NORDIC DENDROMETER NETWORK

1st Meeting

Book of Abstracts

13-15th October 2025

Ås, Norway

This meeting would not have been possible without the support of:

Convenor: Danielle Creek, Norwegian University of Life Sciences, Norway

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SNS Network Grant 2025: Danielle Creek, Line Nybakken, Jane Uhd Jepsen, Morgane Merlin, Johannes Edvardsson, Maartje Klapwijk, Ólafur Eggertsson, Samuli Junttila, Yann Salmon, Zuosinan Chen, Anders Ræbild, Mukund Palat Rao, Tommaso Jucker, Jan Tumajer, Jan Krejza

Monday 13th October

Time	Session / Item	Talk #	Speaker	Title
09:00–09:10	Welcome / Housekeeping			
09:10–09:40	**Keynote 1**	1	Kathy Steppe	TreeWatch technology uncovers the hidden stories of trees
09:40–09:45	Talk	2	Gaby Inga Guillen	Quantifying the importance of growth rate, growth occurrence and growth phenologhy for annual wood increment in Czech Republic
09:45–09:50	Talk	3	Marcin Klisz	Inter-population variation of seasonal stem size variation at the edge of European beech distribution (Eastern Europe).
09:50–09:55	Talk	4	Martin Weibull	Dendrometer analysis of tree water dynamics and radial growth of Norway spruce in Hyltemossa ICOS site
09:55–10:00	Talk	5	Radim Matula	A network of automatic dendrometers for monitoring climate impacts on tree growth and carbon uptake in European and eastern US forests
10:00–10:05	Talk	6	Johannes Edvardsson	Monitoring Tree Growth on Peatlands- Combining Dendrometers, Wood Anatomy, and Microcoring
10:05–10:10	Talk	7	Alma Piermattei	A new perspective on tree growing season determination
10:10–10:15	Talk	8	Olafur Eggertsson	Radial growth studies on native Birch (Betula pubescens) in Iceland
10:15–10:20	Talk	9	Ewa Zin	Tree circumference dynamics in multi-species old-growth forest stands of Białowieża, NE Poland (2016–2020), recorded by band dendrometers
10:20–10:25	Talk	10	Francesco Marotta	Impacts of a changing climate on past and future tree growth at the treeline
10:25–10:30	Talk	11	Tommaso Jucker	Resilience and adaptability of Africa’s tropical dry forests to climate change
10:30–11:30	Coffee Break & Icebreaker			
11:00-11:25	**Dendrometer basics**		**Danielle, Natkon, Tomst**	**Dendrometer Basics- types, installation tricks and techniques, come with all your installation questions!**
11:30–11:35	Talk	12	Nikola Tričković	Tracking Tree Growth Dynamics with Dendrometers on ICP Forests Level II plots in the Czech Republic
11:35–11:40	Talk	13	Harold Hauzeur	TreePulser: Radial Growth Dynamics and Physiological Responses of Temperate Tree Species under Climatic Drivers
11:40–11:45	Talk	14	Jane Jepsen	Dendrometer-based assessment of the impact of insect defoliation and climate on growth in sub-arctic mountain birch
11:45–11:50	Talk	15	Anna Candotti	Stem growth cessation detected by dendrometers precedes hydraulic failure in bark beetle–infested Norway spruce
11:50–11:55	Talk	16	Jaime Sebastián Azcona	MortaliTree - Characterization of key physiological traits in tree decay and mortality processes in Mediterranean forests
11:55–12:00	Talk	17	Eva Verena Müller	Validating Species-Specific Drought Stress in SWAT+ Using Dendrometer Data

12:00–12:05	Talk	18	Enrico Tomelleri	Water-use strategies and growth responses to drought in montane Norway spruce forests
12:05–12:10	Talk	19	Alessandro Bizzarri	Dendrometers as useful tool to help deciphering the Fate of Burned Trees After a Forest Fire
12:10–12:15	Talk	20	Yuwen Zhang	Does physiology alone explain Betula pendula recovery from drought?
12:15–12:20	Talk	21	Mukund Rao	Atmospheric aridity decouples carbon assimilation and growth in temperate deciduous oaks
12:20–12:25	Talk	22	Paal Krokene	Bark beetle monitoring
12:25–12:30	Talk	23	Nikolaus Obojes	Characterizing tree growth and drought impact along an elevation gradient in the Alps
12:30–14:30	Lunch (12:30–14:30)			
14:30–15:00	**Keynote 2**	24	Roman Zweifel	The TreeNet network – from stem radius data to signals of growth and drought
15:00–15:05	Talk	25	Holger Lange	Measuring tree transpiration with point dendrometers?
15:05–15:10	Talk	26	Christina Hackmann	Dendrometer data as a multitool - analyzing tree drought response, growth phenology, and spring-time rehydration
15:10–15:15	Talk	27	Daniela Nemetschek (Krebber)	Towards understanding the links between tree growth, canopy phenology, whole-ecosystem carbon fluxes and interannual climate variation in temperate forests
15:15–15:20	Talk	28	Johannes Cunow	Root Growth Synchronization in Snow Covered Boreal Forests
15:20–15:25	Talk	29	Zuosinan Chen (Zoey)	Boreal forest ecohydrology under changing snow-rain seasonality: in-situ continuous water isotope and water flux measurements
15:25–15:30	Talk	30	Celina Nilsen	Above- and Belowground processes affecting tree health
15:30-16:15	Coffee Break			
16:15–16:20	Talk	31	Mianzhi Wang	Partitioning of nighttime transpiration and stem water refilling: linking nighttime transpiration, refilling, and stem activity
16:20–16:25	Talk	32	Line Nybakken	«Skogbrukerforskning» an advanced citizen science project
16:25–16:30	Talk	33	Anita Zolles	Ongoing Analyses and Collaborations at BFW (Austria)
16:30–16:35	Talk	34	Yann Salmon	Introduction to the Finnish dendrometer network
16:35–16:40	Talk	35	Danielle Creek	BorealNet-Norwegian Growth Monitoring Network
16:40–16:45	Talk	36	Roman Plichta	Eight Years of Experience with TOMST Dendrometers
16:45–16:50	Talk	37	Olusegun (Segun) Olaitan Akinyemi	The potential of hyperspectral imaging and deep learning for advancing tropical dendroclimatology

16:50–16:55	Talk	38	Aida Cuni-Sanchez	Fog water and tree growth in tropical montane forests
16:55–17:00	Talk	39	Roman Mathias Link	
17:00–17:10	Conclusion/Housekeeping			
19:30-23:00	SOCIAL dinner			

Tuesday 14th	**Workshops and Discussions**			
TIME START	**TIME END**	**WHAT**	**WHO**	**TIME**
08:25	08:30	Welcome, coffee		
Workshop sessions Part A				
08:30	09:00	Building Effective Systems for Long-Term Ecological Data Management	Anita Zolles	30
09:00	10:30	Inside TreeNet: Database Structure, treenetproc.R, and Nowcasting	Roman Zweifel	90
10:30	11:00	coffee		30
Discussion Sessions				
11:00	12:00	**Topic 1: Dendrometer choices and data analysis**- how do methods compare, standardised protocols, current limitations...?	Holger, Mukund, Alma	60
12:00	13:00	**Topic 2: Integrating dendrometer data with other data streams.** Model decisions and underlying assumptions (zero-growth, freeze/thaw, TWD)	Yann, Daniela, Mianzhi	60
13:00	14:00	Lunch		60
14:00	15:30	**Topic 3: Where do we go from here?** Formalise the network, datasharing/database creation/future funding? Open session.	Tommaso, Danielle	90
15:30	15:45	Coffee		15
Workshop sessions Part B				
15:45	16:45	Combining dendrometer data with other data streams	Mukund Rao	60
16:45	17:30	DendroAnalyst	Nikolaus Obojes	45
17:30	18:00	PLOTeR	Roman Plicta	30

