TRACE 2018

Tree Rings in Archaeology, Climatology and Ecology

BOOK OF ABSTRACTS

Alfried Krupp Wissenschaftskolleg
Greifswald

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Tree Rings in Archaeology, Climatology and Ecology
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Book of Abstracts

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Foreword

Dear TRACE-participants,

do you know Bruno Huber? One of the first scientists that introduced, refined and applied the method of dendrochronology and crossdating in Central Europe, the scholar who prepared and used thin sections to understand tree water transport over 90 years ago, the 'forward-thinker' who derived sapwood to leaf-area ratios in the 1920s today known as "Huber values"? Well, welcome to Greifswald! You are visiting the town and university, where Huber worked and taught early on in his career as a botanist, forester, plant physiologist, plant anatomist, and one of Europe's first dendrochronologists.

At this conference, we have compiled diverse scientific conference sessions around the topics Bruno Huber explored successfully in his career. We are building on the foundations people like him carefully constructed. TRACE 2018 brings together students, senior scientists, scholars, and practitioners on topics spanning archaeology, plant and forest ecology, physiology, extreme events, climatology, wood anatomy and methodological advances of tree-ring science. We are happy to welcome more than 150 scientists from over 30 countries, contributing over 50 oral and over 80 poster presentations.

Conferences such as TRACE 2018 are opportunities. Opportunities to exchange ideas and new developments, discuss with old colleagues and newcomers alike, the very core of our scientific endeavors. Let yourself and your thinking be "challenged", engage in constructive dialogue, network, observe, learn, and share your insights. We have big shoes to fill (see above) – we count on you.

Last but not least – Have fun! Enjoy the old city of Greifswald and surroundings, the Baltic Sea coast, the experimental forest and the tree planting campaign and don't forget to qualify for the T-RACE semifinals. Curious? Good – Let's start TRACE 2018.

On behalf of the organizing team,

Martin Wilmking

Organizing committee

TRACE 2018 is organized by the tree-ring lab "DendroGreif" (Landscape Ecology and Ecosystem Dynamics Working Group, Institute of Botany and Landscape Ecology, University of Greifswald), in cooperation with the Association for Tree-Ring Research (ATR).

Jill Harvey	University of Greifswald
Jelena Lange	University of Greifswald
Tobias Scharnweber	University of Greifswald
Martin Wilmking	University of Greifswald
Marieke van der Maaten-Theunissen	TU Dresden
Ernst van der Maaten	TU Dresden

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TRACE 2018 Conference

Tree Rings in Archaeology, Climatology and Ecology
April 24-27 2018, Greifswald, Germany

Tuesday, April 24

Location: Pomeranian State Museum, Rakower Straße 9

18:00 – 22:00   Registration and Icebreaker

Wednesday, April 25

Location: Alfried Krupp Wissenschaftskolleg, Martin-Luther-Straße 14

08:00   Registration & hanging posters

09:00   Conference Opening

Session 1: Forests under change – tree-ring perspectives on global change impacts
Moderator: Prof. Dr. Ute Sass-Klaassen

09:15   **Ute Sass-Klaassen** Session Introduction

09:30   **Andrew Hacket-Pain** Climatically controlled reproduction drives tree growth

09:45   **Carla Vázquez-González** Environmental significance of resin duct differentiation assessed by its quantification in tree rings of a Mediterranean pine

10:00   **Alen Berta** Investigation of age and site index in unevenaged private forests in Croatian Mediterranean and Submediterranean with dendrochronological methods and multispectral satellite images

10:15   Poster Session 1 with Coffee Break:
- Forests under change – tree-ring perspectives on global change impacts
- Tree rings and knowledge of the human past
- From leaves and roots to the wood – explorations of tree physiological functioning in a changing world

11:00   **Stefan Kruse** Responses of high latitudinal tree stands to global warming at the Siberian Arctic treeline – combining dendrochronology and simulation modelling

11:15   **Marcin Klisz** Provenance-specific growth reaction of Norway spruce

11:30	**Jenny Berg** Investigations into changing periodicity of western spruce budworm at its western distribution limits on Vancouver Island, BC, Canada
11:45	**Georgios Skiadaresis** Groundwater extraction increases growth sensitivity of pedunculate oak trees (*Quercus robur* L.) to summer drought
12:00	**Tanja Sanders** Intensive forest monitoring: describing stress from two sides
12:15	**Johannes Edvardsson** ECHoES – Effects of tree Colonization on Hydrology and carbon sequestration in peatland EcoSystems

12:30	**Lunch**

Session 2: Tree rings and knowledge of the human past
Moderator: Assoc. Prof. Dr. Aoife Daly

13:45	**Aoife Daly** Session Introduction
14:00	**Karl-Uwe Heussner** Dendrochronological Data from the Hanseatic City of Greifswald
14:15	**Lisa Shindo** Buildings and wood trade in Aix-en-Provence (South of France) during modern period
14:30	**Marie-Therese Barrett** Refining the statistical parameters for constructing tree-ring chronologies using short-lived species: Alder (*Alnus glutinosa* Gaertn)
14:45	**Andreas Kirchhefer** Cultural modified pines in Dividalen, Norway, reveal 17th-18th century dynamics of reindeer herding and Sámi use of forest resources
15:00	**Andrew Trant** Eco-cultural legacies of forests and plants over millennia

15:15	**Coffee Break**

Session 3: From leaves and roots to the wood – explorations of tree physiological functioning in a changing world
Moderator: Assoc. Prof. Dr. Mary Gagen

15:45	**Mary Gagen** Session Introduction
16:00	**Matthias Saurer** Combining tree-ring growth and carbon isotope variability to infer the long-term drought responses of trees
16:15	**Giovanna Battipaglia** Elevated CO_2 influences the productivity and the water use efficiency of the invasive woody species Ponderosa pine in savanna-like ecosystems of Nebraska
16:30	**Ivan Tychkov** Simulated cambial phenology of Siberian conifer trees and global climate change

16:45	**Elisabeth Robert** Variation in leaf, xylem and phloem tissue fractions along environmental gradients: testing the functional equilibrium hypothesis
17:00	**General Poster Session and Refreshments**
18:00	**Association for Tree-Ring Research Annual Meeting**

Thursday, April 26
Location: Alfried Krupp Wissenschaftskolleg, Martin-Luther-Straße 14

Session 4: Exploring the tree-ring archive to study climate variability
Moderator: Dr. Rob Wilson

08:30	**Danielle Verdon-Kidd** An Intercomparison of Reconstructions of the El Niño/Southern Oscillation Based on Different Proxy Data
08:45	**Fan Zhao** Spring drought fluctuation inferred from tree-ring δ^{18}O during the past 200 years and linkage with El Niño-Southern Oscillation in Diancang Mountain, Northwest Yunnan
09:00	**Sonja Szymczak** The intra-annual oxygen isotope cycle of tree-ring cellulose from pine trees as indicator of current and past hydroclimate
09:15	**Giles Young** Climate from Stable Oxygen Isotopes in United Kingdom Oaks
09:30	**Xiaochun Wang** Inverse phase relationship between the East and South Asian Monsoon over the past millennium and unprecedented weakening of the East Asian summer monsoon in recent decades
09:45	**Scott St. George** A new framework to test the origins of western American megadrought
10:00	**Tom Levanič** Suitability of endemic Balkan pines for climate reconstruction: case study from the W Balkan

10:15	**Poster Session 2 with Coffee Break:** ▪ Exploring the tree-ring archive to study climate variability ▪ Open poster session

11:00	**Marko Kazimirović** Climate-growth variability of beech chronologies: a case study from NP "Djerdap", Serbia
11:15	**Lara Klippel** A 1000+ year reconstruction of temperature extremes for the northeastern Mediterranean region
11:30	**Ryszard J. Kaczka** What can we learn from using daily climate data for growth-climate response analyses?
11:45	**Lixin Lyu** Usage of daily weather data for pattern recognition of tree-ring climate signals along environmental gradients

12:00	**Invited "provocative" lecture by Rob Wilson** All climate reconstructions are "wrong": A tree-ring perspective to understanding past climate

12:30	**Lunch**
14:00	**Mid-Conference Excursions:** **(1)** Tree-planting campaign**, (2)** City tour**, (3)** Experimental forest

18:00	**Public Lecture** by Prof. Harald Bugmann, ETH Zürich, Switzerland *Ein Streifzug durch die Wälder der Vergangenheit, Gegenwart und Zukunft* (Lecture in German); afterwards snacks and drinks

Friday, April 27
Location: Alfried Krupp Wissenschaftskolleg, Martin-Luther-Straße 14

Session 5: Methodological challenges in analyzing tree-ring data
Moderator: Dr. Holger Gärtner

08:30	**Holger Gärtner** Session Introduction
08:45	**Jernej Jevšenak** Comparison of linear and nonlinear machine learning methods for the analysis of statistical relationships between tree-rings and climate
09:00	**Darren Davies** SwanCal: An R-Shiny App for Reconstructing Past Climates from Tree-Rings
09:15	**Christin Carl** Direction Specific Radial Growth of *Robinia pseudoacacia* L. Stump Shoots - A Competition Analysis
09:30	**Jörg Niederberger** Phosphorus in Space and Time – P distribution within the woody biomass of trees
09:45	**Viorica Nagavciuc** Influence of decayed wood in tree rings stable isotopes analysis
10:00	**Allan Buras** Schizophrenic shrubs: Multi-directional, multi-proxy exploration of intra-individual growth heterogeneity

10:15	**Poster Session 3 with Coffee Break:** ▪ Methodological challenges in analyzing tree-ring data ▪ Inside wood – xylem anatomical features as indicators of change ▪ Towards the extremes – growth responses and resilience of trees after climatic disturbance

Session 6: Inside wood – xylem anatomical features as indicators of change
Moderator: Assoc. Prof. Dr. Marco Carrer

11:00	**Marco Carrer** Session Introduction

11:15	**Angela Balzano** Xylogenesis investigations and dendrochronology reveal the functions of IADFs in Mediterranean woods
11:30	**Jan Tumajer** Studying wood anatomical response of *Betula pendula* to mechanical damage using experimental approach
11:45	**Alma Piermattei** Exploring inter-individual wood anatomical variation along a *Picea abies* altitudinal transect
12:00	**Agata Buchwal** From anatomical to annual growth rings scale: dendroecological signal derived from *Betula nana* chronology in Northern Alaska
12:15	**Angela Luisa Prendin** Evidences of cyclic *Eurois occulta* outbreaks in West Greenland based on shrub-ring anatomy and remote sensing

12:30	**Lunch**

Session 7: Towards the extremes – growth responses and resilience of trees after climatic and environmental disturbance
Moderator: Prof. Dr. Marieke van der Maaten-Theunissen

13:45	**Marieke van der Maaten-Theunissen** Session Introduction
14:00	**Ouya Fang** Tree rings reveal a major episode of forest mortality in the late 18th century on the Tibetan Plateau
14:15	**Robert Weigel** Experimental Plant Ecology meets Dendroecology: Indications for the influence of winter climate on growth towards the cold distribution margin of European beech (*Fagus sylvatica* L.)
14:30	**Mohsen Arsalani** Reconstruction of droughts using a tree-ring width chronology of *Q. brantii* in the Zagros oak woodlands, Iran
14:45	**Dominika Wrońska-Wałach** Dendrogeomorphological analysis of foothills' landslides activity - an example from Wiśnickie foothill
15:00	**Gottfried Jetschke** On the track of extreme growth responses – a review and evaluation of methods for pointer year detection

15:15	**Coffee Break**

15:45	**Andrea Hevia** Do long-term nutrient imbalances contribute to drought-triggered forest dieback? Insights from tree-ring chemistry
16:00	**Martina Lavrič** Growth and drought response of *Quercus pubescens* willd. in different soils of sub-mediterranean region
16:15	**Henriette Schmidt** Reactions of rare native tree species in Germany to drought stress
16:30	**Raúl Sánchez-Salguero** Forest vulnerability to a warmer 21st-century climate: Assessing climate extremes using process-based models of tree growth

16:45	**Conference Closing Remarks** **Please Remove Your Posters**

19:00   **Conference Dinner and Awards**
Location: Theater Café, Anklamer Straße 108

Climatically controlled reproduction drives tree growth

Andrew Hacket-Pain (1)*, Christian Zang (2), Giorgio Vacchiano (3), Davide Ascoli (4), Renzo Motta (5), Marco Conedera (6), Igor Drobyshev (7), Janet Maringer (8), Franco Biondi (9), Liam Cavin (10), Christoph Dittmar (11), Isabel Dorado Liñán (12), Wolfram Elling (13), Michael Grabner (14), Claudia Hartl (15), François Lebourgeois (16), Tom Levanic (17), Juergen Kreyling (18), Ernst van der Maaten (18), Marieke van der Maaten-Theunissen (18), Annette Menzel (2), Lena Muffler (18), Ionel Popa (19), Catalin-Constantin Roibu (20), Tobias Scharnweber (18), Robert Weigel (18), Martin Wilmking (18), Andrew Friend (21)

(1) Geography and Planning, University of Liverpool, UK (2) TUM School of Life Sciences, Technical University of Munich, Germany (3) European Commission, Joint Research Centre, Italy (4) Dipartimento di Agraria, University of Naples Federico II, Italy (5) DISAFA, University of Turin, Italy (6) Swiss Federal Institute for Forest, Snow, and Landscape Research WSL, Switzerland (7) Forest Research Institute & Southern Swedish Forest Research Centre (SLU), Sweden (8) Institute for Landscape Planning and Ecology, University of Stuttgart, Germany (9) Department of Natural Resources and Environmental Science, University of Nevada, USA (10) Biological and Environmental Sciences, University of Stirling, UK (11) c/o CZ, TUM School of Life Sciences, Technical University of Munich, Germany (12) Forest Research Centre, INIA-CIFOR, Spain (13) c/o CZ, TUM School of Life Sciences, Technical University of Munich, Germany (14) Institute of Wood Science and Technology, University of Natural Resources and Life Science, Austria (15) Department of Geography, Johannes Gutenberg-University Mainz, Germany (16) Agronomy, Forestry, Water and Environmental Science and Technology, AgroParisTech, France (17) Department of Forest Yield and Silviculture Slovenian Forestry Institute Ljubljana Slovenia (18) Institute of Botany and Landscape Ecology, Greifswald University, Germany (19) National Research and Development Institute in Forestry, Romania (20) Forest Biometrics Laboratory, Faculty of Forestry, "Stefan cel Mare" University of Suceava, Romania (21) Department of Geography, University of Cambridge, UK

Correspondence: andrew.hacket-pain@liverpool.ac.uk

Climate and tree growth are closely linked, but the direction, duration and timing of growth-climate relationships are not consistent, and the processes that create observed correlations are poorly understood. The processes that cause lagged effects of climate on future growth are a major source of uncertainty. These lagged climate correlations are commonly found in empirical tree ring chronologies, but are not well produced by vegetation models.

