hydrological models. The resulting N leaching fluxes spanned more than a factor 100 and were related to potential N saturation indicators mapped for Swiss forests. The elaborated multivariate regression model to estimate N leaching (R^2=0.42) included as the main drivers N deposition, precipitation, and indicators for N availability and soil deepness of a Swiss soil map. The uncertainty of the prediction was estimated to be about a factor 3 (at 95% significance level). A higher risk for elevated N leaching was estimated for parts of the Central Plateau, the Jura and Southern Alps region of Switzerland. The estimates compared well to N concentrations determined for 61 groundwater sampling sites in forested catchments. The method allows the creation of overview maps showing the areas that potentially have a high or low risk for elevated nitrate leaching.

The effect of ozone and nitrogen deposition on the vitality of Fagus sylvatica and Picea abies in Switzerland

ID: 199

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The intercantonal long term forest observation in Switzerland has been initiated in 1984. Currently 6268 European beeches in 98 plots and 4762 Norway spruces in 77 plots are observed (Braun *et al.*, 2018). The plots cover gradients of soil properties, drought, stand age as well as nitrogen (N) deposition and ozone. The latter were mapped in spatial resolutions of 0.01 or 0.0625 km2 and at time resolutions of 5 or 1 years, respectively (Braun *et al.*, 2014).

Ozone flux (Phytotoxic Ozone Dose, POD1) was negatively correlated with stem volume increment of beech and Norway spruce. In beech the regression confirmed the dose- response curve derived from experiments (Mills *et al.*, 2018), in Norway spruce the relation derived from epidemiology was steeper. High July temperatures (Norway spruce) or high fructification (beech) increased the slope of the regression.

Stem volume increment increased with N deposition up to a maximum at 25 (beech) or 30 kg N ha^{-1} yr^{-1} (Norway spruce). At high N deposition the effect of drought on beech stem increment was increased. In Norway spruce high N deposition increased the mortality by bark beetles strongly alone and in combination with drought. Low foliar K concentrations were related with increased mortality in both beech and Norway spruce, low foliar P with increased mortality in beech. This represents an indirect effect of N deposition as foliar K is negatively related with N deposition.

Long-term monitoring of forest ecosystems of the taiga zone of European Russia

ID: 201

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The aim is to study the trends and causes of changes in the soil and vegetation cover of forest ecosystems in the taiga zone over the past 200 years. Objects of research: polygons of soil-ecological monitoring of the Lisino educational and experimental forest area of the Leningrad region (Russia). The forest area is characterized by typical for the taiga zone pine and spruce forests, as well as soils. The materials of the field trip for the participants of the II International Congress of Soil Scientists (1930) formed the basis for the assessment of changes. At that time 7 soil sections under the forest vegetation of different composition, bonitet, and age were laid. Eighty years later, new pits were laid in their place and a description of the vegetation cover was made. The availability of initial information on the state of forest ecosystems at the beginning of the XIX century and the study records of 1930 and 2012 provided an opportunity to identify trends in the development of the soil-forming process. Analysis of meteorological data over a 150-year period showed that air temperature and precipitation fluctuated within the climatic norm during this period. Soil changes are associated with drainage reclamation and vegetation succession.

Polygons with an area of 2 ha were allocated around the investigated sections in order to conduct soil-vegetation monitoring. Large-scale soil and relief maps (Scale 1:500) were created, and the vegetation cover was described. Substantiation was provided for the designation of the Lisino Biosphere Polygon for monitoring forest ecosystems of the taiga zone.

Tree health and annual and periodical radial growth in coniferous trees in northern Italy

ID: 204

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With the 2018 megadrought causing widespread canopy damage to forests in central Europe, the question whether this can result in reduced tree and forest growth became of renewed interest. Such a question has clear relevance for the functional interpretation of forest health data as collected in Europe since the 1980s and in the climate change debate. For instance, Rohner *et al.* (2021) showed that drought-induced defoliation and leaf browning are associated with lower growth- and carbon sequestration rates.

Here we investigated relationships between tree health indicators (crown defoliation, damage) on annual (measured by tree-ring width on 69 Norway spruce trees) and periodical (expressed in terms of 5-10 years Basal Area Increment for 346 trees from five coniferous species) tree growth. Data originated from seven ICP Forests Level I plots and one Level II plot in Trentino, northern Italy. Diameter, defoliation and damage data were collected between 1997 and 2011 as part of the annual crown condition survey carried out by the local forest service. Two cores per tree were collected from haphazardly selected dominant trees at each monitoring plot in 2012.

Our first results involving within tree means of log ring width and square root defoliation indicated a slight negative correlation (-0.26). We also fitted simple linear models to single tree data and obtained plot level estimates of slope parameters. Bootstrap analysis of these estimates also confirmed a significant negative association between defoliation and ring width.

We will further investigate possible generalized relationships between tree health and growth in various time windows (annual, 5 or 10 years), across different species, site factors and defoliation level.

Deposition properties in 18 Level II forest monitoring sites in Turkey

ID: 208

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Hydrogeochemical characteristics of water and in relation to that, deposition, affects the porosity and texture of the soil; and characteristics of water and soil directly affect the plants. Some elements may be toxic to the plants if they are abundant, on the other hand if there is not enough elements, they may limit the development of the plant.

In Turkey, annually 477 deposition samples from 15 Level II Forest Monitoring Sites were collected in 2017, and from 18 Level II Forest Monitoring Sites in 2018, 2019 and 2020; the pH, conductivity, alkalinity and amount of elements were measured. Annual average of pH was 6.59 in 2017 which was the highest annual average of the 4 years. Each year the mean was below 7, so the water was acidic, and it was within the limit values. Annual average of conductivity was measured as 74.14 in 2020, which is 54% increase when compared to previous year and is the highest value of the 4 years.

Alkalinity annual averages increased each year; from 2017 to 2020 it increased 242% (from 138.41 μeq/L to 472.43 μeq/L). The highest annual average value among cations was Calcium. All the elements that were measured; K, Ca, Mg, Na, N-NH_4, Cl, N-NO_3, S-SO_4, N and dissolved organic C (mg/L) were within limit values, although there were fluctuations in values, the annual averages increased from 2017 to 2020.

Evaluation of air temperature and precipitation values in Turkey

ID: 209

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Vegetation season starts depending on air temperature and precipitation, and the optimum temperatures for vegetation season changes depending on the location. Although plants in different locations demand different precipitation amounts, precipitation generally has a positive effect on vegetation. Nowadays, the effects of climate change on precipitation and temperature trends can be seen evidently, it is of the utmost importance to monitor the temperature and precipitation values to understand their effects on vegetation and to manage the forests accordingly.

Turkey is monitoring meteorology data in 52 Level II Forest Monitoring Sites. In these sites, there are 50 automatic meteorology stations. The air temperatures are measured daily and the annual averages are as follows: 10.55°C in 2015, 10.48°C in 2015, 5.34°C in 2016, 11.44°C in 2017, 12.52°C in 2018, 11.90°C in 2019, 11.84°C in 2020. Except the decrease in 2016, the air temperature showed an increasing trend until 2018, and decreased slightly in 2019 and 2020. The precipitation values measured in the same locations were as follows: 1.88 mm in 2014, 2.08 mm in 2015, 1.36 mm in 2016, 1.75 mm in 2017, 5.30 mm in 2018, 2.17 mm in 2019. In 2016, the precipitation value decreased, and in 2014, 2015, 2017 and 2019 the values were close to each other. The highest annual precipitation value was in 2018 (5.30 mm).

Assessment of air pollutants at Level II forest monitoring sites in Turkey

ID: 210

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Air pollution has direct toxic effects on plants; it also affects plant health indirectly by changing pH and solutes in the soil. The particles causing the pollution might block the stomata and prevent light and air diffusion. On the other hand, some materials might pass through the stomata and cause toxic effects. Both these events cause a drop in photosynthesis rates. Photosynthesis plays a big role in preventing climate change by decreasing atmospheric CO_2 and other greenhouse gases. Around 3000 materials that are not a natural part of the atmosphere are released and causing air pollution.

In Turkey, air quality assessments were performed in 18 Level II Forest Monitoring Sites between 2017 and 2020. During these assessments, the amount of NH3 (causes necrosis and drying of plant tissue), NO_2 (causes needle blight in conifers and chlorosis in broadleaves), SO_2 (causes color change in leaves, leaf loss) and O_3 (causes color change in leaves, necrosis) were measured in 2017 (between August-December), 2018 (between January-December), 2019 (between April-December) and 2020 (between April- December). Annual averages of the results for these years were; for NH_3 3.98, 5.66, 4.39, 4.91; for NO_2 4.45, 3.29, 3.13, 3.49; for SO_2 3.22, 2.22, 2.34, 2.61 $\mu g/m^3$, respectively. The measurements for O_3 were fluctuating and time to time they were above limit values (Black Sea Region and Mediterranean Region). The other values were within the limit values. The highest annual average for O_3 was measured in 2017, and there was a 28.46% increase in annual average of O_3 from 2017 to 2020.

Session 2:

The Exchange – Methodologies and models within ICP Forests and beyond

Oral presentations

Responses of Swiss forests to long- and short-term environmental changes

ID: 182

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Forests play an important role in global biosphere-atmosphere gas exchange, affect and are affected by climate change. Thus, responses of CO_2 and H_2O vapor fluxes of forests to long- and short-term environmental changes such as global heating and extreme events, respectively, are crucial to understand their vulnerability in the future.

Within the Swiss FluxNet, net ecosystem fluxes of two forests have been measured with the eddy covariance technique at the Lägeren (mixed deciduous forest dominated by beech) since 2004 and at Davos-Seehornwald (subalpine evergreen forest dominated by spruce) since 1997, making the latter one of the oldest ecosystem flux sites globally. The Davos site is also a Class 1 Ecosystem Station within ICOS RI. Both sites serve as research platforms, adding further measurements, e.g. from the Swiss TreeNet.

Both forests have been carbon sinks ever since measurements started, despite large climatic variations, except for 2018 when the Davos forest turned almost C-neutral for the first time. Stem diameter measurements supported this observation. Over the last 100 years, water-use efficiency (WUE) increased for both forests, driven by climate, CO2 concentrations and N deposition. In the short-term, both forests acclimated fast by increasing their WUE in response to spring droughts (2011, 2018). But during the summer drought in 2018, only the Davos forest increased its WUE compared to previous years. Without long-term, high-quality, complementary measurements, such changes in forest responses to environmental change would be undetected and not understood.

The Dimensions of the Phosphorus status of European beech forest ecosystems

ID: 217

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Decreasing phosphorus (P) concentrations in leaves of European beech have been observed recently (Talkner *et al.* 2015). In turn, beech forests showed great plasticity of P mobilization by trees and microorganisms, and of internal allocation, storage, and resorption of P. This challenges the use of indicators for the P nutritional status. During the last seven years, the DFG research programme Ecosystem Nutrition (SPP 1685) explored the P nutrition of beech forests and their adaptation to low P supply. Here, we provide a synthesis of detailed analyses of beech forests at five silicate and three carbonate sites, as well as from N×P forest fertilization and greenhouse experiments.

We suggest to employ three dimensions to characterize the P status of forest ecosystems: The P-status of trees, soil microorganisms, and soils. Adult beech trees sustain sufficient P in leaves over a wide range of soil P, while P of stem wood, bark, or fine roots and of saplings is more responsive. The C:P stoichiometry of microbial biomass is a good indicator of P supply to microorganism. Also, changing soil P supply affects composition and functionality of microbial communities. These plant and microbial traits are related to the vertical distribution of P in soils, the forest floor turnover and the temperature-dependent P mobilization. Leaching of P from forest floor correlates positively with soil P stocks, indicating that P is more strongly recycled and retained in P-poor systems. Based on our synthesis, we introduce a new, three- dimensional approach to assess the P status of beech forests.