Wednesday 15th		**Field visit**	
TIME START	**TIME END**	**WHAT**	**WHO**
08:00	09:20	depart Oslo S to Hurdal ICOS	bus
09:20	11:00	Hurdal ICOS	
11:00	11:30	Travel Hurdal ICOS to Skrukkelia forest site	bus
11:30	12:30	Skrukkelia forest visit	
12:30	12:50	Travel Skrukkelia to Hurdalssjøen Hotell	bus
13:00	15:00	Lunch Hurdalssjøen Hotell	
15:00	15:30/40	Hurdalssjøen Hotell to Oslo airport	bus
15:30	16:30	Travel Oslo airport to Oslo S	bus

The potential of hyperspectral imaging and deep learning for advancing tropical dendroclimatology

Olusegun Olaitan Akinyemi[1], *Muhammad Hassaan Farooq Butt*[1], *Zenebe Girmay Siyum*[2], *Buruh Abebe Tetemke*[2], *Abebe Damtew*[2], *and Meley Mekonen Rannestad*[1]

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Abstract

Tropical dendroclimatology faces challenges due to complex species-specific phenological cycles, irregular growth patterns, and limited methodological tools. We are testing a novel approach to tropical dendroclimatology by combining hyperspectral imaging with deep learning techniques to characterize growth dynamics in key tropical species. One of the species we are studying, *Faidherbia albida*, exhibits an inverted phenology: it sheds its leaves during the rainy season and remains green in the dry season. Similarly, we are investigating *Boswellia papyrifera* which typically sprouts its leaves just before the onset of the rainy season. This species is notable for its unique phenological cycle: reproductive activity, including flowering and fruiting, takes place during the dry season, while leaf shedding and sprouting are timed to coincide with the approach of the rains. Although the exact timing can vary with location and local environmental conditions, the leaves generally emerge in anticipation of the rainy season. We intend to supplement our image-based measurements with point dendrometers to characterize fine-scale growth dynamics. This combined approach will help pinpoint the species optimal growing season and the associated climatic conditions, as well as expand methodological options for tropical dendroclimatology.

MortaliTree - Characterization of key physiological traits in tree decay and mortality processes in Mediterranean forests

Jaime Sebastián Azcona

IRNAS-CSIC, Spain

Recent years have witnessed a rise in forest decline and tree mortality across the globe, particularly in warm and dry regions such as Doñana and Sierra de Guadarrama National Parks in Spain. In both areas, several tree species are experiencing widespread symptoms of decline. Drought-induced hydraulic failure has been identified as a critical mechanism leading to tree death.

The *MortaliTree* project aims to investigate these decline and mortality episodes by identifying the physiological drought-survival thresholds in two affected species: *Pinus pinea* in Doñana and *Pinus sylvestris* in Sierra de Guadarrama. We combine field-based ecophysiological measurements with mechanistic modeling and historical climate data to assess whether these species have already surpassed their hydraulic limits, thus clarifying the causes of current decline patterns.

The project objectives include (i) physiological characterization and threshold determination for drought survival, (ii) environmental monitoring of growth and water status, and (iii) simulation of past and future drought scenarios to predict mortality risk. By integrating physiology, long-term monitoring, and modeling, *MortaliTree* provides a framework for assessing forest vulnerability under climate change.

Dendrometers as useful tool to help deciphering the Fate of Burned Trees After a Forest Fire

Alessandro Bizzarri[1], Alessio Giovannelli[2], Claudia Cocozza[1]

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Mediterranean ecosystems are highly vulnerable to climate change, particularly to recurrent forest fires that threaten forest health and biodiversity. Prompt assessment of post-fire tree vitality is essential for addressing forest restoration and management strategies based on nature-based solutions (NBS). This project focuses on evaluating physiological responses of *Pinus pinaster* trees before and after prescribed fire by assessing effects on metabolite patterns and stem growth dynamics. Moreover, the study aims to identify early indicators of irreversible damage in fire-affected trees. A field experiment was established in managed stands in Tuscany (Italy) by modulating different fire intensities. The 2024 and 2025 growing seasons of fifteen trees were monitored by using high-resolution dendrometers, custom-built at the University of Florence using Arduino-based technologies. These devices continuously and non-invasively monitored stem diameter variations, offering a precise proxy for water use and stem growth. Complementary data will be collected through microcore sampling to assess cambial activity and carbohydrate allocation (starch and soluble sugars). These measurements provide an integrated understanding of tree physiological status and responses to fire-induced stress. By using dendrometers as a key tool, this research supports the development of rapid assessment methods for tree vitality, contributing to informed decision-making in forest restoration across Mediterranean regions.

Mediterranean region; Pinus pinaster; Dendrometers

Stem growth cessation detected by dendrometers precedes hydraulic failure in bark beetle–infested Norway spruce

Anna Candotti, Henrik Hartmann, Enrico Tomelleri

Free University of Bozen-Bolzano, Italy

Keywords: Picea abies, Ips typographus, disturbance, tree mortality

Bark beetle infestations can cause rapid mortality in Norway spruce, yet the sequence of physiological changes leading to death is not fully understood. We used high-resolution automatic band dendrometers, combined with sap flux sensors, to assess stem growth and water transport responses in mature spruce during infestation and in trees subjected to simulated attack via girdling or compression in the Latemar Forest (Eastern Alps, 2023–2024). In infested trees, dendrometer records showed cessation of radial growth within days of infestation, while sap flux density (Fd) declines >40% occurred weeks later.

Infested trees also exhibited earlier stomatal closure at lower vapor pressure deficit (VPD) and ~50% reduction in conductive sapwood depth compared to healthy trees. In contrast, girdled and compressed trees maintained stem growth and Fd over two growing seasons, showing no mortality, indicating that mechanical phloem disruption alone does not reproduce the rapid decline observed in beetle-infested trees. These findings support the hypothesis that bark beetle–induced mortality is preceded by a rapid reallocation of resources away from cambial growth toward defence processes, before detectable hydraulic failure. Our results demonstrate that high-resolution dendrometers can provide an early, sensitive indicator of bark beetle impact, capturing growth cessation that precedes hydraulic failure. This highlights the value of radial growth monitoring for early detection, mechanistic understanding, and improved modelling of European bark beetle–driven Norway spruce mortality.

Boreal forest ecohydrology under changing snow-rain seasonality: in-situ continuous water isotope and water flux measurements

Zuosinan Chen[1,*], Jiayuan Li[1], Hannu Marttila[1], Riku Paavola[1,2], Pertti Ala-Aho[1]

Water, Energy and Environmental Engineering Research Unit, University of Oulu, Finland

High-latitude regions are warming more strongly and faster than the global average, with apparent changes in snow-rain seasonality. These not only directly change the total amount and the timing of regional water inputs, but could also alter how water moves through and exits boreal forest ecosystems. However, how tree water uptake strategies and the boreal forest water cycle respond to the ongoing rapid change in seasonal precipitation is not well understood. While the methods and equipment for measuring forest water fluxes are well developed, the stable water isotope technique is currently the best tool available to researchers. After extracting water from the target water pool (e.g., xylem water from tree cores or branches) and the possible water sources (e.g., soil water from different soil depths), the water isotopic signal measured by isotope analyzers tells where and how much the target water comes from. However, such sampling method is discrete, destructive, and time-consuming, which is not ideal for investigating the highly dynamic forest (eco)hydrological processes, especially for understanding the underlying ecophysiological mechanisms. Therefore, for the first time in northern environments, we combine the innovative in-situ continuous measurements and event-based sampling of stable water isotopes and water fluxes along the entire water movement pathway in a typical boreal forest (Scots pine, *Pinus sylvestris*), i.e., snow (snowfall-snowpack-snowmelt), rain (rainfall-throughfall and stem flow), soil (vertical and horizontal profiles), roots, and trunks. Meanwhile, the 6-year snowpack manipulation allows the long-term effect of reduced and additional snow on root and tree water uptake to be tested.