In this study, we use newly available datasets for European beech (*Fagus sylvatica* L.) to investigate the interplay of climate, tree reproduction and radial growth across the species' geographic distribution. We use a tree-ring network that includes data from 14 countries, and a recently published database for tree reproduction (MASTREE, Ascoli et al. 2017). We hypothesise that previous year climate has important effects on growth through "lagged" or "legacy" effects (e.g. resource depletion). Additionally, we propose that previous year climate has an indirect effect on growth by controlling the annual reproductive effort, via climatic cues for high annual productive effort ("mast years"). We use Structural Equation Models (SEMs) to compare alternative models that include direct relationships between climate and growth, and indirect relationships via reproductive effort.

We found that climatically controlled variation in reproductive effort was a key control on growth in beech, and that it was the main factor controlling growth in some regions of Europe. Tree ring width could not be adequately explained unless we accounted for variable allocation to reproduction. Furthermore, lagged correlations between growth and previous summer climate were explained by the interplay with reproductive effort, and other "carry-over" effects did not appear necessary to explain observed growth variations. We argue that attempts to understand variation in tree growth need to incorporate flexible allocation of resources, including allocation to reproduction. This will improve our ability to reproduce observed variability in tree growth and growth-climate relationships, and improve predictions of future changes in growth.

Reference: Ascoli et al. 2017. Ecology, 98, 1473

Environmental significance of resin duct differentiation assessed by its quantification in tree rings of a Mediterranean pine

Carla Vázquez-González (1)*, Vicente Rozas (2), Ricardo Alía (3), Luis Sampedro (1), Rafael Zas (1)

(1) Misión Biológica de Galicia, Consejo Superior de Investigaciones Científicas, Spain. (2) Departamento de Ciencias Agroforestales, Universidad de Valladolid, Spain. (3) Centro de Investigación Forestal, CIFOR-INIA, Spain.
Correspondence: cvazquez@mbg.csic.es

In Mediterranean regions, temperature and drought frequency will likely increase by the end of this century. Biotic stress caused by plant pathogens and herbivores is also predicted to rise associated with global change. The ability of tree species to overcome the new environmental conditions will depend on both, their environmental plasticity and the extant intraspecific adaptive variation in functional traits related to resistance and tolerance against environmental stressors. Phenotypic variation for traits related to growth, productivity and abiotic stress tolerance have been well studied, but little is still know about defensive traits. Aditionally, most studies focus on the assesment of defensive function as punctual snapshots, whereas defensive investment is influenced by past climatic and biotic events during the tree lifespan.

Resin ducts are specialized structures for the synthesis and accumulation of oleoresin, the main defensive compound of conifer trees against pest and pathogens. The abundance of resin ducts have been related with the resistance to specific herbivores and pathogens, thus becoming a trait with potential adaptive value. Resin duct production is costly, and as any other trait, their phenotypic expression may rely on genotypic and environmental factors. Therefore, understanding the interactive effects of these factors on this major defensive mechanism becomes crucial to predict the performance and survival of Mediterranean trees in the near future.

Tree–ring anatomy is a valuable source of ecological information. Traditionally, tree rings have been used to asses the influence of climatic factors over traits related to growth, but inter-annual variability of any tree-ring-related feature can be quantified. Such is the case of axial resin ducts which reflect the variation of defensive investment of long –lived pine trees across their lifespan.

Here we applied dendroecological methods to retrospectively asses the phenotypic variation in the yearly expression of defensive structures of *Pinus pinaster* from a common garden experiment. we aimed (i) to asses the effect of environmental factors driving resin ducts phenotypic expresion and (ii) to ascertain the ontogenic variations of defensive investment along the tree lifespan. We used stem cores collected in two 40 years old replicated provenance genetic trials with contrasted climatic conditions, both of them with provenances from seeds collected across the whole natural distribution range of the species. We sampled four wood cores from 10 trees per each of 9 provenances in each place. We measured tree-ring width series and seperately counted the axial resin ducts in both the latewood (LW) and the earlywood (EW) for the last 40 years on every core.

We found that phenotypic expression of defensive traits was affected, not only by the particular site environment but also by their inter-annual variation, as indicated by a significant variability in resin duct production between years and sites. Additionally, relative defence investment showed contrasting patterns of resin duct differentiation in the EW and LW across sites and ontogenic states. Density of resin ducts was several fold greater at early developmental stages than at older stages in the EW, while the opposite trend was observed for LW. Besides, while density of resin ducts for the EW was twice greater in the unfavourable site, it was 30 % lower in the LW when comparing to the favourable emplacement. Altogether, our results evidence a plastic behaviour in the phenotypic expression of defensive investment modulated by local environment with opposite patterns for each tree-ring compartment. Our work emphasized the usefulness of dendroecology as a powerful tool for assessing the phenotypic plasticity in defensive investment along the whole lifespan, which will allow us to better understand the environmental interactions driving resin duct formation.

Investigation of age and site index in unevenaged private forests in Croatian Mediterranean and Submediterranean with dendrochronological methods and multispectral satellite images

Alen Berta (1)*, Tom Levanič (2), Zrinka Mesić (1), Davor Korman (1), Ivona Žiža (1), Nela Jantol (1), Vladimir Kušan (1)

(1) Department of Natural Resources Management, Oikon ltd Institute of Applied Ecology, Croatia
(2) Department of Yield and Silviculture, Slovenian Forestry Institute, Sloveni
*Correspondence: aberta@oikon.hr

Private owned forests in Croatia covers approximately one third of the afforested land (cca. 720.000 ha of 2.5 million hectares). These forests were not actively managed in the past although they had to adhere to certain laws and regulations through history, but owners had a possibility to decide what and when to do with their ownership. This resulted in a great number of forest owners, small forest properties (average plot is 0.32 ha/average property is 2 ha- due to inheritance and dividing the land) and multiple owners on one property which led to uneven aged forests with great diversity of stand structures in small areas.

Although Croatia has more than 250 years of organized forestry, this mostly entailed state forests. Some Forest Management Plans (FMP) for private owned forests were created after the WWII, but they enclosed only few percentage of the private owned forests and after few renewals, it has stopped (in Croatia FMP are valid for 10 years).

During the last decade, Extension Services has started to support development of the forest management plans for private owned forests. Presently, FMPs have been developed for more than a half of private owned forests in Croatia. During the creation of those plans, yield tables and normal models for state owned forests, primarily evenaged stands with long-time management, were used because similar has not been developed for uneven aged and poorly managed forest. This obviously gave the wrong results, but faced with the lack of data, any data was good.

With this research we have encompassed private owned forests in Croatian Mediterranean and Submediterranean where Holm oak (*Quercus ilex* L.) and Pubescent oak (*Quercus pubescens* Wild.) are prevailing main species in forest stands. These forests are representing almost half of the private owned forests in Croatia. Main goal was to determine age of those stands and create yield tables regarding site indexes revealed trough analysis of yearly radial increments.

First, we cored 1286 oak trees on 383 locations spread through Croatian Mediterranean and Submediterranean. We cored 2-3 trees of mean diameter on the plot and one dominant tree; double core was taken from at least one tree per plot. Some cored trees were two centuries old. Due to high eccentricity of the tree's centre only 379 of the cores were cored to the centre. Additionally, with use of the chronologies we have manage to utilize most of the approximately 850 cores that were cored very close to center.

This research is in final stage and these data (stand age and grouping by site index/productivity level) will be used for correlation with Sentinel 2 multispectral satellite data ie. with plain multispectral bands and various vegetation indices (NDVI, EVI, LAI, etc.).

These models and yield tables will expedite and optimize operational forest management, if used during creation of inventory or yield prediction for private owned forests. Also, these results could have notable application for the carbon sequestration assessments of the forests and consequently for the creation of the GHG National Inventory Reports, according to UNFCC convention. Furthermore, by implementing the models for average stand age assessment, it could lead to the more precise use of the growth models for evenaged stands where age is the main input data. Also, depending on suitability and precision, these models can be used for monitoring the degradation of these stands/forests.

Responses of high latitudinal tree stands to global warming at the Siberian Arctic treeline – combining dendrochronology and simulation modelling

Stefan Kruse (1)*, Mareike Wieczorek (1, 2), Laura S. Epp (1), Alexei Kolmogorov (3), Anatoly N. Nikolaev (3, 4), Ingo Heinrich (2), Florian Jeltsch (5, 6, 7), Alex Gerdes (8), Luidmila A. Pestryakova (3), Romy Zibulski (1),Ulrike Herzschuh (1, 9, 10)

(1) Polar Terrestrial Environmental Systems Research Group in Potsdam, Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Germany, (2) GFZ German Research Centre for Geosciences, Telegrafenberg, Germany, (3) Institute of Natural Sciences, North-Eastern Federal University of Yakutsk, Russia, (4) Melnikov Institute of Permafrost SB RAS, Russia, (5) Department of Plant Ecology and Nature Conservation, Institute of Biochemistry and Biology, University of Potsdam, Germany, (6) Berlin-Brandenburg Institute of Advanced Biodiversity Research (BBIB), Germany, (7) ZALF, Leibniz-Centre for Agricultural Landscape Research, Germany, (8) Institute of Physics and Astronomy, University of Potsdam, Germany,(9) Institute of Biology and Biochemistry, University of Potsdam, Germany, (10) Institute of Earth and Environmental Science, University of Potsdam, Germany
Correspondence: stefan.kruse@awi.de

It is generally assumed that tree populations at the Arctic treeline will respond by densification and northwards migration to global warming. Both processes would lead to vegetation-climate feedbacks and a further warming is likely. Unfortunately, recent global vegetation models overestimate response speeds, so that the strength and timing remain rather uncertain. To unveil major processes of treeline advance, we combined field investigations with a simulation-based approach.

Our study region covers the treeline ecotone at the southern Taymyr Peninsula, from closed forest in the south to single-tree tundra in the north. In addition to field data, we designed a new individual-based and spatially explicit model, the *Larix* vegetation simulator LAVESI. To achieve a most realistic model, each life history stage of larches is handled explicitly. The in situ information of tree stands were analyzed to infer stand structure, tree age, and seed quality and quantity from seven sites, and were used to parameterize the model. We investigated the effects of intra-specific competition and seed availability on the specific impact of recent climate warming on larch stands.

In the closed forest and the forest tundra, trees were present for at least ~240 years. Establishment history at all sites but the two southernmost ones are positively correlated to increasing temperatures. In the single-tree tundra, creeping krummholz individuals started to change their growth form to erect trees ~130 years ago. Seeds at this site are of lowest quality, compared to the closed forest and the forest tundra, and recent recruitment is nearly absent. Simulations with LAVESI further suggest that intra-specific competition limits stand-densification in the south, whereas seed limitation hinders further range expansion or densification in the single-tree tundra. Additional simulations of hypothetical tundra-taiga transects suggest that the treeline migrates only by few meters per year into treeless tundra, and the reaction generally lags behind the climate warming by decades.

Provenance-specific growth reaction of Norway spruce

Marcin Klisz (1)*, Radosław Puchałka (2), Marcin Koprowski (2), Paweł Przybylski (1), Anna Tereba (3)

(1) Department of Silviculture and Forest Tree Genetics, Forest Research Institute, Poland (2) Department of Ecology and Biogeography, Nicolaus Copernicus University in Toruń, Poland (3) Department of Forest Ecology, Forest Research Institute, Poland
Correspondence: m.klisz@ibles.waw.pl

Climate-induced changes in radial growth rate seems to be provenance-dependent and therefore could be interpreted as a proxy of their natural adaption to changing temperatures and extreme weather events. To investigate provenance-specific growth reaction in particular the genetic, environment and G × E effect, wood material from IUFRO 1972 Norway spruce provenance trails were collected. For better understanding the molecular determinants of growth reaction, nuclear microsatellite variation (SSR markers) were determined. As a main climatic factors triggering climate-induced growth reaction standardized precipitation evapotranspiration index (SPEI) and Palmer drought severity index (PDSI) were applied. The climate of provenance origin, in relation to actual Norway spruce distribution in Poland, were verified based on PCA analysis of bioclimatic parameters. In this study three main hypotheses have been posed: i) climate-induced growth reaction in Norway spruce is provenance-specific, that ii) the provenance variation of growth reaction manifests mainly during drought years that iii) the nuclear microsatellite variation of the spruce populations is not directly related to growth-reaction. The main findings of these studies support the thesis that provenance-specific growth-reaction studies should be incorporated of into forest tree breeding programs when searching best genetic material fit for climate change.

Investigations into changing periodicity of western spruce budworm at its western distribution limits on Vancouver Island, BC, Canada

René I. Alfaro (1,2), Lara vanAkker (1), <u>Jenny Berg</u> (2)*, Brian Van Hezewijk (1), Qi-Bin Zhang (3) , Dan Smith (2) and Jodi Axelson (4)

(1) Canadian Forest Service, Pacific Forestry Centre, 506 W Burnside Rd, Victoria, BC, Canada, V8Z 1M5 (2) University of Victoria Tree-Ring Laboratory, Department of Geography, University of Victoria, BC, Canada, V8W 3R4 (3)Institute of Botany, Chinese Academy of Sciences, 20 Nanxincun, Xiangshan, Haidian District, Beijing 100093, China (4) University of California, Berkeley CA, 94720
Correspondence: vedaworks@gmail.com

The western spruce budworm (WSB) is a serious insect pest of conifers in western North America. Forest health is greatly impacted by the larval stage, which consumes the foliage. During budworm outbreaks defoliated trees produce narrow rings which can be used to date past outbreaks. Several studies have examined the historic reoccurrence of this budworm in the continental regions of North America using dendrochronology (Flower et al., 2014; Axelson et al., 2015; Alfaro et al. 2014; Ellis and Flower, 2017). However, no studies have examined the historic disturbance patterns of this defoliator at its extreme western distribution. Our study compiled a set of twelve site chronologies to investigate the severity and return interval of WSB outbreaks west of the Coast Mountains of B.C. in Douglas-fir dominated forests of eastern Vancouver Island and gulf islands. Our methodology for identifying outbreaks included sampling both WSB host and sympatric non-host tree species in the region. The subtraction of the non-host species chronology from our Douglas-fir host chronology produced a high-resolution corrected index; which indicates annual growth loss associated defoliation rather than climatic factors such as, drought. Our multi-century outbreak reconstruction indicates that this western periphery of WSB habitat maybe less of a forest health issue in the coming years due to an observed reduction in regionally synchronous behaviour as well as, dwindling outbreak severity in the mid-to-late 20th century in comparison to interior budworm trends.