Ectomycorrhizal fungal communities and functional genes drive forest productivity across the ICP Forest Network

ID: 191

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Ectomycorrhizal fungi are central members of the forest fungal community, forming symbiosis with most trees in temperate and boreal forests and enhancing plant access to limiting soil nutrients. Decades of greenhouse studies have shown that tree seedlings acquire more nitrogen and grow faster in combination with specific ectomycorrhizal fungi, but whether fungal effects observed between tree seedlings and individual ectomycorrhizal fungi scale up to affect the growth of mature trees and entire forests harboring diverse fungal communities remains unknown. In this study, we combined a continental set of forest inventory data from the ICP Forest network with molecular ectomycorrhizal fungal community surveys to identify potential fungal mediated effects on forest productivity and paired this alongside a tree growth response to microbiome manipulation study conducted under controlled conditions. We found that ectomycorrhizal fungal community composition was a key predictor of tree growth, and this effect was robust to statistically accounting for other well-known drivers of tree growth. We also found higher ectomycorrhizal fungal energy production and inorganic nitrogen metabolism but lower organic nitrogen acquisition enzyme encoding gene proportions in fast versus slow growing forests. Lastly, we sampled soils from fast and slow growing forests and introduced their microbiomes into a sterilized growth medium to experimentally isolate microbiome effects on tree development. Consistent with our observational analysis, tree seedling growth was accelerated in tandem with microbiomes from fast growing compared to slow growing forests and was correlated with ectomycorrhizal community composition. By linking molecular community surveys and long-term forest inventory data in the field and pairing this with a microbiome manipulation study under controlled conditions, this work demonstrates an emerging link between the forest microbiome and forest productivity.

The water budget of forests – the big unknown outside of our intensive monitoring plots?

ID: 132

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The water budget is a crucial site factor for forest health, which has so far been assessed and mapped locally by forest site mappers. In the course of climate change, however, it can be assumed that the existing static methods of forest site mapping will reach their limits when it comes to realistically characterizing the increasing dynamics of acute drought stress as well as long-term changes in the plant-available soil water.

In the presentation, simulations of the site water budget for various ICP Forests Level II plots are presented and the transferability of the model to unobserved areas is discussed. The water budget model used, LWF-Brook90, enables a differentiated representation of the vegetation and the soil water flows through a variety of model parameters. For the model application on unobserved sites, however, this means that many model parameters have to be approximated or derived using transfer functions.

Using exemplary ICP Forests Level II plots with measured data on the site water balance, sensitivity analyses were used to determine which parameters have a particularly strong influence on the model output. It was also examined to what extent target functions for model calibration, that go beyond the classic fitting of modeled to measured time series (e.g. hydrological signatures, fuzzy rules), can reduce the model uncertainty and improve the model application in unobserved areas.

Linking in situ measurements with remote sensing in Level I and II ICP Forests network in Romania: Prototyping a national forest monitoring system

ID: 178

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Long term monitoring networks like ICP Forests, provide a wide range of in situ measurements, collected in a standardized way, that can be used to meet the information requirements of different user categories. In the view of the new technological developments, it is recommended that remote sensing techniques to complement long-term monitoring programmes (Parr *et al.*, 2001).

In the framework of EO-ROFORMON (http://eo-roformon.ro/) project, we will define the requirements for a national forest monitoring system based on Earth Observation and in situ data. The forest monitoring system will allow the retrieval of an organized time series of measurements for defined biological variables designed to provide defensible answers to questions about forest status and changes. The monitoring system would provide the basis for informed decision making (policies and socio-economic) in forest resource management. A case study analysis for the definition of a national forest monitoring system will be carried out based on the corpus of knowledge developed in EO-ROFORMON and the ICP Forests monitoring network. The synergy between the information provided by the transnational ICP-Forest network and the use of EO data will be considered. The objectives and information content provided by such a monitoring system will be defined in coordination with relevant stakeholders. The system will be designed to incorporate existing and future EO systems, particularly the ESA long-term missions focused on operational monitoring.

Canopy and growth response of beech trees after the 2018 drought in Switzerland

ID: 142

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Changes in hydrological cycles and temperature regimes will affect forest health and growth, and therefore their role in C sequestration. A severe spring-summer drought hit central Europe in 2018 leading locally to premature leaf senescence. In late summer 2018 and 2019, we inspected 75 plots of the Swiss National Forest Inventory to detect how beech trees responded to the drought, and to evaluate possible lasting effects in the subsequent year. In 2018, we observed a frequency of beech trees affected by severe leaf browning (SLB) and severe crown transparency (SCT) significantly higher than in existing long-term baseline data. The most significant predictors of the occurrence of SLB and SCT were previous growth, species composition, tree size and precipitation deficit. Overall, basal area increment (BAI) was significantly lower in 2018 compared to the 2009–2017 average. Trees with SLB and SCT grew significantly less than unaffected trees, with the median C increment having been 40–100% lower. Canopy condition and growth largely recovered after favorable climate conditions in 2019, with almost no instances of SLB, and SCT comparable to long-term baseline data. BAI in 2019 was significantly higher than in 2018 and 2009–2017, and weakly related to the crown condition in 2018. We conclude that the 2018 drought caused rapid canopy deterioration of beech in northern Switzerland associated with immediate reductions in tree growth and tree-level C sequestration. These effects were mainly temporary, and most of the investigated trees recovered their crown status and growth in 2019.

Continuous approximation of leaf area index and phenological phases within deciduous forests based on temperature measurements

ID: 196

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This study presents a novel method to characterize the Leaf-Area-Index (LAI). For this purpose, we used temperature measurements conducted as part of the ICP Forests programme at the Level II monitoring station in Klausen Leopoldsdorf (Lower Austria) in the years 2011–2017. Additionally, temperature measurements from a nearby open land station were utilized. The Level II plot is located at an altitude of 510 m a.s.l. and characterized by European beech with an age of about 80 years.

Since the tree crown greatly affect the local radiation conditions, we focused on the difference in daily maximum temperature between the forest and the open land station: DMAX=TMAX_ZAMG-TMAX stand. DMAX was standardized and compared to standardized LAI values obtained from hemispheric photographs. These photos were conducted once a year at 16 different photographic points throughout the Level II plot and thus in immediate vicinity of the temperature sensor. We determine a significant high correlation of 0.9 between LAI measures and DMAX. Furthermore, when examining the average course of the year for DMAX we were able to identify phenological phases such as leaf unfolding, the end of leaf growth as well as the begin and end of defoliation. These phases were also verified by phenological observations.

Our analysis suggests that the impact of forests on their site climate can be used to identify phenological features and allows for continuous estimates of the leaf area index.

Long-term irrigation in a drought-stressed pine forest accelerates carbon cycling and leads to vertical redistribution of soil organic carbon pools

ID: 167

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Severe summer droughts have led to increased mortality of pine trees in inner-Alpine valleys since the 1990s. Drought limits the metabolic activity and hence C cycling in the plant and soil system. However, the net effect on SOC is unclear, as drought affects both C inputs and outputs.

We aimed to examine how long-term irrigation affects soil C cycling and SOC pools in a large-scale experiment running since 2003 in a water-limited pine forest in Switzerland. We assessed soil respiration and rates of C turnover by laboratory incubation and foliar mass loss in litterbags, as well as microbial diversity and soil C stocks.

The decadal-long irrigation stimulated ecosystem productivity with increased litter fall and fine root biomass (+50% and +40%, respectively). Soil CO_2 efflux increased under irrigation, as well as C-mineralization and litter decomposition by soil macrofauna, coupled with shifts in the soil microbiome from oligotrophic to copiotrophic lifestyles. Water addition did not affect total SOC stocks, but resulted in a C loss in the organic layers (-900 g C m^{-2}) and a C gain in the mineral soil (+970 g C m^{-2}). This vertical SOC redistribution may be due to increased: 1) litter mineralization and belowground C inputs, 2) fauna-mediated incorporation of litter, microbial processing of litter-derived C. This study sheds light on belowground C dynamics of forest ecosystems under drought. Long-term irrigation in a drought-prone forest altered C fluxes, the belowground community and the vertical SOC distribution. However, the net effect on SOC stocks was negligible due to a balancing out of C inputs and outputs.

Where does the water come from? Variations in soil water uptake depth in a beech forest during the 2018 drought

ID: 120

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Reduced water availability is the most critical driver for tree mortality and impairment of trees' functions. High uncertainty still exists regarding the ecohydrological belowground interactions at the soil – root interface on short to seasonal time scales.

We carried out high-resolution in situ observations of stable isotopes in soil and xylem water to track the water uptake of beech trees in the hot and dry summer 2018. We set up a laser isotope system to continuously probe the $\delta^{18}O$ signature in the water vapor being in equilibrium with the soil water at different soil depths and in the xylem of beech trees in a forest in Switzerland and applied a Bayesian isotope mixing model (BIMM) to resolve the origin of the water taken up.

Mid of June the drought period started with extended phases of high temperature and only infrequent precipitation. At the same time, soil water content decreased in the upper soil layers and transpiration as well as radial growth started to decline, and this pattern became more pronounced until the end of August. In the soil water, a strong ^{18}O enrichment in the upper 5 cm and a slighter enrichment in 15 cm developed during this period. The BIMM results indicated that tree xylem water was made up by > 80% of shallow soil water (0–15 cm) at the onset of the drought and that this contribution continuously dropped to < 20% by the end of August, when deeper soil water and groundwater became more important. End of August, intensive rainfall events terminated the drought period when shallow soil water pools became partially replenished, and transpiration increased again. Within days, the contribution of shallow soil water to tree xylem water increased and reached a share of > 70% a couple of weeks later. With this in situ method applied, real-time information of the plasticity of soil water use becomes available and we can trace the effect of drought and drought release on root activity of trees in different soil depths.

Session 2:

The Exchange – Methodologies and models within ICP Forests and beyond

Poster presentations

Trade-offs between ecosystem service provision and the predisposition to disturbances: a NFI-based scenario analysis

ID: 106

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Scenario analyses that evaluate management effects on long-term forest ecosystem service provision (ES) also need to account for disturbances. We aimed at revealing trade-offs and synergies between ES and disturbance predisposition (DP) at the scale of a whole country.

The scenario model MASSIMO was used to simulate forest development for years 2016-2106 on 5086 sample plots of the Swiss National Forest Inventory (NFI) under 5 management scenarios. Model output was evaluated with indicators for 1) the ES a) timber production, b) old-growth forest proxies and c) protection from rockfall and avalanches and 2) for a) storm and b) bark beetle DP.

The DP indicators corresponded well (AUC: 0.71–0.86) to storm and beetle damage observations in logistic regression models. Increased timber production was generally accompanied with decreased DP (storm: >−11%, beetle: >−37%), except if conifers were promoted. Decreased DP and old-growth indicators in scenarios of increased timber production revealed a trade-off. Growing stock increased under business-as- usual management along with a reduction in conifer proportion, resulting in a reduction of beetle DP accompanied by increasing old-growth. DP was elevated in NFI plots with high avalanche and rockfall protection.

By evaluating ESB and DP based on single-tree data at a national scale we bridged a gap between stand- and national-scale assessments. We advocate for future amendments that include climate-sensitive forest development and disturbance modelling to strengthen decision making in national forest policy making.

Assessment of land use change on environmental security

ID: 126

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Ecological security as the guarantee for accomplishing sustainable development has become an important research topic because of serious ecological degradation and environmental pollution in the Middle Volga region. The ecological security can be affected by natural factors, such as global climate change and natural disasters, human activities, and land use change. Land use change can directly transform wide landscapes, impact on the biodiversity and eco-productivity. The main objective of this research is assessment of land use change in the Middle Volga region of the Russian Federation ground-based observations and geospatial technologies. A method for assessing the environmental security of the territory is developed and tested using spatial and temporal data obtained from Landsat satellites and ground surveys over the past 20 years. The work used modern methods of situational modeling of environmental security assessment based on numerous criteria, including land use change. Spatio- temporal analysis of the dynamics of climatic features of the studied territory over a long period will allow identifying trends in the effects of changes on the land cover and identify the main factors contributing to the restoration (improvement) of environmental security. The study proposes to use methods of spatial and temporal differentiation of vegetation cover, as well as simulation scenarios in accordance with the goals of socio- economic development of region.