Keywords: *stable water isotope, tree water uptake, forest water cycle, precipitation seasonality, boreal forest*

BorealNet-Norwegian Growth Monitoring Network

Danielle Creek*, Line Nybakken, Johan Asplund, Isabella Børja, Attila Nemes, Hans Ole Ørka, Terje Gobakken, Martin Bader, Holger Lange, Ole Martin Bollandsås, Rachel Kuzmich, Junbin Zhao, Volkmar Timmermann

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The boreal zone is warming twice as fast as the global average due to climate change, however, the ways in which these forest ecosystems are responding to the rapidly changing conditions are poorly understood. Forests cover about 38 percent of Norway's land area, or about 122 000 square kilometres, of which all are classified as part of the boreal forest biome. Declines in the growth and vitality of boreal trees will have profound impacts on forest ecosystems, reducing biodiversity, limiting the ability of trees to sequester carbon and risk the financial stability of the forestry industry. There is an urgent need to predict the impacts of the rapidly changing climate on boreal forest species to ensure the ongoing preservation and correct management of these areas.

In this short talk, I will introduce to you BorealNet, a new tree growth monitoring network across Norway, with the first sites established in 2022. We have installed autonomous high-resolution dendrometers and microclimate sensors across key forested areas collecting tree growth data from more than 50 individual forest plots across Norway.

Beyond ground-based measurements, we connect tree growth with remotely sensed spectral indices of forest productivity and stress, and LiDAR-derived structural information obtained from drone surveys. By further combining this data with detailed analyses of soil physical and chemical properties and tree rooting dynamics, we aim to obtain a multidimensional understanding of boreal forest growth, health, and stress tolerance, linking processes from soil to space. BorealNet will fill critical knowledge gaps on the impact of climate extremes and climate-related disturbances on boreal forest ecosystems through coordinated, long-term, ecosystem-based research and monitoring efforts.

Fog water and tree growth in tropical montane forests

Moses Sainge- Department of Natural Sciences, Manchester Metropolitan University, UK

Aida Cuni-Sanchez - Department of International Environment and Development Studies (Noragric), Faculty of Landscape and Society, NMBU.

Abstract:

Fog can be an important source of water in tropical montane forests. While it can foster tree growth, limited light availability during foggy periods can also hamper photosynthesis and therefore, tree growth. In this study we investigated the relationship between fog water inputs and tree growth in Loma mountains in Sierra Leone. We monitored fog, temperature and rainfall, and tree growth using point dendrometers for 12 months.

We found that tree growth varied across elevations and species, with higher growth rates for pioneer species at lower elevations. Results suggest that fog reduces tree growth, but further work is needed as high variation between individuals was observed.

Root Growth Synchronization in Snow Covered Boreal Forests

Authors: Johannes Cunow[1] & Gesche Blume-Werry[1]

[1]Department of Ecology, Environment and Geoscience, Umeå University, Umeå SE

Root systems are critical for tree stability, resource acquisition, and forest resilience, and carbon storage[1]. Yet, we do not know whether all roots grow at the same time. While growth asynchrony is well established between shoots and roots[2,3] or among leaves, twigs, and stems[4], coarse and fine roots have not been compared directly. Coarse and fine roots occupy the same soil environment but fulfill distinct roles with distinct growth regulation. Fine roots elongate with primary growth while coarse roots expand radially with secondary growth. We ask: 1) Is radial root growth (in coarse roots) synchronized with primary, elongational growth (in fine roots) in boreal trees, and 2) Do both processes respond similarly to shifts in soil conditions, such as those induced by snow cover? We combine hermetically sealed root dendrometers with high-resolution, AI-assisted minirhizotrons to deliver the first in-situ comparison of coarse and fine root growth dynamics under variable soil conditions. Preliminary insights will be presented.

Keywords: *Terrestrial Plant Ecology, Functional Root Ecology, Temporal Soil Ecology, Greenhouse Gas Fluxes, Herbivory, Reindeer, Snow Cover Changes, Minirhizotron, Image Processing R Package, (Secret Hydrologist)*

Webpage: https://github.com/jcunow

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Monitoring Tree Growth on Peatlands – Combining Dendrometers, Wood Anatomy, and Microcoring

Johannes Edvardsson*, Loïc Francon, Silvia Piccinelli, Christophe Corona, Markus Stoffel

*Department of Geology, Lund University, Sweden.

Keywords: Band dendrometers, Sweden, Peatlands

Abstract: Between 2018 and 2021, around 40 band dendrometers were installed on Scots pines (*Pinus sylvestris* L.) growing on four southern Swedish peatlands with established research infrastructure. These dendometers were complemented by additional instruments on nearby mineral-soil pines. Interpreting data from the extremely slow-growing peatland trees proved challenging, prompting a methodological study that combined dendrometry with quantitative wood anatomy.

We developed an integrative framework to quantify tree growth responses to local temperature, precipitation, and water-table fluctuations by (1) establishing a 60-year chronology of cell-wall thickness and tracheid size, (2) recording hourly diameter variations since 2018 with 30 band and 15 point dendrometers, and (3) studies of wood formation through microcoring during two growing seasons.

Our findings demonstrate the value of combining invasive and non-invasive approaches to disentangle irreversible growth from reversible stem-size fluctuations, which dominate in peatland trees. We show clear contrasts between peatland and mineral-soil pines in the timing of wood formation, climate sensitivity, and growth rates. Importantly, monitoring wood formation improves our understanding of climate–growth relationships and provides new insights into future carbon dynamics under varying hydroclimatic regimes. These results will also help us interpret tree growth responses to ongoing peatland rewetting projects that we are monitoring on two peatlands.

Information: My name is Johannes Edvardsson, and I'm a researcher at Lund University in Sweden. I installed some dendrometers in Lithuania in 2013 during my postdoc and later purchased and installed additional ones after 2017 when I became a researcher in Lund. The idea was that these would be used within the framework of a PhD project, but that never materialized. I therefore intended for someone else to work with these dendrometers, but at the same time I have maintained them and downloaded data from them all these years without completing or publishing it. I would now like to do so and am also open to new collaborations, as I find it difficult to make enough time myself.

Radial growth studies on native Birch (Betula pubescens) in Iceland

Ólafur Eggertsson

Agricultural University of Iceland and Land and Forest Iceland

Dendrometers are high-resolution instruments that measure continuous changes in stem diameter of trees. They provide valuable insights into tree growth dynamics by capturing both short-term fluctuations (caused by water status and transpiration) and long-term radial growth associated with cambial activity and wood formation.

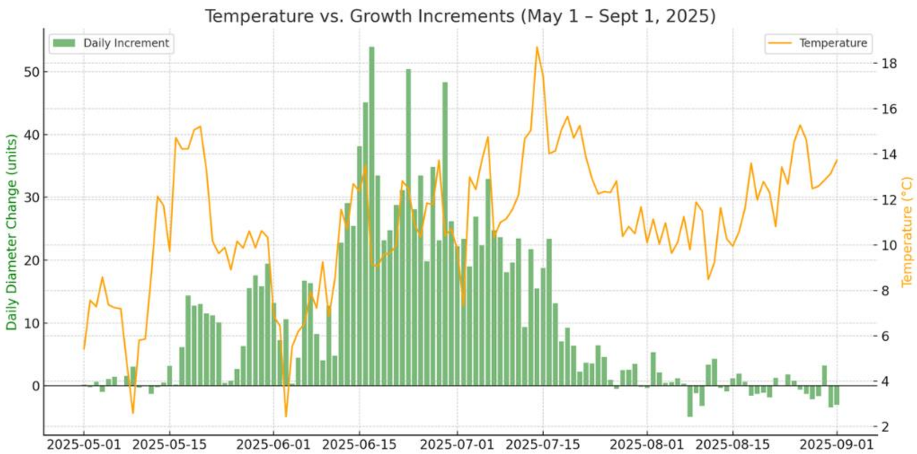
In Iceland, I have used point dendrometers from ECOMATIK (RD), but more recently I have been working with dendrometers from Tomst. In my experience, the Tomst dendrometers are more practical, as they log data automatically and have a long-lasting battery.