Groundwater extraction increases growth sensitivity of pedunculate oak trees (*Quercus robur* L.) to summer drought

Georgios Skiadaresis (1)*, Julia Sohn (1), Jürgen Bauhus (1)

(1) Chair of Silviculture, Faculty of Environment and Natural Resources, Freiburg University, Germany
Correspondence: georgios.skiadaresis@waldbau.uni-freiburg.de

In future, groundwater dependent ecosystems are very likely to receive increased pressure from indirect effects of the ongoing climate change. In central Europe, floodplain oak forests already receive increasing pressure through extraction of groundwater for industry, agriculture and domestic use. Here, we focus on pedunculate oak (*Quercus robur*) forests which are known to depend partially on groundwater to cover their water needs. We sampled and analysed tree-ring width series of oak trees and investigated the development of the relationship between climate and annual growth under three differing groundwater regimes.

   Three sites were examined where groundwater extraction has resulted in dramatic lowering of groundwater tables and loss of access to groundwater for the trees. These sites were compared to similar sites in close proximity that have not been affected by water extraction. Additionally, sessile oak (*Quercus petraea*) trees growing at upland sites on free draining soils and which never had contact to the groundwater table were utilized to isolate the climate signal for each studied region. We hypothesised that groundwater extraction would increase climate sensitivity of growth because precipitation deficits cannot (or to a lesser degree) be buffered through ground water. Moreover, we expected that the effect of lowered groundwater tables on climate-growth relationships would be less pronounced in younger trees, which developed their root system under the condition of lower water tables.

   Overall, growth of oak trees at all sites was significantly correlated with summer drought. In contrast to our expectation, younger Q. robur trees appeared to be more sensitive than older trees growing under similar conditions, while the opposite was evident for Q. petraea. Moving window correlation analysis revealed that growth sensitivity to summer drought increased following the extraction events for the trees growing at the affected sites. On the other hand, sensitivity of trees growing at the wetter sites remained relatively stable over time. Surprisingly, sensitivity of the studied sessile oak trees growing in the drier uplands increased with time at a pace similar to that of trees at sites where groundwater is extracted. Our results imply that loss of contact to groundwater increases the susceptibility of oak trees to summer drought while access to groundwater buffers the negative effects of summer drought events on their growth. Moreover, the increased sensitivity of younger trees to summer drought suggests that future generations of oak will be equally affected by lowered groundwater tables.

Intensive forest monitoring: describing stress from two sides

Tanja GM Sanders (1), Daniel Ziche (1) and Wolfgang Beck (1)

(1) Thuenen-Institute of Forest Ecosystems, Eberswalde,Germany
Correspondence: tanja.sanders@thuenen.de

Tree growth is influenced by a variety of factors. One, or the combination of two, is regularly used in dendroecology: temperature and precipitation. While other factors are known to have a possibly equally high impact, be it soil condition or biotic damages, climate-growth correlations are still standard. This might be due to easy availability of climate data at nearly every location, worldwide. However, the actual drivers of growth at any given site might not be revealed without knowing the stresses the tree experiences. While a negative pointer year or a growth decline tells us a clear story, the reasons might be various and most likely the answer will be in the unique combination of them. To really understand what drives tree growths, we need to understand its environment beyond the information from gridded climate data.

Using data of the intensive forest monitoring plots of ICP Forests1 (Level II) we have meteorological measurements in close proximity to the forest; but we also have information on the solid soil phase, deposition, phenology, water availability, biotic damage, competition and more. Based on tree-ring data, we determine pointer years, sensitivity, and recovery for several plots in Germany. Additionally, we looked at the site conditions to better understand the information provided by the chronologies. The benefit of the detailed site and stand description is shown at the example of two oak sites growing under very contrasting conditions; allowing us to gain a deeper understanding about the breadth of potential adaptation to site conditions for oak.

On a broader scale dendroecological studies at the ICP Forests Level II network and its various gradients, allow studies on site adaptation for many more species but also studies on the impact of the growing season or nitrogen deposition on tree-ring width.

PS: Please get in contact with icpforests-pcc@thuenen.de if you would like sample at the plots and for data access.

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1 The intensive forest monitoring is organized under the umbrella of the United Nations Economic Commission for Europe (UNECE) as the 'International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests' (ICP Forests); a programme within the 'Working Group on Effects' (WGE) of the 'Convention on Long-range Transboundary Air Pollution' (CLRTAP). The mission of ICP Forests is to "carry out multifunctional long-term monitoring of forests within the UNECE region and beyond and provide scientific knowledge on the effects of air pollution, climate change and other stressors on forest ecosystems" (Strategy of ICP Forests 2016–2023; to be adopted at the 32nd Meeting of the Task Force of ICP Forests).

ECHoES – Effects of tree Colonization on Hydrology and carbon sequestration in peatland EcoSystems

Johannes Edvardsson (1)*, Paul Miller (2), Mats Rundgren (1), Leif Klemedtsson (3), Mats Nilsson (4), Eeva-Stina Tuittila (5), Marija Tamkevičiūtė (6), Christophe Corona (7, 8), and Markus Stoffel (8, 9)

(1) Department of Geology, Lund University, Sweden, (2) Department of Physical Geography and Ecosystem Science, Lund University, Sweden, (3) Department of Earth Sciences, University of Gothenburg, Sweden, (4) Department of Forest Ecology & Management, SLU, Umeå, Sweden, (5) University of Eastern Finland, Finland, (6) Nature Research Centre, Vilnius, Lithuania, (7) GEOLAB, Clermont-Ferrand, France, (8) Dendrolab.ch, Department of Earth Sciences, Geneva, Switzerland, (9) Institute for Environmental Sciences, University of Geneva, Switzerland.
Correspondence: johannes.edvardsson@geol.lu.se

Healthy peatlands are globally important long-term greenhouse gas (GHG) sinks contributing to vital carbon sequestration, biodiversity, and fresh-water purification 1,2. However, climate change, increased nitrogen deposition and anthropogenic activities (e.g. drainage and peat harvest) may cause water-table and vegetation changes, which rapidly transform the peatlands into GHG net emitters. Strongly reduced carbon sequestration is expected if drier conditions turn moss-dominated peatlands into tree-covered conditions3. At present there is growing bulk of evidence for accelerating shrubification and tree colonization at northern Hemisphere peatlands 4,5. But, despite the global importance of peatland ecosystems, we still lack a holistic and integrated understanding of the processes linking peatland tree colonization with hydrology and carbon sequestration.

In the recently started project ECHoES (Effects of tree Colonization on Hydrology and carbon sequestration in peatland EcoSystems), we therefore aim to study linkages between tree colonization – hydrology - carbon sequestration in peatlands by, (i) monitoring of peatland tree colonization, hydrology and GHG fluxes compare, (ii) ecosystem modelling, and (iii) comparisons between ongoing and past colonization events during the Holocene. To fulfil our research objectives, ongoing processes will be studied using monitoring equipment (dendrometers), peat stratigraphic analyses and dendrochronology. To enable comparisons with earlier tree colonization events, such as the tree establishment during the Holocene Thermal Maximum, subfossil peatland trees will be used.

At present, fieldwork campaigns are underway to install dendrometers at peatland complexes in Sweden, Finland, Estonia and Lithuania. At several of our study sites, state-of-the-art equipment for GHG fluxes (CO_2 and CH_4), water-table fluctuations and meteorological parameters are already in place, and hourly monitoring have been ongoing for many years. For the studies of past tree colonization events, more than 1000 subfossil trees from sites in southern Sweden and Lithuania have already been collected and analysed 6,7. This material will serve as a basis for the comparisons between past and present colonization events. Moreover, contacts with research teams in Germany and Denmark have been established, which will allow for comparisons with an even larger subfossil wood material 8. Our ongoing studies show that trees have colonized Northern Hemisphere peatlands repeatedly during the last 10,000 years. But to clarify the cause and effects of these events, as well as future implications of the ongoing peatland tree colonization, the ECHoES project will explore new methods to model ongoing processes and unravel information stored in the subfossil trees.

The outcome of the ECHoES project will advance our knowledge about links between tree colonization, moisture variability, and carbon sequestration in peatlands, which in a wider context has a direct impact on the global carbon cycle. Such information therefore has high societal relevance as it provides valuable input to environmental governance, particularly as a basis for ecosystem services and strategies for carbon sequestration in the context of future climate change.

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Dendrochronological Data from the Hanseatic City of Greifswald

K.-U. Heussner (1)*

(1) German Archaeological Institute, Berlin
Correspondence: dendro@dainst.de

In the hanseatic city of Greifswald many historic buildings are well-preserved. Due to its location close to the water, the groundwater level is high. This provides very good preservation conditions for wooden structures in the underground. At the time of the foundation of the city (it received its town charter in 1250) the groundwater level has been slightly lower than today. It rises at the beginning of the 14th century owing to climate changes, the building of dams and large-scale forest clearance for agriculture. Because of embankments and the erection of buildings on top of older structures, many wooden structures got into the groundwater area where they are preserved up until today. Many of them came into light during the course of intensive construction activity after the fall of the Wall in Germany.

Few of the excavated woods are dated to prehistoric times (about 2165 BC to the 1st century AD). Relating to the history of Greifswald from its beginnings up until modern times, 11.171 wood samples are submitted to our laboratory for dendrochronological examinations. Out of these samples 71,4% are successfully dated. Thereby, Greifswald is the most well-documented city in the so-called "Wendish Quarter" of the Hanseatic League from a dendrochronological point of view. Right from the beginning of the research emphasis is placed on the sampling of as many species of wood as possible. Most common in the samples from Greifswald is the use of oak (*Quercus*). Especially in the samples from trading woods and in younger periods pine (*Pinus*) occurs. Other species of wood that are extensively used are beech (*Fagus*), alder (*Alnus)* and ash (*Fraxinus*). To a lesser extent further species are used as lumber. For most species of wood (oak, pine, beech, alder, ash, maple) well-documented city chronologies for the Middle Ages and beyond could be compiled. During the foundation period of the city the main source for wood is its surrounding area. From about 1280 on the surrounding forests are vastly exhausted. More and more wood gets imported via the Baltic Sea. In comparison with other hanseatic cities the wood trade in Greifswald extends to a lesser degree than that in cities that are located further to the west, such as Stralsund, Rostock or Wismar. The state of research on the latter cities is about the same as that in Greifswald. Depending on their origin, the imported woods differ significantly in their treatment and their tree ring construction.

The dating of the wood samples reflects the ups and downs of the city's development. Few of the samples derive from features that prove a settlement in Slavic times already (e. g. A 11/HGW 214, 994 +/-10, 1075 +/-10). The earliest samples from Greifswald that can be referred to the development of the city, date to about 1200, i. e. roughly 50 years before its first documentary evidence. There is a very intense building activity during the 13th and 14th century which is followed by a crisis in the 14th century. Afterwards the city develops slowly but continuously up until modern times. Today, the recent history of Greifswald is reflected in its broad variety of historical buildings that still are sustained and provide further dendrochronological data.

Buildings and wood trade in Aix-en-Provence (South of France) during modern period

Lisa Shindo (1)*, Sandrine Claude (2)

(1) Aix Marseille Univ, CNRS, Minist Culture, CCJ, Aix-en-Provence, France, associate member, (2) Direction Archéologie de la ville d'Aix-en-Provence, France
Correspondence: shindo@mmsh.univ-aix.fr

Aix-en-Provence history dates back to Antiquity (it is the first Roman foundation in Gaulle), but the city centre architecture is inherit from the status of Aix-en-Provence as a parliamentary capital. Constructive activity during 17th and 18th centuries is a result of parliamentarians 'requests: they order their particular mansions in the city, their pleasure residences in the countryside, and finance friaries or chapels in churches.

Since 2013, timbers from 10 buildings are studied on the occasion of restauration works: 4 particular mansions (Caumont, Deudon de Pierrefeu, Estienne d'Orve and Maynier d'Oppède), 3 castles (Grand-St-Jean, Jas de Bouffan and the Seuil in Puyricard) and 3 churches (Madeleine, Notre-Dame-de-Consolation and St-Jean-de-Malte). At the same time as dendrochronological analysis, some of these buildings were the subject of archaeological studies. We propose here to present one aspect of this significant building activity in Aix-en-Provence: the supply of provision and the timbers implementation.

Most of studied timbers are Fir trees (Abies alba Mill.), a specie with a wood of good quality, strong, straight fibers, and allowing long spans (up to 12 m). 145 Fir trees are dated with dendrochronology and the average chronology is 1303 – 1933. This is the first abies archaeological chronology in this region.

Lower Provence region does not have large forests for timber production and Aix-en-Provence's Fir trees were imported. On the one hand, we will present our results related on timber trade (marks from woodcutters, traders, carpenters or others): they remind us the wood route from mountains, on roads and by stream driving. On the other hand, we will mention the provided solutions to thwart the supply of provisions difficulties: the important reuse economy and technical innovations (reinforced beams, repairs)

This interdisciplinarity approach, between dendrochronology and archaeology, enhances the knowledge on buildings, wood trade and mountain and plain exchanges, in the South of France.

Refining the statistical paramaters for constructing tree-ring chronologies using short-lived species: Alder (*Alnus glutinosa* Gaertn)

Marie-Therese Barrett (1)*, David Brown (1), Gill Plunkett (1)

(1) Archaeology & Palaeoecology, School of Natural and Built Environment, Queen's University Belfast, Northern Ireland
Correspondence: mbarrett08@qub.ac.uk

The dendrochronological potential of short-lived species has had varying degrees of success in the past. Where there has been a level of success with short sequenced assemblages, the focus has been on visual comparisons, based on the occurrence of signature rings. Of vital importance to alder's ability to be cross-correlated is that it produces a significant amount of distinguishable signature rings. Between 2012 and 2013, a large artifical island (crannog) of medieval date was excavated at Drumclay, County Fermanagh, Northern Ireland, and revealed a site of significant longevity, dating from the 9th to 16th centuries AD. This excavation exposed a vast number of well-preserved waterlogged archaeological features, resulting in the retention of over 9,000 individual wood samples. Oak timbers were used scarcely in the construction of the crannog, with the dominant wood species identified during excavation being alder. While the oak timbers have proved successful in providing spot dates and indicating phases of activity, the full chronological potential of the wood assemblage lies in the ring patterns of the principal species, alder, particularly with respect to understanding construction phases and site evolution. Previous failures to build chronologies using alder have been attributed to the short-lived and site specific nature of the species. Here, we test whether the measurement of large numbers of samples from a single context within a single site overcomes the limitations posed by alder.

  We measured the ring-widths of 19 alder timber samples from a single archaeological feature within the crannog's infrastructure to test if a robust context chronology could be built. The average ring sequence length ranged from 30 to 60 rings, with one timber extending to 108 rings. Visual correlations were used to aid ring pattern matching but only in conjunction with statistical correlation using only t values of 3.5 and higher. We used radiocarbon wiggle-matching to test the robustness of our constructed chronology. Our results to date show that problems of autocorrelation can arise when long alder sequences (>100 rings) are used in conjunction with short sequences (30 to 60 rings). Establishing a rigorous protocol for sample selection has enabled us to develop a more statistically refined methodology that has produced t-values as high as 8.3. We show that in order to construct the best possible alder chronology, multiple ring patterns need to be examined from each context. We recommend examining short-lived assemblages on their own merits; the best approach in these cases is not to look for the longest sequences but instead to focus on the those from the mean sequence range.