The reported study was funded by RFBR, project number 19-55-80010\19.

Monitoring forest carbon exchange in complex terrain

ID: 130

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Concurrent below (0.14 • canopy height) and above canopy sonic anemometer vertical velocity (w) measurements reveal frequent decoupling events between the air masses below and above the canopy at a dense spruce forest stand in mountainous terrain.

Several single-level approaches based on steady state and integral turbulence characteristic tests as well as u* filtering and two-level CO2 flux filtering methods are tested. These tests aimed at evaluating the filtering schemes to address decoupling and its effect on above canopy derived eddy covariance CO2 fluxes. Two new filtering methods are introduced based on w raw data below and above the canopy. One is a telegraphic approximation agreement, which assumes coupling when w both above and below canopy are pointing in the same direction. Another one evaluates the cross correlation maximum between below and above canopy w data. This study suggests that none of the single-level approaches can detect decoupling when compared to two-level filtering approaches. We tested the correlation of the newly introduced filtering approaches with the parameters u*, global radiation, buoyancy forcing across the canopy and wind shear across the canopy. In any case, this correlation was not existing or weakly positive, suggesting that concurrent below and above canopy measurements are mandatory for addressing decoupling sufficiently. Sonic anemometer measurements near the forest floor and above the canopy are sufficient to apply the new procedures and can be implemented in a routine manner at any forest site globally.

Assessing biodiversity from space: Functional diversity across spatial scales and optical sensors

ID: 134

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The increasing need for continuous global information on the biodiversity of Earth's forests calls for new approaches using satellite data. Functional diversity from functional traits, which can be derived from remotely sensed data, is linked to ecosystem functioning and stability. We transferred existing methods to map functional diversity based on airborne imaging spectroscopy (APEX) in a temperate forest ecosystem in Switzerland to multispectral satellite data (Sentinel 2). We selected three physiological traits related to forest health, stress, and potential productivity, namely chlorophyll, carotenoid, and water content and applied corresponding indices to Sentinel-2 and APEX data. We observed changes at different spatial and spectral resolution in two functional diversity metrics, namely richness and divergence (Schneider *et al.*, 2017). We reproduced observations of diversity patterns at the spectral resolution of Sentinel-2. Furthermore, both diversity metrics allow for qualitative comparisons across different spatial resolutions. The diversity patterns based on the different sensors with the same spatial and spectral resolution allow the same interpretation, as the altered results originate in the scaling, rather than the sensor specifications. The next steps include the analysis of the approach at larger extents and in inter- and intra-annual time-series. This will allow assessment of functional diversity at the continental to global scale exploiting the full potential of satellites.

Bridging forest inventories to improve international reporting on biodiversity

ID: 149

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National forest inventories (NFIs) significantly contribute to monitoring forest biodiversity worldwide. However, international reporting and comparisons of biodiversity information derived from NFIs are complicated by inconsistent sampling designs. Building upon species-area relationships, we analyzed how different sample plot areas affect the reporting of tree species richness and developed a method to improve international comparisons by minimizing biases from different plot areas. The latter is achieved by accounting for environmental heterogeneity effects in fitting power-law species-area relationships based on aggregating independent NFI plots by random sampling. This allows predicting the expected species richness for a standardized plot area, thus serving as bridge-building between different NFIs. Preliminary results suggest that the reporting of tree species richness may be significantly affected by plot area, stressing the need to develop methods to make international comparisons more reliable. Using Swiss NFI data we have successfully calibrated and validated our bridge-building approach and are now incorporating data from other countries' NFIs to further refine and spatially extend our approach. This work is expected to improve international reporting and monitoring of the status and trend of forest diversity. Our approach not only is applicable to other area-dependent count data within NFIs, but could also enable cross-comparisons of national inventories dedicated to monitor diversity.

Canopy nitrogen fertilization of two Italian temperate mountain forests: an isotopic approach to quantify the fate of atmospheric nitrogen depositions

ID: 152

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Nitrogen (N) is considered the main limiting factor of net primary productivity in many temperate forests. The human acceleration of the N cycle could alleviate this limitation, thus stimulating carbon (C) sequestration. Several ^{15}N isotope trace experiments in temperate forest suggest modest C sequestration as little additional N is assimilated by trees; however, in most of these experiments the tracer has been added directly to the forest floor, neglecting the potential N uptake by the forest canopy. To understand if the fate of N is influenced by forest canopy processes, we are conducting two parallel experiments in two different forests stands (*Quercus petraea* and *Fagus sylvatica*), where 20 kg N ha^{-1} y^{-1} are applied above (NAB) or below (NBL) the canopy layer, using NH_4NO_3 with a known ^{15}N isotopic signature. We hypothesize that: i) the N uptake by trees is higher in the NAB than in the NBL treatment and ii) forest growth rate is affected by the type of treatment. The experimental sites are periodically sampled for all their components to determine the total N content and its isotopic signature. This will permit to calculate the recovery of N-fertilizer in tree tissues, soil and leaching-water, allowing us to understand how N allocation diverges under these two fertilization strategies. Tree growth is monitored with band dendrometer, read every year during dormant season. Preliminary results of recovery and forest growth rates will be shown.

High frequency stable isotope signals as proxy for physiological responses to climate – Dual isotope approach at a European scale

ID: 155

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Picea abies and *Fagus sylvatica*, are two of the most important tree species in Europe, and their responses to climate are being extensively investigated especially at the limits of their distribution. However, their physiology at temperate sites is not yet fully understood. In a European tree-ring network, 10 sites sampled throughout Central Europe. Tree-ring width and stable isotope chronologies (C and O) were used as indicators of physiological performance under different environments. The year-to-year variability of the isotope time series for the last 100 years was analyzed in relation to tree-ring growth, spatial distribution, and seasonal climate.

Climate sensitivity of radial growth of both species was rather variable and site-dependent and strongest at the driest sites. Variability in the isotopic ratios consistently responded to summer climate, particularly to VPD. The high $\delta^{18}O$ coherence of the short-term variability between sites and species highlights the strength of the environmental signal in the O chronology also across large distances. On the contrary, $\delta^{13}C$ shows lower correlations between sites and species, showing a stronger site- dependency, and a lower intra-annual variability. The generally positive correlation between the year-to-year differences in $\delta^{13}C$ and $\delta^{18}O$ across most sites demonstrates the strong role of stomatal conductance in controlling leaf gas exchange for these species. However, in the last decades, sites showed a different shift in the isotopes relationships, with the warmer sites showing an increase of both $\delta^{13}C$ and $\delta^{18}O$ and consequent decrease of photosynthetic rates and stomatal conductance at warmer sites, and their dependency on atmospheric moisture demand and soil water availability.

Understanding the underlying physiological mechanisms controlling the short-term variation in tree-ring records will help with defining the performance of these ecologically and economically important tree species under future climate conditions.

Design-based improvements in change estimation for the Swiss National Forest Inventory through integration with external monitoring networks and data sources

ID: 171

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Swiss Federal Research Institute WSL

Model-assisted estimation is frequently applied in forest inventories. However, the performance of the estimators depends on identifying groups of auxiliary variables that when included together correlate well with the target variable. In order to gain insight to how variables from external sources such as ICP Forests potentially interact, we present a case study where 50 auxiliary variables organized into five categories (spatial, topographical, vegetation height model (VHM), satellite imagery and variables identified by the Swiss Long-Term Forest Ecosystem Research) are used in a model-assisted framework for change estimation in the Swiss National Forest Inventory. All combinations of categories are passed through a variable selection algorithm and their precisions are assessed. An estimator that combines plots from external sources derived from either purposive or probabilistic sampling is also presented. The results show that (i) each individual category can provide a moderate increase in precision of 9% to 17% reduction in estimated variance, (ii) there are diminishing returns in precision as more auxiliary information is included, and (iii) the most substantial increases of 26% to 32% occur when including multiple categories together. Satellite imagery and VHM showed the highest potential for variance reduction, whereas nitrogen deposition and climate tended to have diminishing returns when combined with imagery or VHM, probably because of multicollinearity. We observed that, once limitation due to the availability of certain auxiliary variables is removed, the magnitude of the precision can augment considerably.

14-years of tree-growth monitoring along a 1400 m elevation transect in the Lötschental

ID: 172

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Since 2007, the WSL Dendrosciences group is monitoring intra-annual growth variations on more than 40 mature larch and spruce trees along a elevation transect (800 – 2200m asl) in a central Alpine valley (Lötschental) in Switzerland. Such gradient offers the valuable and unique opportunity to study high-resolved tree growth-related processes under different temperature levels but at comparable environmental conditions.

The strength of this setting is the length of the continuous weekly micro-coring. These unique observations add the opportunity to not only investigate high-resolved tree physiological processes (as assessed with sapflow sensors and dendrometers), but also to link the environment (e.g.; temperature, relative humidity, soil moisture and water potential) to the activity of the cambium and to its final product, i.e. the tracheid morphology and the tree-ring structure.

The poster aims i) at presenting the study settings and ii) at showing its potential for transdisciplinary studies linking a large range of high-resolved site and physiological measurements to significant ecological processes, from cell formation to global biochemical cycles.

Architectural requirements for forest monitoring data integration in EnviDat

ID: 173

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EnviDat is the environmental data portal of the Swiss Federal Research Institute WSL. It focuses on the publication of research data and facilitates the access to WSL's wealth of long-term monitoring data from a wide range of environmental topics, including data from forest research and related fields.

EnviDat is actively developing its capabilities for integrating monitoring data, starting with the integration of data coming from the Greenland Climate Network (GC-Net) automated weather stations. In the process of defining the software architecture needed for the integration of real-time monitoring data in EnviDat, we have identified a number of core architectural requirements: a) data retrieval, b) pre-processing and c) visualization, in addition to d) proper metadata documentation.

The implementation of real-time pre-processing of heterogeneous data sources poses major challenges because this should include: 1) reading from different file formats, 2) consolidating input data, 3) implementing basic quality control, 4) harmonizing to a standard output format, and 5) generating standard metadata information for an automated update of EnviDat records. The resulting data sets should be visualized using charts and maps, including summary parameters for longer periods, and detailed views for the most recent time windows.
The development of such an architecture will substantially benefit and enable the integration of monitoring data from a range of WSL projects and programs, including the Swiss Long-term Forests Ecosystem Research Program (LWF) and related activities.

A new experimental plantation network to test the future climatic suitability of 18 tree species in Switzerland

ID: 184

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Climate change will allow many tree species to colonize new habitat, but natural migration rates are slow. In the context of assisted migration, the question arises, which of the tree species supposedly adapted to the climate expected on a given site towards the end of the 21st century, can already establish and grow there today. To answer this question and to improve the knowledge about the factors driving mortality, health and growth of tree species along large environmental gradients, a new network of 59 experimental plantations is currently being established in Switzerland. This is a joint effort of the Federal Institute for Forest, Snow and Landscape Research (WSL), the Federal Office for the Environment (FOEN), cantonal forest services, forest managers, professional organizations and forest owners. The experimental plantations will be monitored over several decades, to validate site-specific tree species recommendations for forest practitioners and to create a long-term infrastructure for applied research.

Using a participative approach involving cantonal forest authorities and other stakeholders, 18 tree species have been selected for testing. The experimental design has been developed using power analysis. While nine species of major interest will each be tested at 35 of the 57 sites, another 9 species are assigned to 15 sites. Seven provenances will be tested per species, to cover the provenance variation within species.

In our contribution, we will justify the overall approach, describe the experimental design, illustrating trade-offs between different design alternatives, and compare our trial to previous species and provenance trials. The contribution is meant to stimulate a debate over the start of similar trials.