My most recent study involves data for the native Birch (Betula pubescens) in Iceland. The dendrometer data were collected at 15-minute intervals together with temperature measurements.

The raw series were combined to daily values to calculate mean temperature, minimum and maximum temperature, and daily stem diameter. From this, daily increments in stem diameter were derived, allowing identification of the onset and ending of radial growth during the 2025 growing season.

Analysis of the dendrometer data from April to September 2025 shows clear patterns of stem radial growth. Growth onset occurred on 15 May 2025, shortly after a period of rising temperatures in spring. Growth continued throughout the summer months and stopped in early August marking the end of the active growing season. But some cambial activity occurred until middle of August.

Daily growth increments varied considerably, with the highest rates generally observed during periods of warmer weather in June and July. Temperature fluctuations corresponded closely with changes in daily increments, highlighting the strong influence of climatic conditions on growth dynamics in native birch in Iceland. Correlation analysis showed a weak but positive association between daily increments and mean temperature ($r = 0.26$), suggesting that growth was generally favoured by warmer conditions but constrained during periods of water stress and cold days. I will continue the measurements on the same trees in the coming years.



Quantifying the importance of growth rate, growth occurrence and growth phenologhy for annual wood increment in Czech Republic

Authors: **Gaby Inga Guillen**, Jan Tumajer

Charles University, Czechia

Abstract:

In seasonal climates, wood formation occurs episodically during periods favourable for cell division and expansion. Temperature and moisture interact throughout the growing season to determine i. whether growth can proceed and ii. the rate at which radial growth occurs. To investigate these dynamics, we installed dendrometers in dry, moderate, and cold forests across the Czech Republic to record fine-scale stem size variation (radial growth and fluctuations in internal stem water content in conifers (*Pinus sylvestris*, *Picea abies* and *Larix decidua*) and broadleaves species (*Fagus sylvatica* and *Quercus r*obur). This approach allows us to assess how growing season duration, the frequency of daily growth events, and the rate of growth during these events determine the total annual growth, and how these varies across climatic gradients.

Keywords: growth rate, growth occurrence, growth phenology, intra-annual growth

Dendrometer data as a multitool - analyzing tree drought response, growth phenology, and spring-time rehydration

Christina Hackmann[1,2]*, *Johan Bärwald*[1], *Christoph Leuschner*[2,3], *Martina Mund*[4], *Magali Nehemy*[5], *Sharath Paligi*[3], *Kerstin Pierick*[1,6], *Holger Sennhenn-Reulen*[7], *Christian Ammer*[1,2]

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High-resolution dendrometers are versatile tools in forest and environmental sciences. We present use cases of band dendrometer data at daily and sub-daily scales to analyze (1) tree drought response, (2) growth phenology, and (3) spring-time rehydration, addressing key questions in silviculture, ecophysiology, and ecohydrology.

(1) Using night-time stem rehydration (i.e., daily minimum tree water deficit) as an indicator for tree water stress, we could show the effect of local neighborhood identity on tree drought response. Furthermore, we found that trees maintained stem rehydration – and thus, likely, cambium and phloem functionality – longer than sap flow and stem water storage under progressive drought.

(2) Daily irreversible growth allowed us to analyze intra-annual growth patterns of three tree species in Northern Germany. The study revealed species- and site-specific differences, and temporal complementarity in mixed stands.

(3) We explored stem diameter variation during snowmelt in a mixed hardwood-coniferous forest. Linking it to image-based observations of branch movement, we identified dynamic stem rehydration following snowmelt and rain events, and shrinkage during frost events and dry periods – before the onset of the growing season.

While acknowledging the limitations of dendrometer measurements (such as not capturing all phases of cell growth), many studies have shown the value of this method. To move forward, we suggest clarifying technical differences between models, leveraging the variety of dendrometer-derived variables for different contexts, and expanding our knowledge of their mechanistic links to other physiological measurements.

Keywords: ecophysiology, ecohydrology, silviculture, mixed forests, drought

TreePulser: Radial Growth Dynamics and Physiological Responses of Temperate Tree Species under Climatic Drivers

Harold Hauzeur, Gauthier Ligot, Anaïs Gorel

Gembloux Agro-Bio Tech, Uliège, Belgium

The TreePulser project investigates growth and drought responses of ten temperate tree species in southern Belgium (*T. cordata, P. nigra var. corsicana, P. sylvestris, P. avium, Q. rubra, Q. petraea, A. platanoides, P. menziesii, F. sylvatica, B. pendula*) using a network of 300 TOMST point dendrometers. Radial growth data are coupled with climatic and edaphic variables to quantify species- and site-specific intraannual growth patterns, identify drivers of variability, and evaluate how short-term climatic events and seasonal droughts shape growth dynamics.

To complement these continuous growth records, ecophysiological measurements are being collected on a subset of trees. These include predawn and midday leaf water potential, stomatal traits, hydraulic vulnerability curves, and resource-use traits. This data will provide a functional framework to characterize species-specific drought strategies and link growth responses to underlying physiological processes.

Preliminary analyses of dendrometer data from 2024 revealed pronounced interspecific and site-level differences in radial growth. *Pseudotsuga menziesii* and *Tilia cordata* exhibited the highest increments, while *Prunus avium* and *Quercus petraea* grew the least. Daily-scale analyses of tree water deficit (TWD) and radial growth (GRO) further highlighted strong species- and weather-dependent contrasts, though results remained inconsistent under non-limiting climatic conditions. Ongoing work now focuses on identifying the environmental contexts in which reliable daily signals can be extracted.

Initial ecophysiological campaigns in summer 2025 provided further insight into species' water-use strategies. Predawn and midday water potential measurements revealed contrasting behaviors, with both pine species showing relatively isohydric regulation, whereas *Fagus sylvatica* and *Quercus rubra* appeared more anisohydric. These early results will be complemented with repeated campaigns and additional trait measurements to confirm interspecific differences and clarify their mechanistic basis.

Altogether, TreePulser combines continuous growth monitoring with targeted ecophysiological measurements to build a trait-based understanding of drought responses. This integrative approach will help clarify the links between tree growth dynamics, species-specific hydraulic strategies, and environmental drivers, thereby improving predictions of forest performance and resilience under warmer and drier future climates.

Dendrometer-based assessment of the impact of insect defoliation and climate on growth in sub-arctic mountain birch

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We present research questions, study design and very preliminary results from a newly initiated dendrometer-based monitoring of growth in sub-arctic mountain birch in response to insect defoliation. The point dendrometers are a new addition to a longstanding field-based monitoring of defoliator dynamics along climate gradients in Troms under COAT – Climate-ecological Observatory for Arctic Tundra, www.coat.no. The goals of the current instrumentation are i) to test the reliability of sensors under local conditions, 2) to develop the pipeline for dendrometer data management and data analysis, and 3) to assess, throughout an insect outbreak cycle, the growth response of birch in response to insect abundance (larval density in the canopy), leaf loss and climate.

Research keywords: insect outbreaks, defoliation, sub-arctic, mountain birch *Betula pubescens*, long-term monitoring.

Title: **Resilience and adaptability of Africa's tropical dry forests to climate change**

Authors: Arthur Yambayamba, Daniella Nemetschek and **Tommaso Jucker**

Presented: Tommaso Jucker

While a considerable amount of research has explored how climate change and climate extremes impact tree growth in temperate and boreal ecosystems, much less is known about the tropics. To tackle this knowledge gap, we established a network of point dendrometers along a steep rainfall gradient in Zambia's miombo woodlands and coupled these with measurements of soil moisture and air temperature. We found that tree stem growth was highly synchronized with soil moisture availability and atmospheric water stress at daily, seasonal and interannual scales. Stem growth occurred predominantly at night and just before dawn, when temperatures were cooler, and ceased rapidly in response to soil moisture drying both during and at the end of the growing season. Differences in cumulative annual growth rates along the rainfall gradient were primarily explained by a greater number of growing days in wetter areas, as opposed to faster daily growth rates. Our results indicate that changes in rainfall regimes would profoundly alter productivity and carbon sequestration in Africa's miombo woodlands, the largest tropical dry forest and savanna ecosystem on Earth.