Cultural modified pines in Dividalen, Norway, reveal 17th-18th century dynamics of reindeer herding and Sámi use of forest resources

Andreas J. Kirchhefer (1)*

(1) Dendroøkologen A. J. Kirchhefer, Norway
Correspondence: andreas.kirchhefer@dendro.no

The pine forest of Dividalen in the inner Troms County, northern Norway (68.7°N 19.8°E) is an ancient Sami cultural landscape. Numerous cultural modified pines witness the utilization of forest resources. During systematic registrations in the inner 24 km of the valley, more than 400 cultural modifies pine trees (CMT) were mapped. In the Upper Dividalen Nat. Park, an area nearly untouched by logging, the density of CMTs was determined as 3 trees/ha. About 52 %, rather large scars seem to be traces of harvesting pine innerbark as an important source of vitamins. Smaller scars might mark paths (29%), are related to preserving reindeer sinews (11%), or could not be explained (8%).

After removal of the bark, the trees react by an abrupt growth increase outside the lateral margins, but an abrupt dieback of the cambium just outside the horizontal cuts. Thus, by taking two cores that capture those opposing growth signals, the events of bark removal could be analyzed dendrochronologically. On a limited number of trees (65), a total of 88 scars were dated. The dates of the bark-peelings and tree-markings range from 1619 to 1863. One might explain the onset of bark-peeling by forest dynamics, i.e. the recovery after the heavy die-back of 1460, yielding suitable tree sizes not before the early 1600s. However, it is more likely that the cause is a dramatic change in Sami economy due to colonization of northern Sweden by farmers, mining activity etc. Thus, the old siida system changed, Swedish forest Sami joined the Mountain Sami on their annual migration to the western coast, and apparently discovered the forest resources of Dividalen.

The number of scars increased towards the 1750-1760s, parallel with the increase in both reindeer and human population. Thus, its maximum appeared close to the drawing of the border between Sweden and Denmark-Norway in 1751, which strongly affected the migration of reindeer Sami. Not much later, in the late 1760s, the number of scars suddenly dropped. Diseases in the reindeer herds caused reduction of the number of Sami in the nearby Swedish village Jukkasjärvi and might the abandonment of the summer pastures in Dividalen. This happened more than 20 years before the onset of the Norwegian colonization of the Målselv-valley and 75 years before the establishment of the first farm in Dividalen.

At first puzzling, the number of scars seems to be synchronized with the decadal variability of the Dividalen tree-ring chronology. While attempts to find historical explanations for these fluctuations were not convincing, climate might be the driver for both human behavior and tree-growth. The season for bark-peeling is June, when sap is ascending and the cambium is re-awakening: the bark is easily removed contains much sugar. Also, June is calving season, and Dividalen is calving land. However, when spring was late, the reindeer herds left their winter pastures later, the reindeer calved east of the mountains, and Dividalen was reached or passed first after the bark-peeling season. So, when summers were good (starting early), also pines were peeled.

Within the valley, the few and spatially scattered dated CMTs reveal spatio-temporal variability of human activity, moving between various parts of the valley. It is a well-known fact that summer dwellings moved when pasture or firewood reserves were depleted. Also, dendrochronology reveals that trees were harvested repeatedly, with about 10 years intervals. Apparently, bark was harvested systematical, each year moving on into an adjoining area. With the dated CMTs being older than 100 years and of Sami origin, these trees are automatically protected by law. The field registrations show that outside the national park, 70 % of these CMTs are lost due to, e.g., logging and tar burning, and that the remaining CMTs frequently are damaged. There is an urgent need for strategies for the protection of, as well as research on, these unique archives of Sami history.

Eco-cultural legacies of forests and plants over millennia

Andrew Trant (1)*

(1) School of Environment, Resources and Sustainability, University of Waterloo, Canada
Correspondence: atrant@uwaterloo.ca

Human occupation is usually associated with degraded landscapes. How has 13,000 years of repeated occupation by coastal indigenous peoples (British Columbia, Canada) influenced patterns of forest productivity and plant diversity in temperate rainforests? In particular, how have ecosystem processes changed over the past 6,000 years when intensified intertidal shellfish usage resulted in the accumulation of substantial shell middens? How do these ecological and cultural legacies compare to other patterns globally? Using a combination of airborne LiDAR, archaeological and ecological methods, we examine how the consequences of long-term site occupation, such as shell middens and fire, influence measures of forest productivity and plant diversity at our study site on the Central Coast of British Columbia, Canada. Forest productivity, expressed by forest canopy height, forest width, vegetation greenness, forest canopy cover and plant diversity at habitation sites was compared with forests along the entire coast contained within our study area using LiDAR extracted from the coastal forest boundary. We show that soils at habitation sites are higher in calcium, phosphorous and pH. All of which are limiting factors in coastal temperate rainforests. We also reveal a strong association between habitation sites and low-severity fire. Furthermore, we found differences in plant biodiversity, especially species of high cultural importance. In general, forests growing on sites with shell middens were significantly more productive than those growing on otherwise similar sites. Western redcedar (Thuja plicata) trees growing on shell middens were found to be taller, have higher wood calcium, greater radial growth and exhibit less top die-back. Coastal British Columbia is the first known example of long-term intertidal resource use enhancing forest productivity and we expect this pattern to occur at archaeological sites along coastlines globally.

Combining tree-ring growth and carbon isotope variability to infer the long-term drought responses of trees

Matthias Saurer (1, 2)*, Galina Timofeeva (1, 2, 3), Kerstin Treydte (2), Harald Bugmann (3), Andreas Rigling (2), Marcus Schaub (2), Rolf Siegwolf (1, 2)

(1) Laboratory of Atmospheric Chemistry, Paul Scherrer Institut, Villigen, Switzerland, (2) Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Birmensdorf, Switzerland, (3) Forest Ecology, Department of Environmental Systems Science, ETH Zürich, Zürich, Switzerland.
Correspondence: matthias.saurer@wsl.ch

Increasing drought has been suspected to be a cause of tree decline in various regions. Stable carbon isotopes in tree-rings are sensitive to drought conditions and could therefore be useful for identifying such drought-effects. When a tree is subjected to lack of water, leaf stomatal conductance is generally reduced and as a result also the degree of isotope fractionation during CO_2-fixation. However, it may not be clear from the isotope ratio how much photosynthesis was reduced and thus whether a tree was suffering from a lack of carbohydrates as a result of stomatal closure. Here, we discuss if the combined analysis of $\delta13C$ and growth variations can help to disentangle the importance of different physiological processes. We analysed radial growth and stable carbon isotopes in tree rings ($\delta13C$) in a mature Scots pine (*Pinus sylvestris* L.) forest over the 20th century to elucidate causes of observed tree mortality in one of the driest parts of the European Alps (Timofeeva et al. 2017). Additionally, we investigated the effects of irrigation in this forest stand, where annual precipitation was doubled for a 10-yr period. We found a sustained growth increase and immediate decrease of $\delta13C$ values for irrigated trees, indicating higher stomatal conductance and thus showing that water is a key limiting factor indeed. Growth of now-dead trees started declining in the mid-1980s, when both mean temperature and vapor-pressure deficit (VPD) strongly increased. Growth of these trees was reduced to some extent already several decades earlier, while intrinsic water-use efficiency derived from $\delta13C$ values was higher, indicating a very conservative water-use strategy, possibly at the cost of insufficient carbon uptake. The climate correlation analysis further showed that radial growth of the now-dead trees was highly sensitive to spring and summer mean temperatures as well as VPD. Therefore, the recent increase in atmospheric moisture demand in combination with insufficient soil water supply was likely the main trigger for tree decline and mortality of already weakened trees in Pfynwald. We conclude that the combined analysis of growth and stable isotope variations is very useful for better understanding causes of tree decline.

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Elevated CO2 influences the productivity and the water use efficiency of the invasive woody species Ponderosa pine in savanna-like ecosystems of Nebraska

Giovanna Battipaglia (1)*, Tala Awada (2), Rahel aus der Au (3), Matthias Saurer (4), Paolo Cherubini (3, 4)

(1) Department of Environmental, Biological and Pharmaceutical Sciences and Technologies Second University of Naples, Via Vivaldi, 43 - 81100 Caserta, ITALY, (2) Department, University / Research Institute, Country.
Correspondence: giovanna.battipaglia@unicampania.it

A change in climate would be expected to shift plant distribution as species expand in newly favorable areas and decline in increasingly hostile locations.

The trajectory of these shifts under changing climate, and their scales are particularly critical in a semi-arid environment where temperature, precipitation, and disturbance are key factors determining vegetation type, including transitions between grasslands, savannas and forests. In Nebraska, and other semi-arid regions of the Great Plains, one of the consequences of these changes is a shift in vegetation cover, specifically the increase of woody species encroachment in grasslands and riparian forests, like the transformation of savanna-like ponderosa pine (*Pinus ponderosa* P. & C. Lawson) ecosystems into dense forests.

The factors responsible of this phenomenon are still debatable because, although several factors have been indicated as drivers of those changes, such as decreased fire frequency, over-grazing, climate change, land management, and human-and natural enhanced seed dispersal, it is difficult to disentangle such complex interactions between biotic and abiotic factors.

In this study we used a multidisciplinary approach combining dendrochronology and stable isotopes to improve the understanding of possible causes of this process.Two sites of Nebraska National Forest with sharply contrasting structure and density were analysed: a dense P. ponderosa plantation, and neighbouring open woodlands with widely scattered pine trees.

The aim of this study is to evaluate whether stand structure and/or climate modulates the long-term physiological performance and growth of P. ponderosa trees in a semiarid Nebraska ecosystem.

Our findings show that the increase in growth of ponderosa pines, starting in 1960, at both sites is related to the increase in atmospheric CO2 concentrations, in particular at the sparse site because of higher water availability. No increase in 13C- derived WUEi (intrinsic water use efficiency) of ponderosa pine was recorded indicating the absence of water stress and the ability of this species to withstand adverse climatic conditions.

Simulated cambial phenology of Siberian conifer trees and global climate change

Ivan Tychkov (1)*, Margarita Popkova (1), Victor Iljin, Vladimir Shishov (1)

(1) Department of Mathematical Methods and Information Technology, Siberian Federal University, Russia.
Correspondence: ivan.tychkov@gmail.com

Recent climate change may lead to a sudden and unexpected reactions in growth of trees, the shift of growth seasons, or even the cessation of growth. That is why phenological response of forest plant to climate can provide relevant information in studies of climate changes and its impact. The study goal is to analyze a variability of phenological records obtained for latitude North-Southern boreal transect in central Yakutia and to interpret how recent and ongoing climate changes affect on phenology of conifer trees.

There are several methods to obtain phenological data, two of them: direct field observations of the selected test treesfor the study area based on microcores analysis or estimations obtained by satellite remote sensing.

But the direct observations are limited by the length of observation period (several growing seasons) which are not enough to make a statistically siginifinant conclusion due to high variability of the observed data and limited number of core samples. The obtained data from remote sensing can be affected by various factors (i.e. coarse spatiotemporal resolution, varying aerosol concentrations, etc). It can lead to possible discrepancies (or distortions) between obtained results from both methods.

Process-based simulation can be used as other independent source to obtain the phenological information tested in different conditions of Russia and China. Particularly we use a visual parameterization (VS-oscilloscope) of well-validated process-based forward VS-model of tree-ring width formation as a tool to provide data of vegetation phenological variability, which can be compared with direct observations or satellite data.

The latitude, daily mean temperature and amount of daily precipitation of the studied area are using as input data in VS-Oscilloscope. Dates of the start and the end of the growing season (cambial activity) for each year, and corresponded tree-ring width indices are the particular results of the simulation which can cover much longer time periods (up to 80 years) in comparison with other approaches (up to 80 years). Tree-ring data of 20 sites of conifer species and daily climatic data for 7 stations located across Lena river were used. Obtained residual chronologies were divided into three groups: Northern, Center and Southern parts of region.

For all parts of the transect, the start of the growing season (SOS) has advanced over the last three decades 1981-2014: for northern part, on average, 0.33 d/y (day per year), central part - 0.3 d/y, and for southern part - 0.31 d/y. No significant trends of SOS were obtain for the previous period 1936-1984. May–June air temperatures are the principal climatic driver to start a growing season and variability of season's length.

Variation in leaf, xylem and phloem tissue fractions along environmental gradients: testing the functional equilibrium hypothesis

Elisabeth M. R. Robert (1)*, Teresa Rosas (1), Maurizio Mencuccini (1)(2), Marta Ramírez Boixaderas (1), Cristina Nabais (3) and Jordi Martínez-Vilalta (1)(4)

(1) CREAF, Barcelona, Spain, (2) ICREA, Barcelona, Spain, (3) Centro de Ecologia Funcional, Universidade de Coimbra, Portugal, (4) Universitat Autònoma de Barcelona, Spain.
Correspondence: e.robert@creaf.uab.cat

For a thorough understanding of forest acclimation to a changing environment - especially relevant in the Mediterranean basin where climate change impacts and periods of limited water availability are increasing rapidly - it is crucial to identify how trees allocate carbon to different tissues under varying environmental conditions. In this study, we investigated the allometric scaling relationships among leaf, xylem and phloem areas in six dominant tree species (*Fagus sylvatica*, *Quercus humilis*, *Q. ilex*, *Pinus halepensis*, *P. nigra* and *P. sylvestris*) in Catalonia, northeast Spain. We inventoried fifteen populations per species along a gradient of water availability (based on the ratio of precipitation to potential evapotranspiration) and sampled five individuals per population, resulting in a sample set of 450 individuals. Our objectives were (i) to test the stability of the allometric relationships among these tissues with water availability, (ii) to assess allometry differences among species and (iii) to study the variability in allometric relationships within and among populations for each species. A comprehensive set of leaf and wood traits were also measured at individual branch and tree level to help understand and interpret the observed allometric patterns. We will present the results of this study during the meeting.