A case study for the effects of telecom's microwaves on forest trees

ID: 188

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The effect of telecoms' microwaves on trees has been studied in a few cases, mostly concerned with urban trees. Concerns about the widespread electromagnetic pollution centre on the effects of EMFs on human health; the precise mechanism with which trees interact with the artificial electromagnetic fields in the frequencies of microwaves, was never identified. An area in the South of Italy, National Park of Aspromonte, is proposed as a case study for the effect of microwaves on various species of forest trees typical of the Mediterranean mountain areas. Three very large digital television installations are currently located in the park, spanning their signal as far as 50 km, hitting, on their trajectory, various types of forests, positioned in both valleys and hilltops, at an altitude from 50 to 1000 m asl. The studies published by the telecom industry demonstrate that a relevant fraction of emitted energy is absorbed by various canopies, with some differentiation between species. This information was never tested from a forest monitoring and tree biology point of view; therefore a drone survey is planned in the area, to verify the real signal distribution and various heights. Signal needs to be monitored below the canopies to verify the absorbance, depending on species and location. In this area the effects on trees were registered 6 months after the start of digital TV broadcasting in 2013: an unprecedented very fast decline and death of chestnut trees was recorded, with symptoms including an excessive expansion of the lower trunk, and in the most wetted areas, cracking of the bark and damage to the plant liquid channeling system. The same symptoms affected, after 5 years, all other tree species. Foliage symptoms included discoloration, deformations, necrosis, burnt tips, dissimilar to Ozone damage. The effects on wood include loss of mechanical strength and increased porosity, increasing the flammability in the event of forest fires.

Assessing tree vitality to evaluate forest health: can tree-ring stable isotopes be used as indicators?

ID: 190

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Society is concerned about the long-term condition of the forests. Although a clear definition of forest health is still missing, to evaluate forest health, monitoring efforts in the past forty years have concentrated on the assessment of tree vitality, trying to estimate tree photosynthesis rates and productivity. Used in monitoring forest decline in Central Europe since the 1980s, crown foliage transparency has been commonly believed to be the best indicator of tree condition in relation to air pollution, although annual variations appear more closely related to water stress. Although crown transparency is not a good indicator of tree photosynthesis rates, defoliation is still one of the most used indicators of tree vitality. Tree rings have been often used as indicators of past productivity. However, long-term tree-growth trends are difficult to interpret because of sampling bias, and ring-width patterns do not provide any information about tree physiological processes. In the past two decades, tree-ring stable isotopes have been used not only to reconstruct the impact of past climatic events, such as drought, but also in the study of forest decline induced by air pollution episodes, and other natural disturbances and environmental stress, such as pest outbreaks and wildfires. They have proven to be useful tools for understanding physiological processes and tree response to such stress factors. Tree-ring stable isotopes integrate crown transpiration rates and photosynthesis rates and may enhance our understanding of tree vitality. They are promising indicators of tree vitality. We call for the use of tree-ring stable isotopes in future monitoring programmes.

Combining spectral and molecular approaches to capture leaf pigment dynamics

ID: 197

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Leaf pigments are important indicators of plant performance and acclimation. Field spectroscopy has been widely used to monitor leaf pigments based on leaf optical properties (LOP) and to support continuous, time-resolved, and rapid characterization of an increasing number of ecophysiological parameters from forest trees. However, to the best of our knowledge neither systematic characterizations of uncertainties nor standardized calibration of leaf optical measurements exist to date.

In this study we investigate what level of uncertainty can be tolerated in LOP measurements while ensuring the retrieval of reliable information about intraspecific variation of leaf pigments. We developed a method to separate biological information from measurement uncertainty of spectral measurements acquired with a field spectroradiometer coupled with a leaf clip. Based on a newly developed HPLC method, we can characterize complex leaf pigment profiles used for the calibration of spectral measurements.

We find that in-situ spectral measurements can detect intraspecific variability of leaf pigments within a mature Fagus sylvatica tree sampled on a weekly basis during the growing season 2018. Diversity of spectral features measured within an individual increased by 80% as leaves mature, with a contribution of measurement uncertainty of 3%. This increase correlates with an increasing diversity in pigment metabolites. We conclude that retrieval of calibrated spectral measurements enables us to better monitor in-situ plant-environment responses with field spectroradiometers.

Forest monitoring towards the definition of stomatal-flux critical levels for forest protection against ozone: the MOTTLES approach

ID: 205

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Current European directives for the protection of vegetation from the phytotoxic ozone (O_3) are based on atmospheric exposure (AOT40) that are not always representative of the actual field conditions. Such discrepancy is known to be related to the fact that O_3 effects on forests depend on gas uptake through stomata (stomatal fluxes). The European MOTTLES project contributes to the NEC (National Emission Ceiling) and ICP Forests network for O_3 monitoring in 17 sites in France, Italy and Romania. These monitoring stations allowed: estimating the accumulated exposure AOT40 and stomatal O_3 fluxes (PODY) with an hourly threshold of uptake (Y) to represent the detoxification capacity of trees (POD1, with Y = 1 nmol O_3 m−2 s^{-1} per leaf area); and collecting data of forest-response indicators, i.e. crown defoliation and visible foliar O_3-like injury over the time period 2017–2019. The soil water content was the most important parameter affecting crown defoliation and was a key factor affecting the severity of visible foliar O_3-like injury on the dominant tree species in a plot. The soil water content is thus an essential parameter in the PODY estimation, particularly for water-limited environments. An assessment based on stomatal flux-based standard and on real plant symptoms is more appropriated than the exposure-based method for protecting vegetation. From flux-effect relationships, we derived flux-based critical levels (CLef) for forest protection against visible foliar O_3-like injury. We recommend CLef of 5 and 12 mmol m^{-2} POD1 for conifers and broadleaved species, respectively. Before using PODY as legislative standard in Europe, we recommend using the CLec for ≥ 25% of crown defoliation in a plot: 17,000 and 19,000 ppb h AOT40 for conifers and broadleaved species, respectively.

A concept for a consolidated humus form description in forest soil investigations in Europe

ID: 213

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Humus form is an integrate multi-dimensional phenomena where key soil processes and services are delivered. The humus form characterizes the morphology of the litter and humus layer and the mineral top soil. Occurrence and thickness of these horizons lead to different humus forms, indicating different allocation and quality of the organic matter in a soil profile. Different humus forms develop due to the interaction of various soil forming factors. Thus, the humus form is an indicator of distinct organism communities and abiotic site characteristics. Furthermore, changes of humus forms are a sensitive indicator of anthropogenic impact on soils.

Classification of humus forms has a long tradition and was concurrently developed in different countries. Description is based on elements of different European and North American classifications. The attempts to find a common language in the humus form description (Broll *et al.* 2006, Jabiol *et al.* 2013, Zanella *et al.* 2011) failed due to the absence of an agreement between international stakeholders. A validation of classifications for broader range of climatic regions and vegetation types is necessary. We propose to create a new process where the participating countries agree on the definition of diagnostic horizons and differentiate the main terrestrial humus forms mull, moder, amphi, and mor on the basis of diagnostic mineral and organic horizons.

Furthermore, we propose to differentiate between terrestrial humus forms developing on drained peatland and peat-forming humus forms. The latter may be used as an indicator of the distribution of natural peatlands, and their important function in C-sequestration.

Large-scale mistletoe inventory in Central Poland

ID: 214

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Mistletoe (*Viscum album* L.) is a semi-parasitic plant, and in moderate abundance, it does not pose a lethal threat to a tree. However, recent droughts have made a heavy impact on forests, and in recent years, mistletoe began to appear on a larger scale in regions and in places where it has never been a threat before. The main purpose of this research was to carry out a large-scale mistletoe inventory in central Poland for assessing the number of mistletoe on individual trees and in the stands, as well as to test a new inventory method adapted to Polish conditions. It is based on random sample plots, each consisting of 15 trees on which the impact of mistletoe is assessed. On every sample plot, the mistletoe occurrence, location in the crown, estimate of the percentage within the crown, and the number of mistletoe on a tree were assessed. In addition, for further analysis, information about stands (forest site type, site index) as well as measured trees (age, diameter, Kraft class, crown length, loss of assimilation apparatus, crown type) levels was recorded. Research undertaken in Kozienice Forest (100 km south from Warsaw) took into account 300 sample plots on which 4500 trees were assessed. Preliminary results show that 16% of trees are infected by mistletoe, more than 25% of which are infected heavily by more than 6 specimens.

Ion Exchange Resin method for quantifying bulk (throughfall) deposition

ID: 218

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Quantification of atmospheric deposition on forest ecosystems is mostly derived by regular (weekly to biweekly) measurements of precipitation outside (bulk deposition) and below (throughfall) forests but these methods are costly, labor intensive and inaccurate for reactive elements like N. The “Ion Exchange Resin method” (IER) offers a promising alternative as it provides a way to collect cumulative deposition estimates on a (bi-)monthly to yearly basis, thus reducing cost and labor [3] and it is reliable for reactive elements like N. In addition, IER allows for measurements in areas with little rainfall and low elemental concentrations. The accuracy of IER is, however, hardly ever classified beyond nitrogen. Here, we developed and tested an IER-based method to quantify deposition of macro and micro-elements.

The IER method is based on capture and release of elements. We show that IER is able to capture 100% of added macro-elements (NH_4, NO_3, P, S, Na, K, Ca, Mg) and micro- elements (Fe, Mn, Cu and Zn) under laboratory conditions. Heat (40°C), drought and frost (-15°C) only affected the capture efficiency of Na, NH_4, N (<5%) and P (25%). Elements are released following a 2M KCl extraction for N and a 2M HCl extraction for other elements. Recovery rates after extraction are >99% for Ca, Mn and total N, >95% for S, Fe, K, NH_4, and >90% for Mg, Na, NO_3 and Cu. Our results indicate that IER is a powerful tool for the measurement of bulk (throughfall) deposition of a broad range of elements.

Artificial electromagnetic fields (telecoms) as forests' pollutants. Plans for testing monitoring procedures three protected forests of Italy

ID: 219

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The effect of artificial electromagnetic fields, particularly those associated with the widespread telecommunication networks, have been the object of various studies in the last 10 years, trying to identify the most relevant mechanisms for the interaction between microwaves and the various species in the environment. A severe limitation of the many experiments, conducted on plants for limited time in a controlled laboratory environment, has been the isolation of few variables without good connection with the real on-site environmental conditions. This is particularly true when trees over 15 m high are studied through seedlings or very young trees in environmental chambers. A five years macroscopic analysis of various species in a case study area of the Parco dell' Aspromonte, a protected forest in Calabria (Italy) has outlined, as possible effects the defoliation of trees tops, the transformation of the bark properties and consequent cracking, an excessive swelling of the trunk base which could point to a change in the porosity, and mostly the wood micro-fracturing, resulting in the loss of mechanical properties and effecting the velocity of the spread of forest fires. The mentioned effects are surely due to a combination of air carried agents, which needs to be assessed with long term monitoring on various selected sites, before being further tested in experimental forest or environmental chambers. This contribution shares the initial considerations for the selection of the instrumentation and the design of the forest monitoring to be performed in three protected areas in Italy.

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Oral presentations

Forest soil carbon cycle under drought – linking experiments, monitoring and natural gradients across Switzerland

ID: 154

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Climate projections predict higher precipitation variability with more frequent dry extremes. Drought limits the metabolic activity of plants and soil organisms and hence, carbon (C) cycling in forests and their soils. Longer-term responses, however, are ultimately depending on the resilience of forest ecosystems to drought, which include the recovery and adaptation of plant and soil communities. Here, we present results from experimental manipulations of water regimes in forests at the monthly to multi-annual time scales as well as from natural precipitation gradients reflecting longer-term trajectories.