Inter-population variation of seasonal stem size variation at the edge of European beech distribution (Eastern Europe).

Marcin Klisz, Valentina Butto, Sergio Rossi, Szymon Jastrzębowski

Forest Research Institute (IBL), Poland

In our study, we performed high-resolution measurements of stem size variation to understand the effects of provenance and season on the variability of phenotypic plasticity between and within marginal beech populations. Four marginal beech populations were selected among those growing in a common garden experiment in Oleszyce, south-east Poland. Stem circumference variation were recorded between 2016 and 2018 using automatic tape dendrometers. Our results highlighted the key importance of climatic conditions, i.e. temperature and precipitation in August as well as temperature in June and precipitation in April, are of decisive importance for stem size variation, while the influence of origin is rather small. The temperature in spring and the temperature with precipitation in autumn affect onset and end of stem size variation. Thus, high intra-provenance variation in stem size changes suggests that the local populations will cope with climate anomalies thanks to their relatively high adaptive potential.

Towards understanding the links between tree growth, canopy phenology, whole-ecosystem carbon fluxes and interannual climate variation in temperate forests

Daniela Nemetschek (Krebber)[1], Robin Battison[1], Mathilda Digby[1], Julia Madurini Hall[1], Diana Alfieri[2], Serena Antonucci[3] , Jesús Julio Camarero[4], Mauro Cavagna[5], Isaac Chini[5], Eleanor Cole[6], Samuel Crofts[6], Verónica Cruz-Alonso[7], Michele Dalponte[5], Rafael Da Silveira Bueno[8], Cristopher Fernández de Blas[7], Miguel Ángel de Zavala Girones[7], Viola Filippini[1], Lorenzo Frizzera[5], Damiano Gianelle[5], Matthew William Joynson[1], Katja Kowalski[9], Tommaso La Mantia[8], Jelena Lange[10,11], Concetta Lisella[2], Yadvinder Malhi[12], Jiří Mašek[10], César Morales del Molino[7], Mihai Daniel Nita[13], Thomas Ovenden[14], Paloma Ruiz Benito[7], Giovanni Santopuoli[3], Rupert Seidl[15], Cornelius Senf[9], Ben Sheldon[6], James Speed[16], Pierdomenico Spina[2], Petru Tudor Stăncioiu[17], Roberto Tognetti[3,18], Václav Treml[10], Jan Tumajer[10], Roberto Zampedri[5] and Tommaso Jucker[1]

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Wood production is a key component of terrestrial carbon dynamics, yet we still have a limited understanding of the environmental cues that trigger its start and end during the growing season, and how these seasonal timings relate to leaf phenology and whole ecosystem carbon fluxes. We also lack a clear picture of how increasing temperature and drought stress affect woody productivity, and how phenological patterns and climate

responses vary across temperate tree species, elevations, and regions across Europe. Here, we present two projects addressing these questions by combining regional and microclimate data, NDVI, eddy covariance flux tower, and growth data from over 1,000 automated dendrometers. First, using 2023–2024 data from Wytham Woods (UK), we highlight the challenge of estimating wood production from remote sensing or flux tower data. Specifically, we show that wood growth started later and ended much earlier than suggested by forest- and species-level NDVI or GPP, and that temporal patterns in wood production varied strongly between species. Second, we present an overview and first results of the FORTRESS project, a collaboration across 12 institutions in 8 European countries studying how mountain forests respond to climate variation and extremes. In 2024, we established a network of over 850 dendrometers and 240 microclimate sensors across multiple elevations at 10 sites. Combined with tree-ring data from 1,300 trees and plot-level terrestrial lidar scans, the project will provide important insights into how past and current climate variation, in combination with biotic interactions influence growth dynamics across Europe's major mountain ranges.

Paal Krokene

NIBIO, Norway

The epidemic threshold model states that risk of bark beetle outbreaks depend on two factors: (1) the size of the local bark beetle population and (2) the health status/resistance of the trees. In Norway we have an extensive trap-based monitoring program for the spruce bark beetle Ips typographus, where we monitor beetle abundance using pheromone-baited traps. However, we completely lack data on the general health status of our Norway spruce forests. We are currently exploring the use of dendrometers as a tool to intergrate the effects of precipitation, temperature, and local soil moisture conditions on the water/drought status of the trees. Starting in 2024 we have installed Tomst point dendrometers in a few sites and our aim is to use data on diurnal swelling and shrinking of the stem as a measure of tree drought status. In my presentation I will briefly describe the bark beetle problem, the Norwegian monitoring program, and how we are using dendrometers to assess tree health.

Measuring tree transpiration with point dendrometers?

Holger Lange, Morgane Merlin, Ryan Bright, Junbin Zhao, Helge Meissner, Danielle Creek

NIBIO, Norway

Transpiration of individual trees is typically measured using sapflow sensors. However, to estimate transpiration at the stand level, deploying a large number of sapflow devices would be rather costly; also, sap flow sensors only measure the movement of water within the active sapwood, not accessing other physiological mechanisms and responses (radial growth, water storage) associated e.g. with stress response. On the other hand, point dendrometers are much cheaper and easier to maintain. They can therefore be much more extensively deployed in forest stands. Using the boreal old-growth forest ICOS site NO-Hur in Southeast Norway as case study, we aimed to analyze the relationship between sub-daily (30 minutes temporal resolution) stem diameter changes and sap flow using point dendrometers and Heat Ratio Method sap flow sensors simultaneously installed at 12 Norway spruce trees. We determined effective time lags between the time series of dendrometers and sapflow sensors, and linked the relationships found with individual tree physical attributes, meteorology and soil climate over two growing seasons in 2022 and 2023. Our goal was to assess whether a predictive model of sap flow could be built from measured diameter changes, tree properties and climate, to ultimately reduce the uncertainty of stand level transpiration estimation at the daily resolution across entire forest stands.

Agreement between field-measured and dendrometer-derived water potentials

Roman Mathias Link

Chair of Forest Botany, TUD Dresden University of Technology, Tharandt, Germany

Dendrometers are increasingly used not only to monitor tree growth, but also as an affordable tool to obtain high-resolution data of tree water status. While Tree Water Deficit (TWD) as a proxy of tree water status itself is a useful metric for monitoring tree health, studies focusing on mechanisms and fluxes would benefit greatly from reliable water potential (Ψ) estimates derived from dendrometer data. With plenty of studies being underway that rely on dendrometer data for water potential estimates, it is crucial to perform principled validations of these estimation methods. Particularly, it is essential a) to quantify the magnitude of systematic and random deviations between field-measured and dendrometer-derived water potentials, b) to evaluate whether there are installation-, stem- and species-specific differences in TWD-Ψ-calibrations and c) to determine the effect of decisions regarding sensor choice, measurement and data analysis on the uncertainty budget of dendrometer-derived water potential estimates. I will use my talk to raise consciousness for these issues and propose a collaborative effort to tackle them.

Impacts of a changing climate on past and future tree growth at the treeline

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Keywords: Treeline forest, Vaganov-Shashkin model, dendrometers, Pinus, Tree ring.