An Intercomparison of Reconstructions of the El Niño/Southern Oscillation Based on Different Proxy Data

Danielle C Verdon Kidd (1)*

(1) School of Environmental and Life Sciences, University of Newcastle, Australia
Correspondence: danielle.verdon@newcastle.edu.au

The El Niño/Southern Oscillation (ENSO) phenomenon constitutes the largest single source of interannual climate variability on a global scale. For example, the El Niño phase has been shown to be one of the leading causes of severe drought in the north west of the United States of America, southern Africa, Australia and Indonesia, while contributing to the formation of mudslides, flooding and hurricanes in the southern United States. ENSO has even been shown to influence global sea levels as a result of thermal expansion in the central Pacific during El Niño events. Given the major role that ENSO plays in the global climate system, it is no surprise that numerous proxy records of pre-instrumental ENSO activity have been developed. These ENSO reconstructions have been derived from a range of environmental proxies, including tree ring chronologies (e.g. Stahle et al., 1998; D'Arrigo et al., 2005; Cook et al., 2008; Li et al., 2011), coral fossils (e.g. Dunbar et al., 1994; Urban et al., 2000; Cole et al., 2000; Felis et al., 2000; Tudhope, 2001; Cobb et al., 2003) and flood sediments (e.g. Wells, 1990; Rodbell et al., 1998). Further, documentary evidence, such as records of water levels in the Nile River or ship log books from the Pacific, have been collated to provide an indication of past ENSO activity (e.g. Quinn, 1992; Eltahir and Wang, 1999; Barrett et al., 2017).

This study provides an intercomparison of the various ENSO reconstructions publically available at NOAA's National Centers for Environmental Information. In particular, similarities and differences between proxy records from tree ring chronologies compared to alternate proxies (coral fossils etc.) are highlighted. The spatial distribution of tree ring networks and repeated sampling afforded by the dendro based studies represent clear benefits over regional (sometimes single sample) based proxies. However, to fully capture the ENSO phenomena and its variants (e.g. ENSO Modoki) additional tropical chronologies would be beneficial. This is likely to be achieved through advancement in analysis techniques in recent years for species that don't exhibit annual growth rings (common to the tropics).

Spring drought fluctuation inferred from tree-ring δ^{18}O during the past 200 years and linkage with El Niño-Southern Oscillation in Diancang Mountain, Northwest Yunnan

Fan Zhao (1) (2), Zexin Fan(1)*, Tao Su(1), Shufeng Li (1), He Tang (1) (2), Zhekun Zhou*(1)(3)

(1) Key Laboratory of Tropical Forest Ecology, Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences, China, (2) University of the Chinese Academy of Sciences, China,(3) Key Laboratory for Plant Diversity and Biogeography of East Asia, Kunming Institute of Botany, Chinese Academy of Sciences, China
Correspondence: zhouzk@xtbg.ac.cn; mailto:fanzexin@xtbg.org.cn

To better understand the pattern of long-term climate fluctuation in Southwest China, we developed a new tree-ring cellulose δ^{18}O chronology of *Abies delavayi* Franch from Diancang Mountain in Northwest Yunnan, SW China. The δ^{18}O chronology spans 205 years (1810–2014 AD), which showed significant negative correlations with spring (March–May) relative humidity and precipitation variability. The highest correlation was found between δ^{18}O chronology and spring relative humidity (r = -0.591, *p* < 0.05), indicating that tree-ring δ^{18}O of *Abies delavayi* Franch is strongly limited by spring moisture availability. Therefore, we reconstructed the spring relative humidity variability for the period 1810–2014 used δ^{18}O chronology, which explained 35.1% variance of the actual relative humidity during the calibration period 1979–2014. The results showed two significant dry periods during AD 1815-1835 and during 1923-1940. An drier tendency of regional climate was revealed during recent two decades. Meanwhile, the dry and wet episodes in our reconstructed series were evidenced in other regional drought and precipitation reconstructions from the Hengduan Mountains and nearby regions. The reconstructed spring moisture variability was also in agreement with the historical ducuments and model simulation results. Moreover, wavelet analysis and spatial correlation analysis indicated that spring moisture variability in Hengduan Mountains may be linked to large scale climatic drivers, mainly El Niño–Southern Oscillation (ENSO) due to sea surface temperatures variation in the central and east Pacific Ocean.
Keywords: Tree-ring δ^{18}O, Dendroclimatology, Yunnan, Spring relative humidity, *Abies delavayi* Franch, Drought, Climate change

The intra-annual oxygen isotope cycle of tree-ring cellulose from pine trees as indicator of current and past hydroclimate

Sonja Szymczak (1)*, Achim Bräuning (1), Emilie Garel (2), Frédéric Huneau (2), Sébastien Santoni (2)

(1) Insitute of Geography, FAU Erlangen-Nuremberg, Germany, (2) Hydrogeology Department, University of Corsica, CNRS UMR 6134 SPE, France
Correspondence: sonja.szymczak@fau.de

Oxygen isotope ratios can serve as parameters for water-use efficiency and photosynthetic regulations when high-resolution (intra-annual) isotope chronologies are developed. Additionally, a better understanding of the reasons for small scale isotope variations is essential for a robust paleoclimatic interpretation of long-term tree-ring isotope variability. Our centennial-long oxygen isotope chronologies from *Pinus nigra* tress growing on the island of Corsica revealed that the δ18O signal is very complex and is influenced by several local environmental factors. Hence, we developed intra-annual isotope chronologies along an east-west transect through the Renoso massif in the south of the island. Due to the alignment, the selected sites cover the full range of Corsican climate from coastal sites with Mediterranean climate to alpine conditions with continuous snow cover for several months. The chronologies were developed for two pine species (*Pinus nigra* and *Pinus pinaster*) and cover the last 10 years, thus allowing the exploration of the „normal" intra-annual isotope cycle of the two pine species and the effect of climatic extreme years on the intra-annual cycle. Additional analysis of oxygen isotope ratios in precipitation, needle water, soil water and xylem water will help to interpret the oxygen isotope chronologies and enables us to trace back sources of isotope variability, e.g. different water sources, origin of air masses.

Climate from Stable Oxygen Isotopes in United Kingdom Oaks

Giles Young (1)*, Darren Davies (1), Neil Loader (1), Danny McCarroll (1), Dan Miles, Christopher Bronk Ramsey (2)

(1) Department of Geography, Swansea University, UK. (2) School of Archaeology, University of Oxford, UK.
Correspondence: g.h.f.young@swansea.ac.uk

Western European summers dominated by anti-cyclonic circulation patterns, are characterised by clear skies, warm temperatures, low precipitation totals, low air humidity and more enriched oxygen isotope ratios in precipitation. Such conditions usually result in relatively more positive (enriched) oxygen isotope ratios in tree leaf sugars and ultimately in the tree-ring cellulose formed in that year, the converse being true in cooler, wet summers dominated by westerly air flow and cyclonic conditions. In such regions there should therefore be a strong link between tree-ring oxygen isotopes and the amount of summer precipitation. Stable oxygen isotope ratios from the latewood cellulose of oak trees sampled across Great Britain produce a mean tree-ring oxygen isotope chronology that correlates strongly and significantly with summer surface air pressure and the amount of summer precipitation across the England and Wales region of the United Kingdom. The isotope-based rainfall signal is stronger and much more stable over time than reconstructions based upon oak ring widths. The existence of long, well-replicated oak tree-ring chronologies across the Western Europe mean that it should now be possible to reconstruct both summer precipitation over many centuries and potentially millennia from tree-ring oxygen isotopes.

Inverse phase relationship between the East and South Asian Monsoon over the past millennium and unprecedented weakening of the East Asian summer monsoon in recent decades

Liangjun Zhu (1), (2) Xiaochun Wang (1)*, David J. Cooper (2)

(1) Center for Ecological Research, Northeast Forestry University, 51 Hexing Road, Harbin 150040, China, (2) Department of Forest and Rangeland Stewardship and Graduate Degree Program in Ecology, Colorado State University, Fort Collins, CO 80523, USA.
Correspondence: wangx@nefu.edu.cn

The Asian monsoon is a key component of the global atmospheric circulation, which is divided into two subsystems: The East Asian monsoon and the South Asian monsoon. The lack of long-term and high-resolution records seriously hinders the exploration of the relationship between the two subsystems and their dependency mechanism. This study uses 16 tree-ring series to reconstruct the East Asian summer monsoon index (7-8 months) for the past one thousand years, and tries to reveal the changes in the relationship between the East and South Asian summer monsoon (Shi et al., 2014) for the past millennium and potential association mechanism. Results showed that the East Asian summer monsoon (EASM) existed six strong periods (1100-1150, 1450-1500, 1580-1650, 1700-1720, 1820-1830 and 1920-1930) and four weak periods (1340-1370, 1520-1540, 1580-1650 and 1950-2010 years) in the past millennium. An unprecedented recession of the EASM was detected in recent decades, and the EASM in the Little Ice Age (1560-1730) is stronger than that in the medieval warm period (900-1250). The EASM can be well related to the local and regional (such as Europe, the Atlantic) temperature variation patterns. The relationship between the EASM and the South Asian summer monsoon (SASM) shifted in 1650. The two monsoon subsystem showed significant positive correlation (r = 0.2, p < 0.01) before 1550, became no significant positive correlation (r = 0.02, p = 0.68) from 1550 to 1860, and then shifted into significant negative correlation (r =-0.26, p < 0.01) after 1860. However, it is noteworthy that the first order difference of the two series always maintained negative correlation. In addition, the negative correlation of the two series was obviously enhanced during the volcanic eruption period or the sunspot minimum period. The intensity of the EASM and its relationship with the SASM may be regulated by the land-atmosphere-ocean circulation mode, such as ENSO, NAO, PDO, volcanic and solar activities.

A new framework to test the origins of western American megadrought

Scott St. George (1)*, Toby Ault (2), Jason Smerdon (3), Sloan Coats (4), Justin Mankin (3, 5, 6), Carlos Carrillo (2), Benjamin Cook (3, 5), Samantha Stevenson (7)

(1) Department of Geography, Environment and Society, University of Minnesota, USA, (2) Department of Earth and Atmospheric Science, Cornell University, USA, (3) Division of Ocean and Climate Physics, Lamont–Doherty Earth Observatory, Columbia University, USA, (4) Climate and Large Scale Dynamics Laboratory, National Center for Atmospheric Research, USA, (5) NASA Goddard Institute for Space Studies, USA, (6) Department of Geography, Dartmouth College, USA, (7) Bren School of Environmental Science and Management, University of California, USA.
Correspondence: stgeorge@umn.edu

We know from tree rings and other natural drought records that the western United States has been affected by several 'megadroughts' during the past millennium. But are these exceptionally long-lasting droughts due to unusual external forcings, or are they inevitable given a sufficiently long period of time? Here we present a statistical model that combines sea surface temperature records and drought severity statistics from the western USA, and use that tool to set out an expectation for megadrought, given no other changes in the climate system. Even though this model was trained using only modern climate data (and incorporates no information from tree rings or other proxies), it still produced megadroughts. Moreover, those simulated megadroughts were just as long-lasting, covered as large an area, and were just as severe as real megadroughts estimated from tree rings. That result means that megadroughts can occur in the western United States even if nothing else changes in the climate -- they really are just a matter of time. On the other hand, the only aspect of real-world megadroughts that the model cannot duplicate was the high number of these events during the so-called Medieval Climate Anomaly (800 to 1300 CE). So that cluster of megadroughts may have been caused by some sort of unusual climate circumstances that have not been observed by us during the past few decades. The proxy record tells us that many different kinds of exceptional or unusual climate events happened in the past. But it is often difficult to determine what caused those exceptional events because even, within a period of a thousand years, we still have very few cases. So besides being an aid to understand the causes of past megadroughts, we hope this approach can be applied to other paleoclimate records to distinguish between real interrelations between separate components of the climate system and simple coincidences.

Suitability of endemic Balkan pines for climate reconstruction: case study from the W Balkan

Tom Levanič (1)*, Jernej Jevšenak (1), Polona Hafner (1)

(1) Slovenian Forestry Institute, Department of Yield and Silviculture, Večna pot 2, SI-1000 Ljubljana, Slovenia.
Correspondence: tom.levanic@gozdis.si

The climate of Mediterranean, including Balkan peninsula, is highly subjected to increasing greenhouse gases concentrations and their effects on climate. Forecasted increase in temperature and decrease in precipitation for the Eastern Mediterranean region pose one of the main challenges for the sustainable management of natural resources in countries of the Adriatic and Aegean region. Measured instrumental data about climate variables are scarce in this region and not long enough to detect long-term changes in climate. Therefore, long reconstructions of past climatic conditions based on natural archives are crucial to explore longer interaction between the local climate and largescale oceanic and atmospheric changes over the centuries. Additionally, Balkan peninsula is known as a biodiversity hotspot with preserved old-growth forests and relict tree species due to the late glacial refugia. Among many tree species, two pine species, *Pinus heldreichii* (PIHE) and *Pinus peuce* (PIPE), are particularly interesting for dendroclimatology as they can get very old and grow on extreme sites.

There have been a limited number of studies focused on growth and development of chronologies of PIHE and PIPE. Most of these studies are from the Pirin Mountains in SW Bulgaria. Panayotov et al. (2010) analysed climate signal in tree-ring width chronologies of PIPE and PIHE and concluded that climate signal exists, but is weak. From the same region, Trouet et al. (2012) presented a summer temperature reconstruction (1768 – 2008) based on maximum latewood density measurements. Other studies include the analysis of climate-growth relationship of PIHE on Kosovo (Bojaxhi & Toromani, 2017), in Albania (Seim et al., 2010) and in Greece (Klippel et al., 2017).

Several studies have reported a good potential of PIPE and PIHE for developing long chronologies and warned about the weak climate signal in tree-ring widths (TRW). Therefore, the aim of our study was to developed long PIPE and PIHE chronologies of TRW and stable carbon isotopes ratios (ISO) and to analyse their climate signal. Our research site is located at the northern boundary of species distribution in Montenegro, in mountains with attitude between 1720 and 1860 m, which represents the current upper tree-line in this region.

Despite high and temporally consistent EPS values and good agreement among sampled trees, climate signal in TRW in PIHE chronology is weak. Response to temperature is statistically significant, but weak (r < -0.30). Additionally, there is no response to the precipitation. In case of PIPE chronology, no climate signal in TRW was detected whatsoever. However, ISO in tree rings turns out to be a completely different story. Both, PIPE and PIHE chronologies, have almost identical climate response signal which allows us to merge isotope chronologies into a single composite chronology. Composite chronology has a strong signal related to average monthly temperature in July and August and monthly hours of sunshine duration in August with r > 0.6 and r < -0.6 for single months, respectively. In case of sunshine duration, climate signal was enhanced when July and August values were merged into a single variable (r = -0.70). Temporal stability of temperature, precipitation and sunshine hours signal is consistent. Spatial extent of the composite carbon isotope chronology extends over a very large region including Montenegro, Albania, parts of Bosnia and Herzegovina, southern Serbia and Macedonia.