In ^{13}C-pulse labelling experiments in a young beech forest and a mature pine forest, we show that drought suppresses the allocation of new assimilates of trees to the soil, but that upon rewetting trees allocate greater amounts of assimilates belowground, probably to regain rhizosphere functions and an increased C demand of rhizosphere communities following drought. In a 15-year-long irrigation experiment in a water-limited pine forest, we show that irrigation increased both forest productivity and soil CO_2 effluxes and altered the composition of soil microbial and faunal communities.

Determination of soil C pools revealed C losses in the organic layer under irrigation but C gains in the mineral soil, resulting in negligible net effects. In the longer term, the reduced net C input in the mineral soil under drought is likely to decrease C storage in the soil, which is supported by declining soil C stocks with decreasing precipitation in Swiss forest soils.

Beech nutrition depends on defoliation, soil and climate across Croatia

ID: 211

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Changing climate conditions can be critical for the vitality of trees, as high temperatures and/or drought may cause inadequate nutrition of trees in parallel with a worsening of crown condition. It is crucial to account for nutrient limitation when studying the forest response to climate change (Jonard *et al.*, 2015). Nutrient contents of tree foliage, which reflect atmospheric and soil-related influences, are an important part of UNECE ICP Forests monitoring programme. The main goals of this study were to: (I) investigate the influence of climate conditions on mineral nutrition of common beech, and (II) determine if concentrations of N, P, K, Ca and Mg in common beech foliage differ between tree defoliation classes. Stratified sampling of trees based on their defoliation class (≤25%, >25%) was performed on 28 Level I beech plots (10 in Dinaric, 18 in Pannonian biogeographical region) 2018, 2019 and 2020, five trees per plot and defoliation class. We detected significant nutritional differences between trees of different defoliation classes for P and Mg, but only in certain years. The ratios of N/P, Ca/Mg, K/Ca, K/Mg and K/Ca^{+}Mg were higher for less defoliated trees in most cases. All ratios with Ca (N/Ca, K/Ca, K/Ca^{+}Mg) were higher for less defoliated trees in 2018 and 2019, but not in the drier 2020. Calcium concentrations increased with increasing soil pH ($CaCl_2$) for plots in the Pannonian region, which has a wider span of pH values, while in Dinaric plots with pH mostly higher than 5 such correlation was not found. A multitude of climate factors correlated with nutrient concentrations, but summer temperatures seem to have the strongest negative influence.

Mechanisms explaining N stock and acidity dynamics in German forests between 1990 and 2007 and possible climate change feedbacks

ID: 164

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Nitrogen (N) stocks, soil acidity, foliar nutrition and water budgets of German forest soils were repeatedly assessed on roughly 1800 grid points of the National Forest Soil Inventory (NFSI) in Germany including the plots of the national Level I network. Their compartment-wise dynamics raises interesting questions: (i) why did foliar N nutrition increase, though N-deposition was declining? (ii) how can soil C/N ratios increase under these circumstances? (iii) and how can opposing trends of N stocks in the organic layer and the mineral soil be explained?

The integrated evaluation of the NFSI points to a high relevance of changes in the acid-base status for the underlying nutrient and decomposition dynamics. Recovery from soil acidification is discussed as a factor improving root N uptake and stimulating above-ground growth (Etzold *et al.,* 2020).

Under continued high levels of N deposition, these processes are likely to further destabilize forests of certain tree species especially with regard to their drought susceptibility. Considering the limited water availability for forests in a warming climate and a targeted further decreased deposition of acidity and nitrogen, adequate adaptation strategies in forest management are needed for this situation, where all aspects of ecosystem change are integrated.

Impact of physiology and climate on foliar mercury uptake by European forests

ID: 146

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Uptake of gaseous elemental mercury (Hg(0)) from the atmosphere by tree foliage represents a pivotal flux within the terrestrial Hg cycle. To date, however, physiological and climatic factors controlling foliar Hg(0) uptake remain poorly understood. ICP Forests with its vast pool of foliage samples offers the opportunity to statistically identify parameters regulating Hg uptake rates. We measured Hg in 3831 foliage samples from 247 ICP Forests Level II plots from 2015 and 2017 and combined these measurements with foliar, meteorological and site-specific meta data. Furthermore, we added foliar Hg measurements from 757 sampling sites of the Austrian Bio-Indicator Grid to this European Hg data base.

Linear regression of time-normalized foliar Hg uptake rates per dry weight on leaf nitrogen content revealed a positive correlation across all tree species (R^2 = 0.69; p << 0.05). This finding suggests that foliar Hg uptake aligns along an evolutionary spectrum of tree species, ranging from low to high leaf nutrient contents, from low to high rates of leaf physiological activity, and from long to short leaf life spans. We hypothesize that foliar Hg uptake is best described by an interplay between leaf physiological activity and leaf structure. Climatic parameters (temperature, precipitation, vapor pressure deficit) and geographic characteristics of sampling sites (latitude, altitude) did not or only marginally correlate with foliar Hg uptake rates.

Impact of pollen on throughfall biochemistry in European temperate and boreal forests

ID: 145

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The aim of this study is to get a better view on the effects of pollen on throughfall (TF) biochemistry for the main tree species groups in Europe (oak, beech, spruce, pine). We used generalized additive mixed modelling to study the relationship between long- term series of measured TF fluxes in spring (April–June) at 100 ICP Forests Level II plots and corresponding airborne pollen concentrations (Seasonal Pollen Integral, SPIn) from nearby aerobiological monitoring stations. We also conducted a 7-day laboratory dissolution experiment with bud scales and flower stalks of beech, pollen of beech, common oak, silver birch, Scots pine, Corsican pine, Norway spruce and sterilized pollen of silver birch in a nitrate (NO_3-N) solution (11.3 mg N L). Throughfall fluxes of potassium (K^+), ammonium (NH_4^+-N), dissolved organic carbon (DOC) and dissolved organic nitrogen (DON) showed a positive relationship with SPIn; NO_3-N fluxes a negative relationship. The experiment broadly confirmed the findings based on field data. Within two hours, pollen released large quantities of K^+, phosphate, DOC and DON, and lesser amounts of sulphate, sodium and calcium. After 24-48 hours, NO_3-N started to disappear, predominantly in the treatments with broadleaved pollen, while concentrations of nitrite and NH_4^+-N increased. At the end of the experiment, the inorganic nitrogen (DIN) was reduced, presumably because it was lost as gaseous nitric oxide (NO). Our results show that pollen dispersal might be an overlooked factor in forest nutrient cycling and might induce complex canopy N transformations.

Ectomycorrhizal functionality after 5 years of summer drought in a mature forest

ID: 144

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Middle Europe's forests face an increasing risk of recurring summer droughts. In the Kranzberg Roof experiment we simulated impacts of severe droughts on mature (> 60 y) spruce-beech forests by rain exclusion during the vegetation periods of five consecutive years.
Most temperate trees heavily depend on nutrient exchanges through root symbioses with ectomycorrhizal fungi, but physiological changes due to drought alter the nutrient flows in this system.

Therefore, we monitored the root fungal community functionality by enzyme-activity tests on morphotyped ectomycorrhizae, which we complemented with fungal community metabarcoding and records of environmental parameters as well as tree ecophysiology. Effects on ectomycorrhizal community functionality at drought treated trees were mostly quantitative due to loss of roots, while the enzymatic capabilities at the individual root level remained similar to controls.

In addition, root fungal communities got noticeably dissimilar between ambient controls and rain exclusion plots during the first three years of summer drought, but this effect halted in years four and five.

At our site, most trees survived five years of severe summer drought and probably benefited from the inherent resilience of their root fungal communities.

Patagonian forests vulnerability to climate change: Consequences for management and conservation

ID: 140

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Natural ecosystems at the extreme species distribution are vulnerable to changes and can provide useful insight on management and conservation strategies to counteract effects of recent climate change. Patagonia has unique features: (i) extreme climate and closeness to Antarctica, (ii) relative intact ecosystems, but (iii) few long-term forest studies conducted there. The objective was to determine changes in diversity, forest structure and ecosystem processes and relate them with climate variables and indexes (e.g. El Nino Southern Oscillation, ENSO; Southern Annular Mode, SAM) in the short- medium-term (last 5-20 years). We employed long-term data and experimental plots into managed and unmanaged *Nothofagus* forests, remote sensing and climate indexes. We found evidences of impact of extreme climate events on: (i) crown dieback in natural forests resulting in changing site quality; (ii) tree mortality rates in managed forests (e.g. thinnings) where summer drought and primary productivity net explain most of the tree losses; (iii) seed production can changed due to ENSO (e.g. La Niña increased the seeding) or SAM (increased seeding with negative values of SAM), (iv) daily regeneration growth is related to rainfall events determining survival along the season; and (v) biodiversity indicators (birds and understory) related to net primary productivity and climatic events. Besides an evaluation of the effectiveness of current management and conservation strategies, our monitoring permitted to suggest new ones to increase the resilience of the natural forests to climate change.

Environmental factors, leaf traits and ozone visible symptoms are interrelated in *Viburnum lantana*

ID: 216

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The assessment of Visible Foliar Symptoms (VFS) caused by tropospheric ozone is a common method adopted by forest monitoring programs to estimate ozone impact on vegetation (e.g. ICP Forests). The occurrence of ozone VFS may differ within the same species at the same site, and within leaves of the same plant. However, very few attempts exist to investigate which factors are associated with the occurrence of VFS on different plants of the same species growing at the same site.

The aim of this work was to identify environmental, morphological and physiological factors associated with the occurrence and severity of VFS in *Viburnum lantana* and at the scale of an individual site (i.e. a single site from the ViburNeT monitoring network in Trentino, north Italy) (Gottardini, *et al.* 2017).

V. lantana plants were surveyed based on 1) sun exposure, 2) shading effect from neighbor vegetation, 3) plant height and 4) presence of VFS. Leaves from three different high sections of each plant were then subjected to a phenotypic characterization of leaf area, dry weight, specific leaf area, chlorophyll content, % of VFS and adaxial and abaxial trichome density.

We showed that plants subjected to high irradiation levels had significantly ticker leaves ($p<0.05$) and higher trichome density ($p<0.01$) followed by greater chlorophyll content ($p<0.01$) when compared to shaded plants. Similar trends were observed for higher plants and apical branches when compared to small plants or basal branches respectively ($p<0.05$). VFS at leaf levels were associated with lower specific leaf area ($p<0.001$) and an increased number of trichomes in the abaxial leaf surface ($p<0.05$). Chlorophyll content was also reduced ($p<0.05$) in leaves with high levels of VFS.

Our work provides evidence of a strong relationship between leaf ozone symptoms, leaf morphological traits and environmental variables and offers new insights for interpreting data from monitoring programs on the impact caused by ozone on vegetation.

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Poster presentations

The contribution of ambient aerosols to ‘wax degradation’ and decreasing drought tolerance

ID: 109

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The foliar accumulation of hygroscopic aerosols on leaves is a neglected factor of air pollution that can have direct effects on the drought tolerance of trees. Earlier experiments with experimentally added aerosols created the microscopic impression of ‘wax degradation’ and increased epidermal minimum conductance (g_{min}) (Burkhardt and Pariyar, 2014). Here, we addressed plant responses to aerosol reduction through exclusion of ambient aerosols.

Scots pine, silver fir, and common oak seedlings were grown for 2 years in greenhouses ventilated with ambient air (AA) or filtered air (FA) with reduction to 1% and 14% in particle number and ionic aerosol mass, respectively. Aerosol mass loading was determined by foliar rinsing and surface appearance by scanning electron microscopy.

Foliar carbon isotope discrimination ($\delta^{13}C$) and g_{min} were measured. Air filtration prevented the development of amorphous structures that have typically been interpreted as degraded waxes. The g_{min} of FA plants was 77% to 81% of the respective AA g_{min}, suggesting that aerosols weakened the efficiency of stomatal restriction of water loss. The $\delta^{13}C$ values for 2-year-old fir needles suggested reduced stomatal aperture of AA compared to FA needles.