Treeline ecosystems act as natural observatories of climate change where extreme conditions make trees highly sensitive to climatic variation. At the treeline, growth is commonly considered as temperature limited. However, some recent studies show shifts towards weaker or even negative temperature-growth responses. A possible reason is that warming results in higher atmospheric demand for water, which intensifies drought stress and seasonally suppresses growth. As a result, water availability has emerged as a co-limiting factor of growth alongside temperature at treeline. Process-based models, such as the Vaganov-Shashkin model (VS), translate climate into (sub)monthly growth indices, helping to disentangle the roles of temperature and moisture by accounting for nonlinear climate-growth responses. However, their outputs have rarely been verified using direct empirical monitoring of intra-annual growth based on dendrometers. Our research is based on a network of treeline pine sites across Europe, spanning contrasting hydroclimatic conditions from the Pyrenees to Scandinavia. At selected sites, paired plots at treeline and ca. 300 m below provide an altitudinal gradient that enables the application of a space-for-time substitution (SFTS) framework. The VS model is first be applied retrospectively to reconstruct past growth dynamics and growth phenology at treelines, quantifying how temperature and water availability constrained growth at daily resolution. For future projections, the simplified VS-lite model is applied assuming that growth at lower-elevation stands, which are about 2 °C warmer, surrogates future treeline conditions. By calibrating the model at lower sites and then transferring it to higher elevations with projected climate scenarios, it is possible to explore potential growth trajectories and shifts in limiting factors until mid-century. High-resolution dendrometer data, available at our sites, provide sub-daily records of stem increment. These empirical measurements enable validation of the model and improve our understanding of shifts in growth onset, cessation, and growth rate. By integrating observational and modeling approaches, this research aims to clarify how temperature and moisture jointly constrain wood formation at treeline, and how these constraints may shift under continued warming.

A network of automatic dendrometers for monitoring climate impacts on tree growth and carbon uptake in European and eastern US forests

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Climate change affects tree growth and carbon uptake, yet systematic measurements across climatic zones and species remain scarce. Since 2017, we have built a dendrometer network covering more than 4,000 trees of 65 species across a broad climatic gradient in European and eastern US forests, equipped mainly with point dendrometers. For each species, we target robust replication (≥15 trees at ≥3 sites per region) to quantify stand-level as well as species- and functional type–specific responses to both spatial and temporal climate variation. The network also includes systematic measurements along elevational gradients in the Czech Republic (250–1100 m a.s.l.) and Cyprus (0–1950 m a.s.l.). At all sites, understory soil moisture and temperatures are recorded. This network provides extensive data for understanding climate effects on trees across functional types, but it also serves as a base for studies on different drivers of tree growth, resilience and forest microclimate.

Validating Species-Specific Drought Stress in SWAT+ Using Dendrometer Data

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Research Institute for Forest Ecology and Forestry, Trippstadt, Germany

Abstract

Climate change is expected to increase the frequency and intensity of drought events, posing significant challenges for sustainable forest management. In this project, we develop and test a species-specific drought stress coefficient for SWAT+, which reduces potential transpiration when soil moisture drops below a given threshold. This parameterization is critical for realistically simulating tree water use and growth, and requires empirical validation.

To validate the coefficient, we combine SWAT+ simulations with high-resolution dendrometer data. Dendrometers provide continuous measurements of radial stem growth and allow us to identify periods of growth suppression that correspond to stomatal closure under water stress. We link these observations with soil water data (TDR) and climate data (PET) to derive species-specific soil water thresholds. These thresholds are then used to improve the parameterization of SWAT+ and to generate suitability maps for drought risk at the watershed scale.

This work contributes to better drought risk assessment and supports adaptive forest management strategies under climate change.

Keywords: drought stress, SWAT+, dendrometer data, stomatal closure, soil moisture threshold, forest management, watershed modelling

Above- and Belowground processes affecting tree health

Celina Alexandria Kostich-Nilsen

Swedish University of Agricultural Sciences, Sweden

Susceptibility and death due to attacks from the European spruce bark beetle has increased in Norway spruce stands across Europe and in Sweden since 2015 and 2018. These outbreaks can be linked to drought stress that has weakened the trees after extreme droughts. In times of water stress, the relationships that Norway spruce form with ectomycorrhizal fungi may be critically important, as mycorrhiza fungi are known to benefit the trees through resistance, tolerance and recovery after events such as drought. By stimulating a drought event in a field experiment, we will be able to investigate the relationship between mycorrhiza colonization, community composition, spruce resistance to drought and bark beetle attacks, and soil moisture conditions. Tree growth and stress during this experiment will be measured by dendrometers and soil samples will be collected before, during and after the stimulated drought to assess soil moisture conditions and ectomycorrhizal community shifts.

«Skogbrukerforskning» an advanced citizen science project

Line Nybakken

Norwegian University of Life Sciences, Norway

The project «Skogbrukerforskning» is an advanced citizen science project, where we use point dendrometers to explore interactive effects between silviculture and climatic variations on tree growth and water balance. Foresters (forest owners and professionals) all over Southeastern-Norway are helping finding sites, mounting dendrometers and downloading data. Together we will explore results from mixed conifer forests, selective cuttings and fertilized forests.

Characterizing tree growth and drought impact along an elevation gradient in the Alps

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Climate change is expected to increase the frequency and intensity of extreme weather events. Thus, also mountain forests in the European Alps will increasingly be affected by dry periods. However, trees will react differently to meteorological droughts depending on species, the timing of the drought, and site conditions such as elevation, micro-topography and soil characteristics. To quantify the impact of climate change on mountain forest we installed a network of dendrometer sites along an elevation gradient from 1000 to 2400 m a.s.l. at LTSER Matsch|Mazia in Northern Italy starting in 2012. Band dendrometers (DR/DRL26, EMS, Czech Republic) were used to measure trunk circumference variations of four trees per site and species for on European Larch (*Larix decidua*) and co-occurring evergreen conifers (*Pinus nigra, Picea abies, Pinus cembra*). We did use the zero-growth concept to distinguish between growth- and water-related circumference/radius changes. We found major differences in radial growth and tree water deficits between wet and dry years at low- and mid-elevations. At high elevation, tree water deficits during the growing season were rare for larch, while Pinus cembra reacted sensitively to high vapor pressure deficits. Overall, our study showed that water availability will become a limiting factor for tree growth at lower and mid-elevation mountain forests, while warming might shift competition between species at high elevation.

A new perspective on tree growing season determination

Alma Piermattei, University of Torino, Italy, dendrochronologist

I am particularly interested in enhancing our understanding of intra-annual growth dynamics and how they respond to environmental drivers. I also aim to integrate sensor-based measurements with traditional dendroecological approaches. Currently, I am working with dendrometer data within the TreeTalker Italian Network.

Keywords: phenology, plant growth, timing, environmental drivers, individual trees

Understanding when trees grow is crucial for studying their response to climate change; yet defining the "growing season" remains surprisingly complex. In a recent study (Piermattei, 2024), I explored a novel, integrative approach that aligns four distinct definitions of the growing season proposed by Körner et al. (2023), while also utilising high-resolution dendrometer data. My project combines dendrometers with multiple phenological and physiological indicators, all monitored simultaneously on the same trees and across species. This multi-method framework enables us to compare temporal lags, identify mismatches, and evaluate method-specific uncertainties. In this talk, I will share key insights from applying this approach.

Eight Years of Experience with TOMST Dendrometers

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As dendrometers become standard tools in ecological research, balancing affordability with reliability is key, especially when scaling up to cover larger spatial scales. Over the past eight years, we've worked extensively with TOMST point dendrometers, deploying thousands of units worldwide. We are open to sharing practical insights from long-term use, including technical specifications, common challenges, and how the devices have evolved. Our experience offers valuable guidance for using TOMST dendrometers in large-scale ecological monitoring. The increasing number of installed units generates an enormous amount of high-frequency, high-variability data, which must be efficiently cleaned before any further analysis. For those who prefer visual inspection and semi-manual cleaning, we are developing an interactive tool in R for time-series cleaning and visualization called PLOTeR.