Climate-growth variability of beech chronologies: a case study from NP "Djerdap", Serbia

Branko Stajić (1)*, Marko Kazimirović (1), Janjatović Živan (1)

(1) University of Belgrade-Faculty of Forestry, Belgrade, Serbia
Correspondence: branko.stajic@sfb.bg.ac.rs

The occurrence of a common variance among beech chronologies from NP "Djerdap" and it's relation to climate was investigated by applying dendroclimatological methods. For this purpose, we established chronologies of beech from the sites characterized by different ecological conditions. The necessary climate data were obtained from the meteorological station "Donji Milanovac", situated in the middle between the studied sites.

The radial increment of 48 trees were assembled into three site chronologies. The properties of the raw data within the sites as well as the characteristics of chronologies and their common signal strength were evaluated with the most commonly used dendrochronological indicators. Since growing season in Serbia usually starts at April and ends during October, the amount of precipitation and the mean temperature of these growing period months were considered for further analysis. These averaged vegetation period climate data and chronologies of radial increment values were subjected to Principal Component Analysis. Consequently, the common signal was segregated along its eigenvector axis, enabling us to examine the dependencies between the principal components of chronologies and the corresponding climate data of the current or the previous growing season. In this way, the common variations within chronologies were associated with the most influential climate period. Moreover, the related datasets served as input for the calibration of the response function.

The results show that the largest part of mutual variability was highly related ($p < 0.001$) to climate conditions during the growing season of the current year. Following those findings, the response function outlined the existence of a strong tendency towards a positive response to summer precipitation. Furthermore, it is determined that less than 15% of the common growth response was significantly associated ($p < 0.001$) with the weather of the previous growing season. In order to confirm these preliminary findings, an additional analysis should be conducted after the existing network of researched sites in the studied region has been extended.

A 1000+ year reconstruction of temperature extremes for the northeastern Mediterranean region

Lara Klippel (1)*, Paul J. Krusic (2, 3, 4), Oliver Konter (1), Jan Esper (1)

(1) Department of Geography, Johannes Gutenberg University/Germany (2) Department of Geography, University of Cambridge/United Kingdom (3) Department of Physical Geography, Stockholm University/Sweden (4) Navarino Environmental Observatory/Greece.
Correspondence: laklippe@uni-mainz.de

In the northeastern Mediterranean region, recent studies have successfully used maximum latewood density (MXD) of *Pinus heldreichii* to reconstruct mid to low frequent temperature dynamics (Klesse et al. 2015, Trouet et al. 2012, Trouet 2015). High-resolution records that focus on interannual to decadal climatic changes were derived solely from precipitation sensitive TRW of other species e.g., *Juniperus excelsa* (Touchan et al. 2005), *Pinus nigra* (Akkemik & Aras 2005; Köse et al. 2011, Levanic et al. 2012, Poljanšek et al. 2013, Klesse et al. 2015) and *Quercus* sp. (Akkemik et al. 2005, Griggs et al. 2007, Cufar et al. 2008) providing a dense network of hydro-climatic extremes.

Existing records of reconstructed temperatures extend only back to CE 1521, CE 1768 and CE 1675. Here, we introduce a new millennium-long MXD dataset that spans the period 575-2015 providing history of temperature variability and extremes back to the first millennium. The record is based on 132 high resolution density profiles from samples of living and relict high-elevation *Pinus heldreichii* trees in the Pindus Mountains in Greece. The new chronology robustly covers the period 738- 2014, and reflects temperature variability in August-September (r= 0.61). We focus on interannual-decadal temperature variability and its association with atmospheric circulation patters, and discuss extremes in the light of climate forcing and historical events. In addition, we compare temperature extremes across Europe to identify larger scale spatial patterns and potential forcings.

What can we learn from using daily climate data for growth-climate response analyses?

Ryszard J. Kaczka (1)*, Karolina Janecka (2, 3), Barbara Spyt (2)

(1) Faculty of Earth Sciences, University of Silesia in Katowice, Sosnowiec, Poland, (2) Institute of Botany and Landscape Ecology, University of Greifswald, Germany, (3) Faculty of Mathematics, Physics and Chemistry, University of Silesia in Katowice, Poland
Correspondence: ryszard.kaczka@us.edu.plr

Growth-climate response analyses are the core element of all dendroclimatic investigations. The identification of climatic factors influencing tree growth and determining the dominant factor is likely the most common test performed by dendroclimatologists. The comparison between averaged monthly climate data and tree-ring chronologies remains a standard methodological convention. Nevertheless, monthly divisions (averages and sums) of climate data poorly reflect a phenological calendar and cycle of tree growth. The Vaganov–Shashkin model (Shashkin and Vaganov 1993) and CLIMTREG software (Beck et al. 2013) provide frameworks to integrate climate data of higher temporal resolutions, however, result in complex models. Here we present a straightforward approach of applying daily climate data in a standard statistical approach to compute growth-climate responses. The bootstrap Pearson's correlation is calculated for climate data of all possible periods (i.e., from one to 365 (or 366) days of the year (DOY)). This trial was performed using data from a temperature sensitive subalpine Norway spruce stand in the Tatra Mts., Poland (Büntgen et al. 2007, Kaczka et al. 2016). Eleven parameters of annual tree rings were employed: i) ring width: total (TRW), early- (EWW) and latewood width (LWW), ii) blue intensity: early- (EBI), latewood (LBI) and delta blue intensity (dBI), iv) wood density: early- (EWD), latewood (LWD), maximum (MXD) and minimum density (MID), and v) cell wall thickness (CWT). Ring width (TRW, EWW, LWW) and blue intensity (EBI, LBI, dBI) parameters were measured from digital images of the wood surface with software CooRecorder, Cybis. Wood density (EWD, LWD, MID, MXD) and CWT parameters were measured with the SilviScan, CSIRO. All eleven parameters were measured from the same set of cores and standard chronologies were built with Arstan software using cross-dated measurements from 23 trees. Climate correlations were calculated with DendroCorr software (Hulist et al. 2016) employing instrumental daily data of temperature (1927-2011 CE) from a meteorological station located 2.6 km from the sampling site and at the same elevation (1520 m a.s.l.). Comparisons between the monthly- and daily-based climate-growth responses indicated different temporal periods when the highest correlation values were calculated. In case of TRW climate-growth relationships employing monthly data revealed the highest correlation for the June-July period (r=0.54), whereas using daily data a shorter period most strongly linked to tree growth variability (165-196 DOY, r=0.68). In this period (~165-196 DOY) most of the current-year tree-ring cells are produced by the cambium, providing a clear link between our findings and the physiology of Norway spruce in this region. This physiological-climate relationship is further supported by a strong correlation between EWW and temperature over a similar interval (162-198 DOY, r=0.68), while LWW was related to the temperature over a longer interval (165-302 DOY, r=0.45). The results from correlation analysis between MXD and LBI and daily climate data were similar (r=0.72 and r=0.68, respectively) over the intervals of 110-249 DOY and 97-249 DOY, respectively. Using monthly climate data, MXD and LBI correlation analysis indicated the strongest climate relationship over the April-September period (92-274 DOY). The EWD, MID, and EBI correlated with much shorter periods in the spring season and produced lower correlation values for both monthly and daily climate datasets. The parameters related to latewood density (MXD, LWD, LBI), dBI and CWT were mostly driven by longer periods of temperature data spanning the spring, summer and early autumn (April-September = 64-278 DOY). These findings indicate that parameters representing latewood density are good proxies of growing season temperature reinforcing its usefulness in climate reconstructions.

Usage of daily weather data for pattern recognition of tree-ring climate signals along environmental gradients

Lixin Lyu (1)*, Susanne Suvanto (2), Pekka Nöjd (2), Helena M. Henttonen (3), Harri Mäkinen (2), Qi-Bin Zhang (1)

(1) State Key Laboratory of Vegetation and Environmental Change, Institute of Botany, Chinese Academy of Sciences, Beijing, 100093, China (2) Natural Resources Institute Finland, Bio-Based Business and Industry, Jokiniemenkuja 1,01370 Vantaa, Finland (3) Natural Resources Institute Finland, Economics and Society, PO Box 2, 00791 Helsinki, Finland
Correspondence: lixinlv@ibcas.ac.cn

Environmental gradients (such as latitudinal and altitudinal gradients) can be utilized to forecast the impact of climate change on forests. To improve the understanding on how these gradients impact forest dynamics, the change of the tree-growth/climate relationship, and the time periods during which climate affects growth the most occur along the environmental gradients, pointwise correlation functions are commonly used, based on monthly climate variables. However, the strength of the relationship between tree growth and climatic variables could be underestimated due to a failure in identifying the most influential periods outside of calendar months. Usage of daily-resolution climate data may, however, provide a solution for these problems, especially when investigating growth-climate relationships along an environmental gradient. To address this matter, several R functions were devloped and then used to calculate the sliding correlations between tree-ring chronologies and daily weather data, utilizing tree-ring data from a latitudinal gradient in Finland and from two altitudinal gradients of the Tibetan Plateau. We analysed the latitudinal and altitudinal growth patterns in tree rings and investigated the growth-climate relationship of trees by correlating ring-width index chronologies with climate variables, calculated with flexible time-windows, and using daily-resolution climate data. High latitude and altitude plots showed higher correlations between tree-ring chronologies and growing season temperature. However, the effects of winter temperature showed contrasting patterns for the gradients. The timing of highest correlation with temperatures during the growing season at southern sites was approximately one month ahead of that at northern sites in the latitudinal gradient. In one altitudinal gradient, the timing for strongest negative correlation with temperature at low-altitude sites was ahead of treeline sites during the growing season, possibly due to differences in moisture limitation. Despite of the similarities of tree growth responses to temperatures between latitudinal and altitudinal gradients, differences were also found, possibly due to differential moisture conditions. Collectively, we demonstrated that the use of daily resolution climatic data reveals more accurate information about the climatic signals in tree-ring data than monthly data. The critical time-windows for climatic effects on radial growth occurred earlier at lower latitudes and altitudes than at the cold ends of the gradients. Therefore, the use of daily climatic data may disclose gradient patterns that could not be detected if monthly climate data were used.

All climate reconstructions are "wrong": A tree-ring perspective to understanding past climate

Rob Wilson (1, 2)*

(1) School of Earth and Environmental Sciences, University of St Andrews; (2) Lamont Doherty Earth Observatory of Columbia University, Palisades, NY 10964, USA
Correspondence: rjsw@st-andrews.ac.uk

There is an expansive literature showing the utility of tree-ring data for the reconstruction of past climate. However, as no tree-ring based reconstruction explains 100% of the climate target variance (normally between 30% and 60%), there is unsurprisingly a certain degree of uncertainty. Understanding and quantifying this uncertainty is paramount as tree-ring data are increasingly used to understand the drivers of past climate change.

It is generally common practise to sample many tens of trees per site (often hundreds) while also measuring multiple tree-ring variables (e.g. ring (early + latewood) width, density, blue intensity, stable isotopes and anatomical properties). In theory, combining these different TR variables could improve calibration and associated climate reconstructions. However, how well do we truly understand the climatic/environmental factors that control different TR variables? The so-called "Divergence Issue" is a good case in point where our basic understanding and assumptions of stable climate response to a single climate parameter likely break down. Furthermore, each TR parameter requires some degree of data processing (e.g. detrending of age related trends in traditional parameters like RW or MXD, correction of atmospheric CO_2 trends in $\delta13C$ series etc). Such procedures impact the potential long-term trends and degree of amplitude change of any resulting reconstruction.

In dendroclimatology, therefore, the main sources of uncertainty are related to the strength and stability of the calibrated signal and the long-term trends extant in the processed tree-ring chronologies. Quantifying these uncertainties however is extremely difficult as the target instrumental data are often short and may themselves be prone to substantial uncertainties, especially in their early periods.

My contentious thesis therefore is that all tree-ring climate reconstructions are "wrong". However, some are more wrong than others. Dendroclimatological reconstructions are all too often taken as "truth" when in fact there is substantial uncertainty which is often not well estimated, quantified or communicated. As a community, we have a responsibility to highlight both the strengths and weaknesses of our data. There are a myriad of methods to assess reconstruction and chronology quality that have been well documented over the past 30-40 years. It is surprising how often some of these basic steps are side-lined in the pursuit to publish. My soapbox stance therefore, is that all studies should aim to attain the following:

1. careful consideration of substantial TR replication changes from the recent period to the past. Utilise at least, a reasonable replicated period which is easily assessed using the Expressed Population Statistic;
2. a full period calibration $r^2 > 0.50$;
3. a minimum split period calibration verification approach with Reduction of Error and Coefficient of Efficiency values greater than zero, but ideally much higher – i.e. closer to the calibration r^2 value;
4. the unexplained model error (i.e. residual values) should be random in time – i.e. expressing no linear trend and/or no 1st order autocorrelation;
5. experimentation using multiple appropriate detrending methods (i.e. an ensemble) that can provide meaningful information of detrending uncertainty. No one method will lead to the "truth" and the shorter the instrumental record, the harder it is to validate long term trends expressed in tree-ring data.

In situations where calibration/validation is weak and/or model residuals are not random, we must explore reasons why this is so. Is this a problem of the tree-ring or the climate data? Answering this question is not easy but, as a community, we must not rush to publish data that could ultimately be flawed.

Comparison of linear and nonlinear machine learning methods for the analysis of statistical relationships between tree-rings and climate

Jernej Jevšenak (1)*, Tom Levanič (1), Sašo Džeroski (2, 3)

(1) Department of Forest Yield and Silviculture, Slovenian Forestry Institute, Slovenia, (2) Department of Knowledge Technologies, Jožef Stefan Institute, Slovenia, (3) Jožef Stefan International Postgraduate School, Slovenia
Correspondence: jernej.jevsenak@gozdis.si

Linear regression is the most often used method for the analysis of statistical relationships between tree-rings and climate. However, many studies have shown that by using nonlinear methods, better predictions could be obtained. In our study, we compare (multiple) linear regression (MLR) with selected nonlinear machine learning methods: artificial neural networks (ANN), model trees (MT), bagging of model trees (BMT) and random forests of regression trees (RF). The performance of the learned models was estimated by using 10-fold cross-validation. The measures of performance used in our study are the correlation coefficient (r), the reduction of error (RE), coefficient of efficiency (CE), the root mean squared error (RMSE) and the root relative squared error (RRSE). Models with higher validation (testing) values of r, RE and CE and lower values of RMSE and RRSE are considered to have better predictive capabilities. In addition, to address potential over- or under- prediction associated with a given approach, mean bias was calculated as a difference between observed and estimated mean response for validation data. Bias is reported in the form of density distributions for each method.

To compare the different regression methods, six datasets were used, three datasets with tree-ring width (TRW) and three datasets with mean vessel area (MVA) as independent variable. In a preliminary phase, each of the six datasets was correlated with monthly climate data to find the optimal climate signal, which was used as dependent variable in model comparison.

For all dataset, better results were obtained by the nonlinear machine learning regression methods, which can explain more variance and yield lower error, but the differences between different methods are minor (within 3 % of explained variance). However, the differences are greater for the predictions close to the edges of calibration data, where the transfer functions produced by the different methods start to differentiate.