The co-occurrence of ‘wax degradation’ and reduced drought tolerance of plants exposed to ambient aerosols suggests a common cause. Deliquescent aerosols are amorphous and mobile. The resulting solution may spread across the leaf surface and into stomata, forming wick structures that link apoplastic water to the leaf surface, and reduce stomatal control.

Why are Scots pines dying in the Swiss Rhône valley?

ID: 113

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Since the 1990s, a pronounced decline of Scots pines (Pinus sylvestris) occurred at lower elevations in the inner-alpine Rhône valley in Switzerland. On a forest plot in Visp, the number of living Scots pines decreased by nearly 80% between 1996 and 2018, and the defoliation of individual trees increased on average by 5.6% per year. These changes did not happen gradually, but in four mortality and defoliation events. Which relevant factors changed, and what triggered these dieback events?

In previous research, Scots pine mortality was related to prolonged periods of strongly negative water balance. However, we found that mortality and defoliation events in Visp always followed particularly precipitation poor summer months (July to September), when soil moisture is regularly at a minimum. The sum of wet days and the precipitation intensity during these months explain 60% of the defoliation change observed in the following year, whereas precipitation and evapotranspiration anomalies during the other seasons are largely irrelevant. Further factors such as pests and spring frost may substantially increase the severity of mortality and defoliation, and the number of trees that get highly damaged without dying within a year explains additional mortality occurring with a delay.

There are no significant trends in summer precipitation in the Rhône valley from 1981 to 2018. However, at lower elevations, evapotranspiration increased significantly in spring, summer, and partly autumn. The clearest changes occurred in spring, when various climate change indices point out a strong climatic shift towards drier conditions. We conclude that the increased atmospheric water demand prolonged the duration of minimum soil moisture in summer, and that the vitality of the Scots pines decreased due to climatic changes. As a result, the trees suffer since the 1990s from hydraulic failure in case of absent substantial summer precipitation, leading to the observed Sots pine dieback.

How soil carbon and nitrogen changes in the topsoil formed under different tree species?

ID: 114

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As a carbon pool, soils store more organic carbon (OC) than above ground biomass. The carbon and nitrogen source of this pool is above ground biomass. Determination the carbon and nitrogen stock in forest soils which is formed ecologically sensitive areas is important, because these sensitive areas will be affected first and most severely by global warming. The amount of OC stored in soils may differ depending on the tree species. For this, the study was carried out to determine the tree species effects on organic C and N in the forest soils of even-aged black pine (*Pinus nigra*), lebanon cedar (*Cedrus libani*) and oriental beech (*Fagus orientalis* Lipsky) in karstic ecosystems located Andırın, Kahramanmaraş. Totally 100 ha and a total of 90 soil samples were collected. Collected soils analyzed for determination of organic carbon, total nitrogen.

The results showed that organic C content of the soil was found highest (5.44%) in cedar forest and lowest (4.7%) in pine forest. When the total C stock and N stock values of all species were calculated, the lowest C stock and N stock amounts (40.77 t h and 2.46 t h) were determined in the beech forest and the highest amounts (53.34 t C h and 7.10 t N h) in the cedar forest. Consequently, tree species varieties have a significant effect on soil organic C and N. Depending on the decomposition in the organic matter of cedar stores most carbon and nitrogen. The organic litter composition significantly influences decomposition of organic matter and the amount of carbon stored in the soil.

Are forests thickening due to rising CO_2? Insights from Swiss forests and mechanistic modelling

ID: 116

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Elevated atmospheric carbon dioxide (eCO_2 has been reported to enhance photosynthesis and tree growth rates by increasing both light-use efficiency (LUE) and water-use efficiency (WUE). Tree growth enhancement could be translated into an increase in biomass stocks or associated with a reduction in the longevity of trees, thus reducing the ability of forest ecosystems to act as carbon sinks over long timescales.

The links between growth and mortality, and the implications for forest stand density and self-thinning relationships are still debated. Scarce empirical evidence exists for how changing drivers affect tree mortality due to existing data and modelling limitations. In this study, we combine a mechanistic model with empirical forest data to better understand the causes of changes in tree mortality. Specifically, we test the Grow-Fast- Die-Young hypothesis to investigate if a leaf-level CO_2 fertilization effect may lead to an increase in the biomass stock in forest stands. We use a novel vegetation demography model (LM3-PPA) which allows for explicit representation of individuals and a mechanistic treatment of tree mortality. The key links between leaf-level assimilation and stand dynamics depend on the carbon turnover time. In this sense, we investigate alternative mortality assumptions about the functional dependence of mortality on tree size, tree C balance or growth rate. Model simulations show that increasing photosynthetic LUE leads to higher biomass stocks, with contrasting behavior among mortality assumptions. Empirical data from Swiss forest inventories support the results from the model simulations showing a shift upwards in the self-thinning relationships, with denser stands and bigger trees. This data-supported mortality-modelling can help to identify links between forest responses and environmental changes at the leaf, tree and stand levels and may yield new insight into the causes of currently observed terrestrial carbon sinks and future responses.

The effects of land use types on the soil organic carbon content

ID: 122

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Soil organic carbon (SOC) constantly affected under climatic conditions and land use types. SOC pools consist of variable pools with varying retention times. Maintaining organic carbon in the soil is very important for soil fertility, productivity and also global warming. This study attempts to relate the SOC content with three different land use types (Forest, range and riparian areas) in Başkonuş highland of Kahramanmaraş Province. The main objective of the study is to assess how different land use types of effects soil organic carbon. The surface soil samples were collected in April 2019 from three predominant different land use types and were analyzed for physicochemical properties of soil with standard procedures. The descriptive statistics and analysis of variance (ANOVA) were used for data analysis. The results of the study showed that the forest lands consisted of the highest average of SOC content (6.08%) compared with other land use types (3.88 % for range and 0.60% for riparian areas) at 0–10 cm soil depth. This can be attributed to more inputs of litter and fewer erosion degrees compared to other land use types due to stand cover protection. Similarly, the lowest SOC content under riparian as compared to others was attributed to fewer inputs of organic material and reduction organic matter by leaching. In addition, it is also understood that natural range and pasture areas are among the important carbon sources. The finding indicated that the SOC was found significantly different ($p \leq 0.05$) among the land use types.

Impact of extreme climate factors on forests drought in Republic of Serbia

ID: 124

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This study presents the results of the impact of extreme climatic factors on the occurrence of forest drought in the Republic of Serbia. Drought is certainly one of the most dominant abiotic stressors. Due to prolonged periods without rainfall and high air temperatures, drought can disrupt normal functioning of even completely healthy plants. Drought represents direct and indirect factor that will influence on occurrence of forest decline. It refers directly to the decline of entire plants or parts of plants, while indirectly it is reflected in the appearance of different pathogens that will attack the weakened plants due to its action.

During the 17 years of research (2004–2020) on this topic, it was concluded that the great droughts in the Republic of Serbia is caused by the drought that occurred after several consecutive years of its presence (2011–2013). At the first moment, these damages were even recorded as damage caused by an unknown cause, while through comparing with defoliation, the number of died and almost died trees and the climatic characteristics of the studied period, it reached a conclusion on the real causes. Due to such extreme weather factors, tolerance thresholds have been exceeded, leading to their gradual decline. Another good indicator of the impact of the drought is the large incidental yields in the total yield, within the companies dealing with forest management, that have arisen in the period after extreme climatic factors, in this case droughts.

We can see many advantages of the continuous monitoring method at a large number of sample plots, because the monitoring of phenomena and processes over a longer period of time and on a larger number of samples allows more precise identification of the true causes of the forest decline.

Analysis of floodplain forest sensitivity to drought

ID: 129

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Global Change Research Institute CAS, Czech Republic

Floodplain forests are very complex, productive ecosystems, capable to store huge amounts of soil carbon. With increasing occurrence of extreme events, they are today among the most threatened ecosystems. Our study's main goal was to assess the productivity of a floodplain forest located at Lanžhot in the Czech Republic from two perspectives: carbon uptake (using an eddy covariance method) and stem radius variations (using dendrometers). We aimed to determine which conditions allow for high ecosystem production and what role drought plays in reducing such production potential. Additionally, we were interested to determine the relative soil water content threshold indicating the onset and duration of this event. We hypothesized that summer drought in 2018 had the most significant negative effects on the overall annual carbon and water budgets. In contrast to our original hypothesis, we found that an exceptionally warm spring in 2018 caused a positive gross primary production (GPP) and evapotranspiration (ET) anomaly that consequently led in 2018 to the highest seasonal total GPP and ET from all of the investigated years (2015–2018). The results showed ring-porous species to be the most drought-resistant. Relative soil water content threshold ~0.45 was determined as indicating the onset of drought stress.

Carbon allocation in *Picea abies* (L. Karst) roots during recovery from a five-year long drought

ID: 133

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Within the last years, temperatures in middle Europe increased. Drought periods in summer become more frequent in many regions, which lead to extensive tree die-off. In context of the k.roof experiment (Pretzsch *et al.*, 2014) we tested the ability of mature spruce trees (age 69 ± 2 years) to recover after five years of severe drought caused by experimental rainfall exclusion. After 5 years of drought treatment, the trees have been rewatered by drip irrigation in summer 2019 and subsequently labelled with ^{13}C-depleted CO_2 for two weeks.

We hypothesized that the recovery of spruce trees is sink driven and focused on fine roots and ectomycorrhizal fungi. To track the fine root development, we put fine roots into mesh bags in spring, so they were still connected to the environment and hyphae could reach the root tips. Those roots were documented before and after the rewatering by photographs. To determine the allocation of newly build photoassimilates, we analyzed the $\delta^{13}C$ values in mycorrhized and unmycorrhized fine root tips by isotope ratio mass spectrometry (IRMS).

We found less distinct $\delta^{13}C$ signals in mycorrhized tips than in unmycorrhized tips, which indicates that new assimilates are rather used to form new roots, less to support mycorrhizae. This is underlined by a $\delta^{13}C$ gradient within newly grown long roots. Furthermore, $\delta^{13}C$ signals in control trees were higher than in rainfall excluded trees. This suggests that long-term drought-stressed trees have a reduced capacity for belowground carbon allocation after rewatering compared to controls.

Root carbon-nutrient balance determines downy oak survival and recovery from drought

ID: 143

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The role of carbon (C) and nutrient uptake, transport and storage and especially their interactions in survival and recovery of trees under increased frequencies and intensities of drought events is not well understood.

A full factorial experiment with four water supply regimes ranging from extreme drought to well-watered conditions and two fertilization levels was carried out to investigate the impact of drought and nutrients on downy oak (*Quercus pubescens*) saplings during 2.5 years of drought and after drought release. Physiological traits, such as photosynthesis, leaf predawn water potential as well as tissue biomass together with pools and dynamics of non-structural carbohydrates (NSC) and nutrients at the whole-tree level, were investigated.

Our results showed that fertilization played a minor role in saplings' physiological processes to cope with drought and drought release, but reduced the saplings' mortality during extreme drought. *Q. pubescens* showed increased soluble sugar levels in all tissues with increasing drought, independent of nutrient supply, mostly because of starch degradation, while soluble sugars decreased to the control levels after 28 days of drought release. Only after extreme drought, root NSC concentration were strongly reduced leading to an almost complete NSC depletion after 28 days of rewetting, simultaneously with new leaves flushing. This, at least in the present study, may imply a root carbon starvation in severely stressed trees. We conclude that the stabilized biomass partitioning and the fast recovery of leaf function (refoliation, photosynthesis and water potential) under fertilization and drought, indicates that *Q. pubescens* is a well-adapted species to overcome extreme climatic fluctuations.

Predicting the spread of *Gonipterus scutellatus* forest pest under climate change in Spain using Universal Kriging model

ID: 151

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Defoliation induced by the invasive eucalyptus weevil *Gonipterus scutellatus* is causing significant economic damage to Spanish eucalyptus plantations of Spain since 1991. The origin of *G. scutellatus* is southeastern Australia, where it is under control thanks to the presence of its natural predators (*Anaphes nitens*). But this predator is not present in Spain where eucalyptus is an introduced/exotic species.