Atmospheric aridity decouples carbon assimilation and growth in temperate deciduous oaks

Mukund Palat Rao[1,2,3,4*], *Arturo Pacheco-Solana*[5], *Rong Li*[6], *Bar Oryan*[7], *Johanna E Jensen*[8], *Milagros Rodriguez-Caton*[3,9], *Lily Klinek*[3], *Zoe A Pierrat*[10], *Sophie Ruehr*[11], *Rose Oelkers*[12], *Laura E. Boeschoten*[13], *Kevin L Griffin*[13,14], *Luke M McCormack*[15], *Xi Yang*[6], *Joseph Verfaillie*[11], *Dennis Baldocchi*[11], *Jeremy Hise*[16], *Alexander J. Turner*[17], *Todd M Scanlon*[6], *Laia Andreu-Hayles*[1,2,18], *Jan U H Eitel*[19], *Neil Pederson*[20], *Daniel Griffin*[21], *David Stahle*[22], *Justin T. Maxwell*[23], *Steven Voelker*[24], *Steven A Kannenberg*[25], *Josep Peñuelas*[2&26], *& Troy S Magney*[3]

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Abstract

A diminished terrestrial carbon sink under continued climate change will have significant implications for humanity. A major source of uncertainty in projections of the carbon cycle is the degree to which carbon assimilation and allocation are coupled in vegetation. Here we investigate temporal coupling between photosynthesis and above-ground woody biomass

growth for seven widely distributed North American temperate deciduous oak species across intra to inter-annual temporal and cellular to ecosystem spatial scales. At four monitoring sites (with seven site-years of half-hourly growth and gross primary productivity or GPP estimates), the 'growing season' commenced synchronously with the 'photosynthetic season' but ended two-to-three months earlier. Growth occurred at lower temperature and vapour pressure deficit (VPD) than GPP across daily and seasonal timescales and the annual dispersion in aridity increased the degree of temporal photosynthesis-growth decoupling ($r=0.86$, $p<0.05$). Across a network of 137 tree-ring sites, annual radial growth was insensitive to climate variability after mid-summer despite 26-36% of annual GPP estimated using satellite remote sensing occurring from late summer into autumn. The photosynthetic and growing seasons are therefore distinct and seasonally decoupled across multiple North American oak species even though the two terms are often conflated. Our results suggest that climate change driven increases in temperature and VPD may adversely influence the ability of trees to store carbon long-term in woody biomass notwithstanding impacts on photosynthesis.

We will also introduce and present preliminary results from a collaborative paired flux tower, in-situ remote sensing, dendrometer network comprising 19 locations across 13 countries, which we intend to harness to evaluate these questions across continental scales. This network currently includes 4 boreal sites including 2 in the Nordics. We will extend an invitation to participants to join, collaborate, and contribute to this synthesis.

Bio-sketch

I am an Ecoclimatologist and Carbon Cycle Scientist. I received my PhD from Columbia University in 2020. I was then an Adjunct Professor of Environmental Studies at New York University (NYU), a NOAA Climate & Global Change fellow at University of California Davis (2021-2022), and subsequently a Marie Skłodowska Curie Fellow at the Center for Ecological Research and Forestry Applications (CREAF), Barcelona, Spain (2022-2024). My research aims to illuminate the future of ecosystems and the forest carbon cycle in a changing climate by drawing on my expertise in climate science, plant ecophysiology, dendrochronology, earth system models, and remote sensing. My research spans a broad array of spatial and temporal scales from cells to satellites and seconds to centuries. I am currently working on projects related to the role of tree growth in the forest carbon cycle, the vulnerability of forests to increasing heat waves, and the use of dendrochronology to understand past environmental change and timber transport.

Research Keywords

i. Forest carbon cycling; ii. Climate change; iii. Dendrochronology; iv. Plant ecophysiology; v. Ecology; vi. Land-atmosphere interactions; vii. Remote Sensing; viii. Earth system models; ix. Archaeology

Introduction to the Finnish dendrometer network

Yann Salmon

University of Helsinki

The Finnish dendrometer observation network is currently being build. It relies on a few long-term monitoring stations with years of dendrometers data collected and the addition of new sites following the Swiss Treenet protocol to allow facilitate data integration.

Our sites have been selected from the ICOS, ICOS associated or similar sites equipped with eddy-covariance stations as we aim to relate tree and ecosystem level response to environmental stressors. Here, we want to promote higher integration of dendrometer measurements within the Nordic countries and beyond and discuss the challenges inherent to these methods and their integration in ecosystem level fluxes.

TreeWatch technology uncovers the hidden stories of trees

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Advances in sensor technology are revolutionizing plant ecophysiology, opening new frontiers in our understanding of tree water and carbon dynamics. High-resolution sensors that monitor sap flow and stem diameter variation now provide unprecedented insights into water fluxes, internal storage dynamics, and growth processes. Single-sensor networks have already demonstrated their value: large-scale initiatives such as SAPFLUXNET, DenDrought2018, and PSInet have produced invaluable datasets, though they remain static snapshots. In contrast, real-time monitoring networks like TreeNet deliver dynamic, climate-gradient data on radial growth and tree water deficits, offering powerful tools to study tree function in changing environments.

The next major step lies in integrating multiple complementary sensors into holistic monitoring systems. Such systems can transform trees into living sentinels that continuously signal environmental change. TreeWatch.net (Steppe et al. 2016) exemplifies this approach, combining the Sapflow+ sensor (Vandegehuchte et al. 2012) with point dendrometers to capture the "heartbeat" of trees; the delicate interplay between water transport and turgor-driven stem growth (Steppe et al. 2006, 2015). This integration not only reveals hidden physiological rhythms but also enables early stress detection, high-resolution growth tracking, and deep insights into tree resilience under droughts and heatwaves (Salomón et al. 2022).

In this keynote, TreeWatch technology will be presented as a powerful lens to uncover the hidden stories of trees worldwide (e.g. Steppe et al. 2018), demonstrating how integrated sensing can reshape our understanding of tree function.

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Water-use strategies and growth responses to drought in montane Norway spruce forests

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Long-term drought exposure may induce shifts in stomatal regulation and growth, yet the combined influence of atmospheric and soil drought on mature Picea abies remains poorly quantified. We monitored two montane Norway spruce stands in the eastern Italian Alps from 2020 to 2023—Carezza (wetter, cooler) and Ultimo (drier, warmer)—to assess how contrasting evaporative demand and water availability shape tree water use and growth. Both sites were equipped with automatic band dendrometers, sap flow sensors, and environmental monitoring systems. Stem radius variation from dendrometers was partitioned into reversible tree water deficit (TWD) and irreversible radial growth. At Carezza, higher sap flux density (Fd), delayed stomatal closure, and rapid post-drought recovery characterised responses to moderate vapor pressure deficit (VPD), but repeated dry summers increased TWD and shifted stomatal regulation toward earlier downregulation. At Ultimo, higher mean VPD and low soil moisture produced consistently elevated TWD and negligible radial growth during the 2022 drought, with partial recovery in 2023. Across sites, high VPD and low soil moisture increased TWD and reduced Fd, and multi-year exposure drove a trend toward more conservative water-use strategies. Dendrometer-derived TWD, integrated with sap flow and environmental data, proved to be promising for detecting physiological thresholds, legacy effects, and differences in drought resilience between contrasting montane environments.

Tracking Tree Growth Dynamics with Dendrometers on ICP Forests Level II plots in the Czech Republic

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Worldwide, different types of dendrometers are being used to monitor the cambial activity of trees. In the Czech Republic, on seven core ICP level II monitoring plots, girth bands (DB20) and electronic circumference (DR26 and DRL26) dendrometers (EMS Brno) have been used to monitor tree growth since 2010. Both types of dendrometers are applied to the same tree for mutual measurement and accuracy checking. Readings of girth band dendrometers are being done by trained personnel at least once per month. Electronic dendrometers automatically measure the circumference every 30 minutes, data are stored in the datalogger, and every six hours are sent to the online database. On each monitoring plot, six trees are equipped with both types of dendrometers, while an additional 15 trees are being monitored only by girth bands. Across all plots, dendrometers track the radial growth dynamics of six different tree species: Picea abies (Norway spruce), Fagus sylvatica (European beech), Quercus petraea (Sessile oak), Abies alba (Silver fir), and *Pinus sylvestris* (Scots pine).