None of the considered methods outperformed all the other methods for all datasets. Therefore, we suggest testing several different methods before selecting the best one for application, e.g. for climate reconstruction.

SwanCal: An R-Shiny App for Reconstructing Past Climates from Tree-Rings

Darren Davies (1)*, Giles H.F. Young (1), Danny McCarroll (1), Neil J. Loader (1)

(1) Department of Geography, Swansea University
Correspondence: darren.davies@swansea.ac.uk

Using climate proxies it is possible to overcome the temporal and spatial limitations of direct climate measurements to investigate past climates. As a high resolution climate archive tree-rings are possibly the best source of climate proxies, as it is possible to provide precise annual dates and estimate statistical measures of confidence through building sample replication (McCarroll and Loader, 2004). Once a chronology is developed and the tree-ring proxy of interest is measured, a climate reconstruction can proceed and as a simplification follows 5 stages: Description, Calibration, Verification, Reconstruction and Evaluation. Within each stage there are numerous statistical approaches which range in time expense and complexity. SwanCal, an R based app made accessible through the Shiny package (Chang et al., 2017), aims to streamline this process. SwanCal guides the user through each stage of a tree-ring based climate reconstruction. It includes techniques to evaluate the relationship between the proxy and target variable. Statistical methods such as the Reduction of Error and Coefficient of Efficiency (National Research Council, 2006), as well as the Extreme Value Capture statistic (McCarroll et al., 2015), allows for the evaluation of the produced climate model. SwanCal provides high quality graphical outputs and makes a reconstruction available to download. With SwanCal being freely available online and as a download, it is envisaged that it has the potential to become a useful tool in developing and evaluating tree-ring based climate reconstructions as well as being a useful teaching aid.

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Direction Specific Radial Growth of *Robinia pseudoacacia* L. Stump Shoots – A Competition Analysis

Christin Carl (1,3)*, Allan Buras (2), Dirk Landgraf (3), Peter Biber (1), Hans Pretzsch (1)

(1) Forest Growth and Yield Science, School of Life Sciences Weihenstephan, Technische Universität München, Hans-Carl-von-Carlowitz-Platz 2, Freising 85354, Germany. (2) 2Ecoclimatology, School of Life Sciences Weihenstephan, Technische Universität München, Hans-Carl-von-Carlowitz-Platz 2, Freising 85354, Germany. (3) Forestry and Ecosystem Management, University of Applied Science Erfurt, Leipziger Straße 77, 99085 Erfurt, Germany.
Correspondence: christin.carl@tum.de

The competition for resources within woody perennials is a topic of broad interest. Previous studies have indicated differing growth rates between different stem parts, possibly caused by micro-environmental conditions (Buras and Wilmking, 2014). Despite these preliminary studies, analyses of within-individual resource allocation are rare. However, direction specific lateral radial growth analysis enables to obtain detailed competition indices between neighboring stump shoots. Stump shoot growth after cutting is a survival strategy of many broad leafing tree species worldwide. In this study, we hypothesize that stem disc imagery analysis and measurements of radial growth in specific directions can be used to estimate, model, and simulate the competition of stump shoots.

We combined field measurements with direction specific tree ring analysis of 22 three-year-old black locust (Robinia pseudoacacia L.) stump shoots in a short-rotation-coppice in Germany. From each stumpshoot we sampled one stem-disc and measured basal area increments as well as ring-widths in 29 directions using ImageJ. We particularly emphasized on eight directions (North, North-East, East, South-East, South, South-West, West, North-West) as well as the 21 directions to the neighboring stump shoots. Subsequently, we studied the relationships between direction specific lateral radial growth and obtained field parameters, i.e. basal area, diameter, geographical direction, distance, coordinates, same root. Using mixed models we determined a significant influence of basal area, year, competition index of Hegji, 'mother root', and the diameter relationship of neighbors on direction specific radial growth. Interestingly, stump shoots with the same mother root, showed decreased growth rates in direction to each other, i.e. a limited tree growth of on average 3% per year.

Based on this survey we conclude: Stump shoots with the same root depress the lateral radial growth of each other in the faced direction until on of the stump shoots becomes dominant. Our approach provides valuable information on direction specific lateral radial growth analysis as a subtopic of competition analysis. Moreover, it indicates interesting relationships regarding the competition for resources within trees. Thus, it allows for in-depth ecophysiological investigations to obtain a deeper understanding of inter- and intra-intraspecific competition for resources.

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Phosphorus in Space and Time – P distribution within the woody biomass of trees

Jörg Niederberger (1)*, Martin Kohler (1), Jürgen Bauhus (1)

(1) Chair of Silviculture, Institute of Forest Sciences, University of Freiburg, Germany
Correspondence: joerg.niederberger@waldbau.uni-freiburg.de

Owing to low atmospheric inputs of P, intensive harvesting of biomass typically leads to negative P balances in many European forest ecosystems. There is hence considerable demand for accurate assessments of P held in biomass and exported with harvest. In wood, possible errors in quantification of P can be partially attributed to the great variation in P concentrations between and within sapwood and heartwood. Typically, there is a decline in P-concentrations from the youngest to the oldest tree ring, which can be attributed to retranslocation within parenchyma. In addition, P-concentrations within the heartwood may not be constant either but follow long-term trends, such as a decline from older to younger sections. Furthermore, the proportions of sapwood and heartwood in cross-sectional areas change constantly through secondary stem thickening. Moreover, the concentration of a particular nutrient within a given growth ring may not remain constant but vary with tree height.

If sampling of wood does not capture this radial and vertical variation within tree stems, calculations of P stored in biomass may be associated with a substantial error term. Yet, measures of variation are often not provided for ecosystem P pools and budgets. However, accurate estimates of P in wood and other tree compartments are needed to assess the effects of forest harvesting on ecosystem P budgets.

To track P concentrations along the stem height, we took samples during dormancy from three different sites in Germany, which are characterized by a strong variation of P stocks in mineral soils. We took increment cores at four different stem heights from mature *Fagus sylvatica* and *Picea abies* trees at breast height (1.3 m) and at 25 %, 50 %, and 75 % of total tree height. For *F. sylvatica* we additionally measured P concentration in the first major primary branch, which emerged commonly below 75% of the total height. To measure the P concentration in tree rings we used the laser ablation method, coupled with an ICP-MS. This system allowed us to measure P content at a spatial resolution of approximately 100μm. Thus, we could place more than one measurement within one year ring.

For radial P distribution, we found the well-known decline of P concentrations from bark to pith at all sites. For Norway spruce, we measured at breast height comparable P concentrations for older year rings (6 resp. 16 years) at all three sites. The most recent year at the site with high soil P availability showed considerably higher P concentrations than in trees from the site with low P availability. For the sites with high P supply, we observed constant P concentrations in older year rings or even a little decline with tree height, and for the most recent sap-wood ring no consistent pattern. In contrast, we observed at the site with poor P availability for the most recent as well as for the older year rings a considerable increase in P concentration with increasing stem height, comparable with P concentration levels otherwise observed only at the good supplied sites. For instance, in six-year-old rings in trees at site with low P availability, P concentrations were comparable or even higher than in the most recent tree ring at P rich sites. Additionally, the decline in P concentrations from bark to pith at the P rich sites was not significantly different between the four tree heights, whereas at the P poor site, a considerable difference between the heights in P concentration levels remains till the heartwood.

Soil P availability seems to have a direct influence on the P distribution within specific year rings with tree height, as well as on the translocation of P within older sapwood rings. The patterns found *P. abies* appear to be similar in *F. sylvatica*, but so far not all sampled beech trees were measured.

Influence of decayed wood in tree rings stable isotopes analysis

Viorica Nagavciuc (1, 2, 3, 4)*, Zoltán Kern (2), Aurel Perșoiu (5, 6), Ionel Popa (7)

(1) Faculty of Forestry, Ștefan cel Mare University, Suceava, Romania, (2) Institute for Geological and Geochemical Research, Research Centre for Astronomy and Earth Sciences, Hungarian Academy of Sciences, Budapest, Hungary, (3) Stable Isotope Laboratory, Ștefan cel Mare University, Suceava, Romania, (4) Departement of Geography, Johannes Gutenberg University, Mainz, Germany, (5) Emil Racoviță Institute of Speleology, Romanian Academy, Cluj Napoca, Romania, (6) Institute of Biology, Romanian Academy, Bucharest, Romania, (7) Marin Dracea National Research and Development Institute for Silviculture, Câmpulung Moldovenesc, Romania
Correspondence: nagavciuc.viorica@gmail.com

Stable isotopic composition of tree rings has some added advantages toward tree ring width due to the controlling the climatic signal irrespective of physiological conditions during growth. However, in order to create long chronologies (thousands of years), appear the necessity to use both living and dead trees. Sub-fossil wood can be affected by the decaying process, that introduces uncertainties in stable isotopic measurements. However, the knowledge in this respect is very limited. In order to ascertain the potential of stable isotopes in the sub-fossil tree, we compared the obtained results from two sub-fossil Swiss pine stone trees (D46 and D37), with both decayed and non-decayed wood, and four non-decayed Swiss pine stone samples from the same site. The intra-ring variability is between 0.08 ‰ and 0.53 ‰ for $\delta 18O$ and between 0.51 ‰ and 1.62 for $\delta 13C$. Observed intra-tree $\delta 18O$ variability is less than that reported in the literature (0.5-1.5 ‰) however, for $\delta 13C$ it is larger than the reported values (0.7-1.2 ‰). The inter-tree variability for non-decayed wood ranges from 1.09 ‰ to 2.26‰ for $\delta 18O$, and from 2 ‰ to 4.66 ‰ for $\delta 13C$. The inter-tree differences for $\delta 18O$ are among the literature reported values (1-2 ‰), but are larger for $\delta 13C$; the literature reporting differences in the 1-3 ‰ range (Leavitt, 2010).

The decaying process of wood does not influence the variability of oxygen isotopic composition in alfa-cellulose while carbon isotopic composition it is influenced more by the decaying process in the studied Eastern Carpathian Stone pine material. The differences in $\delta 13C$ between decayed and non-decayed wood are lower than those between different trees from the same site, thus having no or extremely reduced effect on climate reconstructions. Although the securest approach is still avoiding the decayed wood when analyzing the stable isotope composition of tree rings when the fact that alfa-cellulose seems to preserve the original $\delta 18O$ signal at a moderate stage of brown-rot decay, suggest that its use in paleoclimate research can be pursued safely.

The difference between decayed and non-decayed wood are less than inter-site variability, but the limited number of ring data for circumferential variability make our conclusion to be preliminary.

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Schizophrenic shrubs: Multi-directional, multi-proxy exploration of intra-individual growth heterogeneity

Allan Buras (1)*, Ute Sass-Klaassen (1)

(1) Forest Ecology and Forest Management, Wageningen University and Research, Droevendaalsesteg 3a, PB 6708 Wageningen, Netherlands
Correspondence: allan@buras.eu

Shrubs provide valuable information on past environmental conditions, particularly in regions with sparse climate station networks and where trees are absent (Myers-Smith et al., 2015). However, obtaining shrub-dendrochronological data is challenging. This is because shrubs often express a prostrate growth form, a regular occurrence of wedging and missing rings, and a heterogeneity of growth-signals sometimes even within individuals (Buras and Wilmking, 2014). For instance, ring-width series measured from the same stem-disc may express negative correlations as well as Gleichläufigkeit values in the order of 0.5 among each other, this rendering cross-dating a difficult task. Besides the challenges associated with data aquisition, shrub dendrochronological research is yet facing a couple of open research questions, particularly related to the mechanisms causing this intra-individual growth heterogeneity which finally may result in poor cross-dating statistics and weak climate-growth relationships.

To obtain a better understainding of the underlying mechanisms, we here systematically explore each two stems of five juniper specimens - a species which is well-known for its strong eccentricity - for intra-individual growth heterogeneity. Based on multi-directional radial measurements of secondary growth rates, quantitative wood anatomy assessments, and wood density profiles we seek to I) explore how strong each of the proxies is affected by intra-individual growth heterogeneity, II) understand which mechanisms may cause this heterogeneity (e.g. reaction wood, density fluctuations but also micro-site conditions and stem exposure), and III) possibly identify additional and/or the most reliable shrub-proxies of environmental conditions.

Preliminary results indicate remarkable variations of trends and climate signals related to secondary growth but also wood anatomy and density. Ongoing analyses shall reveal whether these variations are related to micro-environmental conditions and aim at identifying systematic patterns, which will help to improve our understanding of juniper resource allocation. Corresponding findings may allow for increasing the precision of juniper based reconstructions of environmental conditions.

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Xylogenesis investigations and dendrochronology reveal the functions of IADFs in Mediterranean woods

Angela Balzano (1)(2)*, Katarina Čufar (1), Giovanna Battipaglia (3) (4), Maks Merela (1), Veronica De Micco (2)

(1) Biotechnical Faculty, Department of Wood Science and Technology, University of Ljubljana, Slovenia / (2) University of Naples Federico II, Department of Agricultural Sciences, Portici (Naples), Italy / (3) University of Campania Luigi Vanvitelli, Department of Environmental, Biological and Pharmaceutical Sciences and Technologies, Caserta, Italy / (4) Ecole Pratique des Hautes Etudes (PALECO EPHE), Institut des Sciences de l'Evolution–Montpellier UMR 5554 CNRS | Université de Montpellier Montpellier, France
Correspondence: angela.balzano@bf.uni-lj.si

In Mediterranean species, cambial activity can show various temporal patterns and duration. Such patterns lead to structural alterations in wood anatomical traits, mainly related to the efficiency and safety in the water transport in order to maintain high conductivity, when water is available, and to prevent phenomena of embolism under water shortage.

Within tree rings, the alternation between the xylem traits promoting either efficiency or safety is visually perceptible through variations in wood density. Variations in the growth conditions can thus determine changes in wood density within the ring, usually called Intra-annual Density Fluctuations (IADFs). Therefore, IADF analysis may provide accurate information on plant's growth responses to climate at the intra-seasonal level.

The physiological and ecological roles of IADFs have been evaluated by combining dendrochronological and quantitative wood anatomy methods (Zalloni et al., 2016). However, to better link IADFs with climate variables, it is necessary to investigate when the various phases of xylogenesis occur in the different species in the various environments.

In this context, we applied classical dendrochronology analysis combined with monitoring of xylogenesis in *Pinus halepensis* Mill., *Pinus pinea* L. and Arbutus unedo L. during summer or throughout a whole calendar year at sites characterized by Mediterranean climate in Southern Italy in order to: (a) identify the timing of xylem phenological phases; (b) analyse the types of IADFs and the timing of their formation; (c) evaluate which factors play the major role in their formation.