This study aims to analyze the spatio-temporal distribution of this insect pest eucalyptus plantations in Spain, to determine their colonization and dispersal patterns in the last decade, which is essential for risk prevention in the future.

Spanish plots with *Eucalyptus* spp. presence belonging to the network ICP Forest Level I and analogous plots measured by local government offices were used to aim this objective. G. scutellatus presence and extent damage were observed between 2004 and 2017. A total of 266 Eucalyptus plots were included in the study, where 167 plots showed presence of eucalyptus weevil in some point in the observed period.

We applied a spatio-temporal Universal Kriging model to study the temporal dynamics of G. scutellatus from 2004 to 2017, its spatial distribution and to identify de main factors (both, biotic and abiotic), which could explain its extension and spread in the Spanish eucalyptus plantations. Based on our results, risk maps can be generated to support decision making for pest prevention and climate warming effects mitigation.

Impact of the European drought 2018 on tree health and mortality in Swiss forest ecosystems

ID: 162

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Ongoing global warming is accompanied by an intensified frequency of extreme weather. In 2018 a combined drought and heat wave hit Central Europe and caused substantial physiological effects on Swiss forests. Many trees showed stress symptoms including reduced leaf water content, leaf discoloration and defoliation but were able to recover in the following year. A surprisingly large number of trees, however, died either in 2018 or the following year. Particularly this high mortality rate is of concern since underlying causal relationships are not fully understood yet. This study aims to contribute to understanding with a remote sensing based assessment of location and quantity of drought effects in Swiss forest ecosystems.

We used Sentinel-2 satellite imagery acquired in August for the reference year 2017 and the event years 2018 and 2019. Data processing included a vicarious calibration and cloud removal, followed by calculating the normalized difference water index (NDWI) as drought stress proxy. Calculated change trajectories of NDWI between 2017 and 2019 served as base for a classification of drought effects on forests. For the canton of Zurich, we found that most trees showed minor signs of stress, while 1.3% of the forest showed significant signs of stress in 2018 but recovered in 2019. 3.8% of the forest could not recover from drought. Our analysis provides important information to advance understanding on causal relationships between tree mortality and environmental factors to eventually facilitate future forest management strategies.

Plasticity of tree fine root traits under drought and irrigation

ID: 165

Brunner, Ivano

WSL, Switzerland

Trait-based approaches are increasingly used to investigate plant strategies for resource acquisition, growth or competition between individual organisms or across species. However, the characterization of responses to environmental stimuli by fine root systems of trees at the trait level is rather limited, particularly regarding the timing and degree of plasticity of the involved traits. These aspects become especially relevant under current climate-driven shifts in environmental conditions. In a long-term irrigation experiment starting in 2003 we investigated the reactions of fine roots of the Scots pine (*Pinus sylvestris*) to the increased soil water availability. The pine forest is located in a water-limited region in the Central European Alps, where increased tree mortality has been observed in the last three decades. The examined fine root traits included system traits, dynamic traits, morphological traits, architectural traits, and chemical traits. A first survey of fine root traits two years after the start of the irrigation treatment did not reveal any trait-based responses. However, the fine root biomass, which was again recorded after nine years or later by coring the topsoil, showed a significant increase compared to the non-irrigated control, with a maximum biomass increase of about 80% (Brunner *et al.,* 2019). The analysis of other fine root traits in addition to biomass showed that irrigation also significantly increased length and production, but did not affect morphological and architectural traits such as diameter, frequency of tips, specific root length (SRL) and root tissue density (RTD). Chemical traits such as C, N, cellulose or lignin were not altered, with the exception of $\delta^{13}C$, as the higher availability of water improves the opening of stomata. Comparing two methods of recording fine root traits, “ingrowth cores” and “soil coring”, morphological and architectural traits were significantly influenced by the methods, except for fine root length.

Above- and belowground metal accumulation and growth responses in young afforestations on model brown field sites

ID: 166

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Ecosystem services of reclaimed metal contaminated sites can include the stabilization of soil pollution combined with biomass production. Here, we investigated ranges of metal accumulation and biomass responses to soil contamination in above- and belowground plant organs for different plant groups on model brownfield sites reclaimed by afforestations.

The experiment was carried out in 32 plots, 3 m^2 each, arranged in a factorial design. In 16 plots, the 15 cm topsoil was contaminated with Zn/Cu/Pb/Cd = 2854/588/103/9.2 mg kg^{-1} using smelter filter dust (control plots: 97/28/37/<1), whereas the either calcareous (pH 7.4) or acidic (pH 4.2) and 1.5 m deep forest subsoil remained uncontaminated. All plots were planted in the same way with spruce, deciduous trees and understorey plant groups.

Comparing contaminated *versus* uncontaminated plots, 2.2/3.2/3.7/2.2/times more Zn/Cu/Pb/Cd had been extracted after four years cultivation. Increase in metal accumulation was generally higher on calcareous than on acidic subsoil. Deciduous trees transferred 0.3/0.4% Zn/Cd from contaminated soil into foliage, spruce 0.04%/ < dl = 0.1 mg kg^{-1} and the understorey 0.08/0.1%. Highest transfer factors were measured for spruce roots (Cu: 0.13%) and lowest for needles (Cu: 0.004%). Metal contamination did not affect understorey biomass, but reduced deciduous tree and spruce biomass by 20-23% on the acidic subsoil. Thus, afforestation of polluted soils is a viable management strategy if tailored to desired ecosystem services and site conditions.

Reference:
Madeleine S. Günthardt-Goerg, Pierre Vollenweider, Sandra Hermle, Rainer Schulin (2019) Growth and metal accumulation of young forest trees and understorey plants on contaminated topsoil: influence of subsoil and time. *Plant and Soil* 437:375-395

Urban air quality in Mongolia: concentrations, sources and future needs of studies

ID: 179

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Mongolia is one of the main source areas of Asian dust; the current situation and future trends of environmental quality have great importance for regional and global atmospheric quality. For the last decades, Mongolia has seen an extensive escalation in population growth, urbanization, and industrialization, together with great increase in mining and usage of motor vehicles. As a result, a substantial increase has taken place in the types and number of emission sources of air pollutants, especially in urban areas. Similar to other countries that necessarily produce more energy in the cold season, extreme seasonal variation in air pollution is characterized in the most cities in Mongolia. During the cold season, air pollution level in the capital city of Ulaanbaatar is ranked as the highest in the world.

Despite the worse air pollution situation, due to insufficient research capacity of the country, to date, research works on characteristics of air pollution have mainly been based on current capability and/or collaboration with foreign institutes. The research gap in this area necessitates numerous investigations, which could have great importance in developing mitigating strategies and minimizing the adverse impact of air pollution on local, regional and global scales.

This work reviews previously available studies and reports in scientific journals and from government on air quality in Mongolia. Based on the existing research works, future needs of studies on ambient air pollution in Mongolia are discussed.

Air pollution and climate change effects on tree growth at Ulaanbaatar city, Mongolia

ID: 192

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Air pollution is one of the main environmental issues in Ulaanbaatar city, Mongolia. During the last two decades, concentrations of atmospheric sulfur dioxide (SO_2), nitrogen dioxide (NO_2) and particulate matter (PM) are violating the national air quality standards. According to the most recent EANET report, SO_2 concentrations are gradually decreasing in most of the long-term monitoring sites in East Asian countries but further increasing in Ulaanbaatar city. In addition, drought is a common extreme event in Mongolia, caused by increasing temperature and lower precipitation amounts. Therefore, extreme climate events and air pollution are expected to be a serious threat for the forests in the vicinity of Ulaanbaatar.

The aim of this study is to investigate the potential effects from air pollution and extreme events on urban trees in the vicinity of Ulaanbaatar city based on stable isotope measurements of $\delta^{13}C$, $\delta^{15}N$ and tree-ring analysis using leaves/needles and tree cores. Tree plant materials were collected from five main tree species grown at two urban and two mountain sites nearby Ulaanbaatar city.

Across all study sites and species, $\delta^{15}N$ composition was obtained within a range from -5‰ to 15‰. For each tree species, $\delta^{15}N$ values were found to be higher at the two urban sites located at 1300 m a.s.l (0 to 15‰) compared to the two mountain sites, located at 1500–1600 m a.s.l (-5‰ to 5‰). So far, our results indicate that urban trees are more affected by anthropogenic pollution than the trees grown at the mountain sites.

In order to test our hypothesis and to further investigate potential effects on tree growth from either air pollution and/or extreme climatic events, additional measurements, including elemental analysis and $\delta^{18}O$ measurement in tree leaves/needles combined with tree-ring analysis are planned and will be conducted and discussed with the above indicated preliminary results.

Is foliar water uptake fostered by aerosol deposition?

ID: 194

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Foliar water uptake (FWU) has been found in more than 100 species and seems to be an important physiological mechanism, also for forest trees. Mechanisms are still elusive, but could involve trichomes, cuticular or stomatal uptake. We hypothesized that deposited aerosols that penetrate stomatal pores could create a pathway for liquid water into the plant (Burkhardt, 2010).

Beech (*Fagus sylvatica* L.) seedlings were grown in greenhouses ventilated with ambient, unfiltered air (AA) and filtered, almost aerosol free air (FA). Leaves were washed to analyze surface aerosols. Weight loss during desiccation was measured. Cut leaves were dried and then sprayed with deuterated water. The length of the drying process varied, each group representing a specific water potential.

Deposited aerosols included mainly sea salt, potassium, nitrate, and sulfate, but little ammonium. AA leaves with aerosols dried out more quickly than FA leaves, possibly indicating the establishment of continuous stomatal water connections across stomata. FWU was found to be highest at the beginning of the drying process and was stronger for AA than for FA leaves supporting the hypothesis.

Direct impact of atmospheric aerosols on the ecophysiology of *Cinnamomum camphora*

ID: 195

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Aerosols may have a direct impact on plants by hygroscopic action of accumulated deposited particles on foliage, causing 'hydraulic activation of stomata (HAS)' and liquid stomatal water loss. This process produces unproductive transpiration and reduces water use efficiency (Burkhardt, 2010).

We studied the possible direct impact of aerosols on carbon assimilation, plant water use and gas exchange of camphor (*Cinnamomum camphora*) trees in the field and in greenhouse studies. Leaves in the canopy of two 35-year-old camphor plantations, one near the east coast (clean air), the other near the west coast (polluted air) of Taiwan were assessed. Camphor seedlings were grown at University of Bonn, in greenhouses ventilated with ambient air (AA) and filtered air (FA). Gas exchange was measured, particularly the response of stomatal conductance (g_{sw}) to increasing vapor pressure deficit (VPD), as well as minimum epidermal conductance (g_{min}), and foliar carbon isotopes ($\delta^{13}C$).

Results from the field and greenhouse studies are currently analyzed and will be presented and discussed on the poster. Environmental conditions showed influences on g_{min} determination. Carbon isotopes indicated differences in the field sites and in the greenhouses. Differences were also found between greenhouses for g_{sw}–VPD measurements, particularly at lower VPD set points (< 1 kPa).

Can trees take up airborne nanoparticles through their leaves?

ID: 198

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Long-term measurements of heavy metals pollution from ICP Forests, ICP Vegetation and ICP Integrated Monitoring are mainly focusing on soils and mosses. However, heavy metals and atmospheric pollutants were also found in tree stems. We ran a greenhouse experiment, using variously surface-charged gold nanoparticles (AuNPs, 40 nm), a) to determine if nanoparticles are taken up by European beech (*Fagus sylvatica* L.) and Scots pine (*Pinus sylvestris* L.) seedlings mainly through the roots or through the leaves, and b) to understand if the surface-charge affects the nanoparticle transport within trees.