This way of tree growth monitoring helps understand both short – and long-term growth dynamics. The monthly readings from girth bands provide robust long-term datasets on diameter increment, while the electronic dendrometers capture fine-scale intra-annual growth patterns. Together, these data enable the identification of species-specific growth phenology, such as the onset and cessation of radial growth, periods of intensive growth, and cumulative annual increment. They also allow us to assess how different tree species respond to climatic stresses, including droughts, heatwaves, and frosts. Such insights are essential for evaluating forest productivity, resilience, and the potential impacts of ongoing climate change.

Keywords: dendrometers, growth dynamics, growth phenology, forest monitoring, climate change

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Partitioning of nighttime transpiration and stem water refilling: linking nighttime transpiration, refilling, and stem activity

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Keywords: sapflow, dendrometer, transpiration, refilling, nighttime

We developed a workflow that partitions transpiration (T) and stem refilling (R) from nighttime sap flux density using VPD and dendrometer measurements. Independent chamber-based transpiration measurements validated the robustness of this approach. By integrating with machine learning techniques, the workflow can be applied across different sites, species, and sap flow sensor types. It also provides new insights into the baselining of Granier-type sensors. Our results show that in boreal forests, nighttime T of *Pinus sylvestris* was strongly regulated by soil water availability and atmospheric demand, whereas R was mainly driven by daytime water use. Importantly, we observed a seasonal synchronization between nighttime T and irreversible stem enlargement, but not with R. Furthermore, dendrometers installed separately on the xylem and phloem enabled us to directly link nighttime T, R, and stem activity. This study highlights a novel framework for better understanding of stem-level processes at night, offering new opportunities to investigate plant water use and growth dynamics.

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Dendrometer analysis of tree water dynamics and radial growth of Norway spruce in Hyltemossa ICOS site

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This BSc thesis examines short-term radial growth and stem water dynamics of Norway spruce (Picea abies) in Hyltemossa, a managed forest in southern Sweden, using dendrometer data collected over two growing seasons. Understanding how meteorological drivers influence tree growth is increasingly important in boreal forest management under climate change. To assess dynamic relationships between radial growth (GRO), maximum daily shrinkage (MDS), and environmental variables—including vapor pressure deficit (VPD), precipitation, relative humidity (RH), temperature, and photosynthetic photon flux density (PPFD)—a rolling window correlation analysis was conducted using the R package NonParRolCor. This tool accommodates non-stationary ecological time series and uses Monte Carlo simulations to address the problem of multiple comparisons. Findings showed that radial growth mainly occurred at night under low VPD (<4 hPa) and low PPFD (<500 µmol m^{-2} s^{-1}). Although VPD and PPFD emerged as dominant limiting factors, their intercorrelation made it difficult to isolate individual effects. Air temperature was weakly linked to growth. MDS correlated with VPD and maximum temperature only during periods of tree water deficit. The study also revealed a bimodal growth distribution, large intra- and inter-annual variability in radial growth, and no consistent lagged effects from meteorological drivers. The results also highlight the limitations of a monitoring-based study especially with a bivariate approach.

About me: I'm currently doing a MSc in Applied Computational Science with a focus on Physical Geography at Lund University. I'm interested in exploring potential directions for my MSc thesis in 2026, particularly in dendrometer applications and forest-climate relationships in Nordic forests.

Keywords: radial growth, Norway spruce, climate-growth relationships, rolling correlations

Does physiology alone explain *Betula pendula* recovery from drought?

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Abstract

Increasing drought intensity, duration and frequency worldwide challenges tree health. In addition to the importance of drought resistance, post-drought recovery capacity is a vital determinant in post-drought tree growth and survival. However, the capacity of trees to recover from different types of drought stress remains largely unquantified. In this study, we applied three different drought treatments (short-term drought, long-term drought, and repeated drought) and a well-watered control to 3-year-old silver birch (*Betula pendula*) saplings growing in a greenhouse. Ecophysiological traits regarding key water- and carbon-relation processes such as sap flow, stem radial variation, leaf gas exchange, water potential, and leaf phenology were continuously measured throughout the drought-recovery process. The preliminary results indicate that water consumption, photosynthesis and tree growth were greatly diminished in all drought treatments, though their recovery capabilities and timing differed. None of the stressed treatments recovered to pre-drought status after re-watering, which might be attributed to their limited ability to repair xylem embolism and restore leaf area. The adjustment of tree-level leaf area emerged as a key strategy to cope with the drought, shedding light on traits other than physiology requiring consideration when studying drought resistance and resilience.

Tree circumference dynamics in multi-species old-growth forest stands of Białowieża, NE Poland (2016–2020), recorded by band dendrometers

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Since 2016, over 250 band dendrometers have been installed in the Białowieża Forest, one of the last primary forests in Europe. These devices monitor stem circumference changes in ten selected tree species in old-growth forest stands across various habitats, aiming to improve our understanding of current growth rates and the response of trees to various environmental factors. The study analysed also meteorological conditions in the area between 2016 and 2020, comparing them to long-term averages from 1951–2020. This period saw diverse weather, including significant anomalies in 2018–2020 and more average conditions in 2016–2017. These variations led to diverse growth responses among the selected tree species. Notably, elm in riparian forests exhibited the highest growth from 2016–2020, while most taxa showed peak growth during the 2017 meteorological growing season. In addition, some of this data was used in a separate study investigating tree growth response to the 2018 heatwave. This heatwave caused stem dehydration but did not lead to consistent growth reductions in European forests. However, managing this large and diverse dataset presented a number of challenges, emphasising the critical importance of long-term records of tree stem volume changes.

Building Effective Systems for Long-Term Ecological Data Management

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Austrian Research Centre for Forests, Austria

Long-term data exchange and storage depend on effective data management. This becomes especially challenging when working with high-frequency sensor data, such as dendrometer measurements, and when projects sometimes require relocating sensors due to budget restrictions. However data management is rarely taught in formal ecological curricula, leaving many researchers to learn through trial.

Drawing from my own experiences managing data across multiple projects, I will share both the pitfalls we encountered and the practical solutions we developed to build a functioning system for storing dendrometer data. The presentation will begin with a brief introduction to working with databases followed by an example of the data management approach at BFW. I will also highlight ongoing challenges and invite discussion on how data management is handled in other institutions. The session is intended as an exchange of experiences and ideas.

research keywords: data management, database, datamanagement, dendrometers

information about me: I am a meteorologist working in forestry.

The TreeNet network – converting data on changes in stem radius into physiologically meaningful information

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The TreeNet network – converting data on changes in stem radius into physiologically meaningful information TreeNet is an environmental monitoring network for measuring tree growth and drought. It is embedded in an international network of environmental monitoring systems (ICOS, eLTER, ICPForests) and is supported by Swiss institutions involved in forest research and the Federal Office for the Environment (FOEN).

Since 2011, TreeNet has been continuously measuring the stem radius of (now) more than 650 trees at around 70 locations in Switzerland. The longest continuous time series originate from a Swiss subalpine spruce forest and begin in 1998. TreeNet has recently started accepting compatible sites from across Europe. High-precision point dendrometers provide micrometer-accurate data in a standardized form, making TreeNet the largest dendrometer network with homogeneous data collection and processing. Each dendrometer site is supplemented by soil water potential sensors at different depths and sensors for air temperature and relative humidity. The data is automatically transmitted every 10 minutes and collected and processed in a central database, allowing near real-time analysis of drought and growth signals in our forests, known as nowcasts (treenet.info). The core of the data processing consists of an SQL database, approximately 100 metadata entries for each individual sensor, automated data processing based on the R package treenetproc, and various routines for processing data input and output, including a data portal and nowcast visualizations.

In addition to some technical background information, my presentation will highlight the enormous potential of a standardized dendrometer network and back this up with current scientific findings, such as why trees only grow at night and during a very limited number of days, and how we quantify drought stress based on the water deficit of trees. Further details will also be presented in the workshop “Treenet and treenetproc.”