AuNPs were supplied once to leaves or to roots separately. For the leaf supply, AuNP concentrations were higher in leaves and stems than in roots. For the root supply, higher gold concentration was found in the roots than in the stems, whereas gold was not detected in the leaves. Overall, AuNP concentrations were higher in beech than in pine, most likely due to higher stomatal activity in beech, resulting in a higher nanoparticle uptake into the leaves. Concentrations of variously charged AuNPs were significantly higher between root and leaf supply and among different tissues ($P < 0.05$).

Trees can take up nanoparticles through both roots and leaves. However, our results confirm that nanoparticles are transported faster from the leaves than from the roots and that the surface-charge may affect the nanoparticle delivery. This study provides a better mechanistic understanding of heavy metal and atmospheric pollutant fluxes in trees, which may be an important contribution when assessing the risk of heavy metals and atmospheric pollutants on forest ecosystems.

Can forest trees take up nanoplastic from their roots and transport them in their aboveground tissues?

ID: 200

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Plastic contamination of ecosystems has increased dramatically over the last decades, raising concerns about negative impacts of plastic particles on aquatic and terrestrial systems. Originally reported as large fragments (macroplastic), the research focus shifted to micro (< 5mm) and more recently to nanoplastic particles (< 1000 nm) (Allen *et al.* 2019). We investigate nanoplastic uptake in the roots of seedlings (1-2 years old) of three different tree species and assessed their transport to different aboveground tissues of the tree. Parts of the main roots of silver birch (*Betula pendula* Roth), sessile oak (*Quercus petraea* Matt. (Liebl.)), and Norway spruce (*Picea abies* (L.) Karst.) were immersed for one or four days into a nutrient solution containing ^{13}C-labelled nano- sized polystyrene (^{13}C-nPS; 99% ^{13}C, d = 28 ± 8. nm). Stable isotope analysis of C showed significant ^{13}C-enrichment in the part of the root that was immersed after one day of treatment in *P. abies* (p= 0.000) and after four days of treatment in *Q. petraea* (p=0.049). No significant ^{13}C-enrichment was found in leaves or in root parts that were not in direct contact with the nanoplastic suspensions. However, the stem of *B. pendula* showed significant ^{13}C-enrichment after one day of treatment (p=0.007). We speculate that ^{13}C-nPS can be taken up in the central cylinder of the root and subsequently conveyed by acropetal transport via the xylem.

Missing adequate growth response of coniferous tree species to climate warming at the Alpine forest line

ID: 203

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There is extensive evidence that at high altitude low temperature during the growing season is directly limiting metabolic activity, which leads to growth reductions and ultimately to formation of the treeline. Climate warming is therefore expected to favor tree growth at this distinctive boundary of tree existence. We developed tree ring series from co-occurring conifers (n >500 trees) along seven alpine treeline ecotones in the Eastern Central European Alps to evaluate whether long-term growth trends are in line with climate warming recorded during the last century. Unexpectedly, results revealed that recent increase in air temperature is not adequately reflected in increase of basal area increment at the forest line (Oberhuber *et al.,* 2020). We explain missing adequate growth response by strengthened competition for resources in increasingly denser stands most likely leading to a shift in carbon allocation to belowground organs.

Furthermore, there are indications that climate factors beyond the growing season also affect radial stem growth. Our study thus primarily highlights the importance of evaluating species-specific morphological and physiological responses of the root system to competition. Such assessments are important because they help predict treeline dynamics and carbon sequestration under an increasingly warmer climate.

10-year monitoring of ecosystem responses to understory removal in a dry oak-pine forest of Central Valais, Switzerland

ID: 212

Vollenweider, Pierre (1); Schleppi, Patrick (1); Vittoz, Pascal (2)

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Forests at low elevation in the Alps have been experiencing not only important temperature increase but also drastic land-use changes in the last century. The main objectives in the Salgesch experiment started in 2010 in Central Valais, Switzerland, were to investigate the 1) competition effects for water and nutrients from understory recruitment in previously grazed forests and 2) interaction between land-use change and climate drivers regarding the vitality of dominant Scots pines. Therefore, 12 circular plots 6 m in diameter and centered on a dominant tree, with the woody understory either removed (RM) or left as control, were established in a dry oak-pine forest. For the last 10 years, responses in the soil properties, ground vegetation and dominant Scots pine have been monitored. The RM treatment caused a steady increase in the water availability and temperature at all soil depths; however, the biological activity was reduced. In the ground vegetation, the abundance/dominance of xero-thermophilic species and xeromorphy of foliage traits were increased. The treated pines showed a growth release and larger sap flows, already fading after 5 years of treatment despite a stable water supply. They also had a larger foliage surface and the needle traits indicated reduced xeromorphy overall, with yearly adjustments. Hence, the different ecosystem components have shown contrasted responses to experimental simulation of past land-use conditions. Recent evolution suggests that the land-use and climate factors co-determine the responses currently observed in dominant pine trees.

Conference Program

Program	Monday, 7 June 2021		ID
15:00-17:00	Guided Tour through the City of Zurich	Moderator: Peter Waldner	
18:00-20:00	Welcome Reception at the Landesmuseum Zurich	Moderators: Peter Waldner & Marcus Schaub	

Program	Tuesday, 8 June 2021		
08:00-09:00	Registration & coffee		
09:00-09:30	Opening / welcome	Moderator: Marcus Schaub	
09:00-09:05	Opening of FORECOMON 2021	Marcus Schaub	
09:05-09:10	Welcome by WSL Director	Christoph Hegg	
09:10-09:15	Welcome by the Federal Office for the Environment	Sabine Augustin	
09:15-09:20	Welcome by ICP Forests Chair	Marco Ferretti	
Session 1	**The Classics - Long-term trends in forest ecosystem processes as affected by air pollution, drought or other extreme weather events**	**Moderator: Marco Ferretti**	
09:30-09:50	Keynote: Accounting for time: long-term effects of N addition on forest biogeochemistry and C sequestration	Federico Magnani	187
09:50-10:05	Nitrogen deposition is the most important environmental driver of continental-scale forest growth in Europe	Sophia Etzold	183
10:05-10:20	Chronic nitrogen deposition effects under climate change in an Austrian karst catchment	Thomas Dirnböck	202
10:20-10:50	Coffee break		
10:50-11:05	Acidification and recovery of forest ecosystems in central Japan during the past few decades	Hiroyuki Sase	159
11:05-11:20	What is the current carbon storage and future carbon sequestration potential of forest soils in the UK?	Elena I Vanguelova	186
11:20-11:35	Trends in water chemistry in Europe and North America	Heleen A De Witt	189
11:35-12:20	Poster pitching; 20 x 2 min per poster slide (see Program for Poster Pitching)	Moderator: Marco Ferretti	
12:20-12:25	Wrap up of Session 1	Co-moderator: Lars Vesterdal	
12:25-13:30	Standing lunch		
Session 2	**The Exchange - Methodologies and models applied within ICP Forests and beyond**	**Moderator: Kai Schwärzel**	
13:30-13:50	Keynote: Responses of Swiss forests to long- and short-term environmental changes	Nina Buchmann	182
13:50-14:05	The Dimensions of the Phosphorus status of European beech forest ecosystems	Friederike Lang	217
14:05-14:20	Ectomycorrhizal fungal communities and functional genes drive forest productivity across the ICP Forest Network	Mark Anthony	191
14:20-14:35	The water budget of forests – the big unknown outside of our intensive monitoring plots?	Heike Puhlmann	132
14:35-15:05	Coffee break		

15:05-15:20	Linking in situ measurements with remote sensing in Level I and II ICP Forests network in Romania: Prototyping a national forest monitoring system	Ovidiu Badea	178
15:20-15:35	Canopy and growth response of beech trees after the 2018 drought in Switzerland	Brigitte Rohner	142
15:35-15:50	Continuous approximation of leaf area index and phenological phases within deciduous forests based on temperature measurements	Anita Christine Zolles	196
15:50-16:05	Long-term irrigation in a drought-stressed pine forest accelerates carbon cycling and leads to vertical redistribution of soil organic carbon pools	Claudia Guidi	167
16:05-16:20	Where does the water come from? Variations in soil water uptake depth in a beech forest during the 2018 drought	Arthur Gessler	120
16:20-17:05	Poster pitching; 20 x 2 min per poster slide (see Program for Poster Pitching)	Moderator: Kai Schwärzel	
17:05-17:10	Wrap up of Session 2	Co-moderator: Nathalie Cooles	

Program	**Wednesday, 9 June 2021**		
Session 3	**The Mechanisms - Air pollution effects on forest ecosystem functioning under extreme and/or prolonged unfavourable climate and weather conditions**	**Moderator: Stefan Fleck**	
08:30-08:50	Keynote: Forest soil carbon cycle under drought-linking experiments, monitoring and natural gradients across Switzerland	Frank Hagedorn	154
08:50-09:05	Beech nutrition depends on defoliation, soil and climate across Croatia	Mladen Ognjenović	211
09:05-09:20	Mechanisms explaining N stock and acidity dynamics in German forests between 1990 and 2007 and possible climate change feedbacks	Stefan Fleck	164
09:20-09:35	Foliar uptake of gaseous elemental mercury by European forests	Lena Wohlgemuth	146
09:35-10:05	Coffee break		
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10:20-10:35	Ectomycorrhizal functionality after 5 years of summer drought in a mature forest	Fabian C Weikl	144
10:35-10:50	Patagonian forests vulnerability to climate change: Consequences for management and conservation	Guillermo Martinez Pastur	140
10:50-11:05	Environmental factors, leaf traits and ozone visible symptoms are interrelated in Viburnum lantana	Michele Faralli	216
11:05-12:00	Poster pitching; 20 x 2 min per poster slide (see Program for Poster Pitching)	Moderator: Stefan Fleck	
12:00-12:05	Wrap up of Session 3	Co-moderator: Bruno de Vos	
12:05-12:15	Closing up of FORECOMON 2021	Marco Ferretti	
12:15-13:15	Lunch	Guides: Maria Schmitt & Anne Thimonier	
13:15-16:00	Guided Tours on WSL Campus		
19:00	Conference & Task Force Meeting Dinner in Zurich		

Program	Thursday, 10 June 2021	
08:30-12:35	37th ICP Forests Task Force Meeting (upon invitation)	
12:35-14:00	Lunch	Moderators: Marco Ferretti & Kai Schwärzel
14:00-16:30	37th ICP Forests Task Force Meeting	

Program	Friday, 11 June 2021	
09:00-12:00	37th ICP Forests Task Force Meeting	Moderators: M. Ferretti & K. Schwärzel
12:00	Closing of the 37th ICP Forests Task Force Meeting	
12:00-14:00	Lunch	
14:00-20:00	Excursion into Inner Alpine Forests, leaving from WSL	Guides: Peter Waldner, Esther Thürig, Peter Brang

Program	Saturday, 12 June 2021	
All day	Excursion into Inner Alpine Forests (continued)	Guides: Peter Waldner, Esther Thürig, Peter Brang
20:00	Closing of Excursion at Zurich Main Train Station	

Poster Pitching Program

Program	Tuesday, 8 June 2021		ID
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11:35-12:20	European beech and oak show different resource dynamics in mast years	Nussbaumer, Anita	112
11:35-12:20	Monitoring of mercury in tree foliage in Austria	Tatzber, Michael	121
11:35-12:20	Fluxes and stocks of nitrogen in the litterfall and soil in evergreen broadleaves and fir forests	Michopoulos, Panagiotis	123
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11:35-12:20	Site types revisited: comparison of traditional Russian and Finnish classification systems for European Boreal forests	Pohjanmies, Tähti	135
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11:35-12:20	Forest monitoring from the cloud - Soil water content case study	Pascu, Ionut-Silviu	158
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11:35-12:20	Assessing the risk of elevated nitrate leaching from Swiss forests	Waldner, Peter	180
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Session 2	**The Exchange - Methodologies and models applied within ICP Forests and beyond**	**Moderator: Kai Schwärzel**	
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