We detected the periods of IADF formation during the calendar year, also linking the different phenological phases of xylem formation to their triggering environmental factors. Although the species showed different timing of cambial activity, L-IADF (earlywood-like cells within latewood) occurred in all of them which were promoted by rainfall events following a period of drought. In P. pinea, we found successive tree rings not always marked by a sharp boundary, possibly because of the lack of a true cambial dormancy. In A. unedo, the formation of more than one IADF was detected in one year. Overall studies also indicate that growth ring boundary in Mediterranean woods does not always coincide with the end (or beginning) of a calendar year (De Micco et al. 2016, Balzano et al. 2018).

In conclusion, the occurrence of IADFs in tree rings suggests the high adaptation capability of the investigated species to frequent intra-seasonal variations of water availability, which is typical for Mediterranean sites. This can be considered a competitive advantage compared to species which are less prone to form IADFs. The consequence of peculiar patterns of cambial production, IADFs and unclear tree-ring boundaries need to be taken into account in dendroecological studies.

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Studying wood anatomical response of *Betula pendula* to mechanical damage using experimental approach

Jan Tumajer (1)*, Treml Václav (1)

(1) Department of Physical geography and Geoecology, Faculty of Science, Charles University, Albertov 6, 12843 Prague, Czech Republic.
Correspondence: tumajerj@natur.cuni.cz; tumajer1@email.cz

Abrupt anomalies of vessels and fibres dimensions were documented to be an effective tool for dating processes causing tree damage, e.g., mass-movements, landslides or floods. However, most of the previous studies relied on the quantitative analysis of wood anatomy of trees injured by natural event without a precisely known timing and magnitude of the event. Range of uncertainties arise concerning the character of wood anatomical response, delay and the extent of the response along tangential and radial axes of stems. Available studies on wood anatomical response based on experimental design, i.e., the controlled artificial damage of previously healthy and vital trees show inter-specific differences in responses. Therefore further studies are needed to capture full range of species-specific wood-anatomical responses.

To fill this gap, we performed deformation experiments in juvenile, unmanaged and monospecific *Betula pendula* stand located in a post-mining area in the NW Czech Republic. First, before the beginning of 2013 growing season selected individuals were treated in 5 different ways (from 4 to 6 replicates per treatment); these included: partial decapitation, scaring the bark and cambium, tilting to 45° from vertical, partial exhumation of roots and soil accumulation on stem base. These treatments were selected to represent events commonly resulting from mass-movement processes. The same experiment was repeated in the middle of 2014 growing season on a different set of trees in the same forest stand.

After the deformation, trees remained in-situ for three growing seasons (until the end of 2015 and 2016 growing seasons, respectively). During this period, microcores were extracted from some of damaged as well as control trees. After the termination of experiments, from two to three cross-sections were cut in different positions along the stem from each deformed tree and from control trees. Each cross-section was split into four perpendicularly oriented parts to, subsequently, prepare a stained microscopic samples. Hence, our sampling approach enables us to analyze growth and wood anatomical response of trees in (1) both inter- and intra-annual timescales, (2) along tree stem, and (3) around stem circumference.

Microsamples were scanned and various quantitative anatomical parameters of vessels - mainly vessel lumen area - were measured. The measurement was performed for three post-experiment tree-rings and as many (up to 15) pre-experiment tree-rings as possible to enable quantification of the intensity of induced wood anatomical anomaly in relation to previous growth.

Our preliminary results suggest that partial decapitation is the strongest type of mechanical damage. Lost of apical meristem always resulted in growth reduction and appearance of missing rings along whole sampled part of the stem. Tilting to 45° effectively induced the formation of tension wood with gelatinous fibers and narrowed vessels in upper part of the stem and partly also on perpendicularly oriented samples. The least intensive growth anomalies in stems were typically observed for trees with exposed roots and for buried trees. Intensity of VLA response to event was comparable with a inter-annual variation of vessel size in the pre-experiment period. Three years of burial were not enough to induce the formation of adventitious roots.

Exploring inter-individual wood anatomical variation along a *Picea abies* altitudinal transect

Alma Piermattei (1)*, Georg von Arx (2), Holger Gärtner (2), Patrick Fonti (2), Camilla Avanzi (3), Andrea Piotti (4), Giovanni Giuseppe Vendramin (4), Carlo Urbinati (5), Alan Crivellaro (6, 7), Ulf Büntgen (1, 2, 8)

(1) Department of Geography, University of Cambridge, UK, (2) WSL, Swiss Federal Research Institute, Birmensdorf, Switzerland, (3) Department of Chemistry, Life Science and Sustainability, University of Parma, Italy, (4) National Research Council, Institute of Biosciences and Bioresources, Sesto Fiorentino, Italy, (5) Department D3A, Marche Polytechnic University, Ancona, Italy, (6) Department TESAF, University of Padova, Legnaro, Italy, (7) National Research Council, IVALSA, Sesto Fiorentino, Italy, (8) Czech Globe, Global Change Research Institute CAS and Masaryk University, Brno, Czech Republic

Correspondence: alma.piermattei@geog.cam.ac.uk

Forest scientists are more and more interested in the influence of environment and genetics on individual tree growth variation. So far, ring width data have been used in few studies aimed at characterizing inter-individual variation in individual tree growth patterns but, nowadays, switching to wood structure represents the next frontier of such investigation. In fact, wood anatomical traits such as conduits diameter, cell wall thickness, and wood density are quite variable at the individual level and can be more directly related to tree ecophysiology. Some traits are strongly affected by tree height and age, some by micro-environmental and climatic conditions and, in general, growth traits showed moderate to high heritability. It is therefore important to analyse wood anatomical traits in relation to all possible triggers.

In October 2012, >300 *Picea abies* trees were sampled in Campolino (northern Apennines, Italy) in three plots along an altitudinal gradient spanning from 1475 to 1750 m a.s.l. Within each plot 50 to 150 trees were cored, and individual growth-climate relationships were assessed. According to their growth response to monthly mean temperature and total precipitation ten trees per plot were selected for anatomical analyses. Tracheid lumen area, cell wall thickness, cell diameters in radial and tangential direction, cell density, number of cells per ring and per tangential millimetre, latewood and earlywood percentage, as well as hydraulic efficiency and safety parameters were measured on the cross-sections of the last five growth rings (2008-2012). Each tree was also genetically characterized with 200 single nucleotide polymorphism (SNP) markers from candidate genes.

All anatomical traits were analysed separately for each growth ring. We then considered the last five growth rings as a short time series and analysed anatomical variation to catch a possible pointer year. We found a large variation in all anatomical features analysed. As expected, some traits were strongly related to tree height and age. The environment (altitude) seemed to play a marginal role on most anatomical features. Each phenotypic group identified by multivariate approaches was also described by genetic markers in order to explore potential relationship between SNP variation and wood anatomical traits.

The number of trees analysed, although enough to shed light on inter-individual phenotypic variation, somehow limited our approach. In fact, further investigations should consider a larger number of trees to statistically support potential relationships between phenotypic traits and genetic markers and make an association genetic study feasible. Moreover, anatomical features can be analysed focusing on single growth rings identified according to specific research questions. As an example, growth rings from a drought year would allow researchers to investigate responses to highly selective events, increasing the chances to single fitness-related traits.

From anatomical to annual growth rings scale: dendroecological signal derived from *Betula nana* chronology in Northern Alaska

Agata Buchwal (1)*, Jeffrey M. Welker (2, 3)

(1) Institute of Geoecology and Geoinformation, Adam Mickiewicz University, Poznan, Poland, (2) University of Alaska Anchorage, USA, (3) University of Oulu, Finland
Correspondence: kamzik@amu.edu.pl

The polar regions have been identified as a global hotspot where climate change induces the most visible and significant ecosystem impacts. Among vast arctic region the tundra biome has been recongizned as a key study area were both abiotic (i.e., climate) and biotic (for e.g., plant growth) components are strongly coupled. Thanks to tundra shrubs, the interaction betwenn those two can be traced in i) annual resolution of growth rings and xylem anatomy and ii) in long time-scales, i.e., longer than on-going experimental and/or monitoring studies.

In order to explore growth responses of arctic shrubs to predicted temperature and snow depth increases we investigated shrubs' annual growth rings and wood anatomy using dendrochronological methods applied to plants growing under control and two experimental plots in Northern Alaska (Toolik Field Station, 68°N). Specifically we evaluated the effects of a 21-year experimental warming (due to open top chambers, OTC's) and snow depth increases on the growth rings and xylem anatomical traits of a circumarctic species - *Betula nana* (dwarf birch).

Both treatments, i.e., passive warming and additional snow depths positively influenced dwarf birch growth. In snow fence plots mean growth ring area has increased to 2.05 mm2 (sd=1.01) and in warming plots to 1.55 mm2 (sd=0.61) and was in both cases higher than in the control site (1.31 mm2; sd=0.41). Both treatments revealed an increased climate sensitivity of *Betula nana* shurbs but retained the strongets growth response of this species to June temperature.

Evidences of cyclic *Eurois occulta* outbreaks in West Greenland based on shrub-ring anatomy and remote sensing

Angela Luisa Prendin (1, 2)*, Marco Carrer (2), Urs Treier (1), Jørgen Hollesen (3, 4), Nanna Bjerregaard Pedersen (3), Bo Elberling (4, 5), Mario Pividori (2), and Signe Normand (1)

(1) Department of Bioscience, University of Aarhus, Denmark, (2) TESAF Department, University of Padova, Italy, (3) National Museum of Denmark, Copenhagen, Denmark, (4) Center for Permafrost (CENPERM), Copenhagen, Denmark, (5)Department of Geoscience and Natural Resource Management, University of Copenhagen, Denmark
Correspondence: angelaluisa.prendin@gmail.com

Insect outbreaks are among the major disturbances in high latitude ecosystems. Such outbreaks cause severe canopy defoliation and reduce the vegetation biomass and C investments, with potential consequences for species composition, functioning and productivity of tundra ecosystems. Outbreaks are expected to increase in severity and frequency in the future due to climate changes. Despite their importance, up to now only few studies tried a retrospective reconstruction of past outbreaks, and none has investigated their effect on shrub anatomical structure, e.g., cell wall thickness. In this research, we use a dendro-anatomical approach combined with remotely sensed data to assess and reconstruct past outbreaks of the moth *Eurois occulta* in West Greenland. We additionally quantify changes in annual growth and C investment for the host species *Salix glauca* L.

We analysed *Salix glauca* L. samples collected along the Nuuk fjord (7 sites, 136 samples) to identify outbreak events and quantify inter-annual variation in conduit diameters and wall thickness. Time series of Landsat images were used to detect NDVI deviations caused by reductions in the photosynthetic activity in the area. Wood samples were successfully crossdated and 7 chronologies were established spanning more than 50 years. We clearly identified three distinctive pointer years of reduced annual growth (1997, 2003 and 2010), where wood-anatomical traits showed either a significant reduction in cell-wall thickness or no variation in vessel size. This implies that under defoliations *Salix glauca* L. undergoes an adjustment in the xylem traits aimed to maintain the hydraulic structure but with a detrimental effect on fiber cell walls.

This multi-proxy approach allowed us to distinguish between abiotic (climate) and biotic (the moth) drivers of narrow ring formation.

Tree rings reveal a major episode of forest mortality in the late 18th century on the Tibetan Plateau

Ouya Fang (1)*, Qi-bin Zhang (2)

(1) Institute of Botany, Chinese Academy of Sciences, China.
Correspondence: oyfang@ibcas.ac.cn

There is a growing research interest on studying forest mortality in relation to ongoing climate warming, but little is known about such events in past history. The study of past forest mortality provides valuable information for determining baselines that establish the normal parameters of functioning in forest ecosystems. Here we report a major episode of previously undocumented forest mortality in the late 18th century on the northern Tibetan Plateau, China. The event was not spatially uniform, in which a more severe mortality happened in dryer sites. We used dendrochronology to compare radial growth trajectories of individual trees from 11 sites in the region, and found that many trees showed positive growth trend, or growth release, during 1796–1800 A.D.. Growth releases are a proxy indicator of stand thinning caused by tree mortality. The growth release was preceded by an almost two-decade long growth reduction. Long-term drought related to weakened North Atlantic Oscillation and frequent El Niño events are the likely factors causing the tree mortality in a large area of the Plateau. Our findings suggest that, besides the effect of drought in the late 18th century, large-scale forest mortality may be an additional factor that further deteriorated the environment and increased the intensity of dust storms.

Experimental Plant Ecology meets Dendroecology: Indications for the influence of winter climate on growth towards the cold distribution margin of European beech (*Fagus sylvatica* L.)

Robert Weigel (1)*, Marcin Klisz (2), Jürgen Kreyling (1), Marieke van der Maaten-Theunissen (1, 3), Lena Muffler (1), Martin Wilmking (1), Ernst van der Maaten (1, 3)

(1) Institute of Botany and Landscape Ecology, University of Greifswald, Germany, (2) Forest Research Institute, Department of Silviculture and Genetics of Forest Trees, 05-090 Raszyn, Poland, (3) Chair of Forest Growth and Woody Biomass Production, TU Dresden, Germany.
Correspondence: robert.weigel@uni-greifswald.de

The dominant forest tree in Europe, European beech (*Fagus sylvatica* L.), covers large parts of continental Europe and thus experiences diverse climatic conditions. In the face of predicted climate change and shifts of distribution ranges, we integrate insights from dendrochronology and climate manipulation experiments to understand the diverse climate-growth relationships towards the distribution margins of beech. Beech is generally reported to be sensitive to summer drought towards dry and continental regions; yet, only few studies have investigated climate sensitivity towards the cold distribution margin of beech. We hypothesized that at colder sites i) growth of beech is more sensitive to winter cold and ii) extreme cold events accompanied by soil frost negatively affect tree growth. We analysed climate-growth relationships and the nature of negative pointer years of eleven beech stands along a large gradient of decreasing winter temperature from more central (Rostock, Germany) to cold marginal (Gdańsk, Poland) beech populations. Additionally, we conducted a multi-site snow manipulation experiment to change soil temperatures and soil frost exposition around our study trees. The effects of altered soil conditions in winter on growth onset and wood increment in the following vegetation period where measured with dendrometers from which we derived onset of growth and absolute growth in 2017. Towards the cold marginal populations, growth became increasingly sensitive to winter cold (February temperature) and less sensitive to summer drought (June precipitation). Manipulated soil temperatures did not have an effect on onset of growth but, across all sites, tree growth increased with warmer soils. Thus, within the study area, the general sensitivity of beech to summer drought shifted towards a sensitivity to winter cold. A range shift of beech across the current cold distribution margin is often assumed to compensate for habitat and productivity losses of drought-prone southern and central populations. With respect to the winter cold sensitivity found in our study, such assumptions should be taken with caution, because influence of winter cold events might persist even during predicted climate warming.

Reconstruction of droughts using a tree-ring width chronology of *Q. brantii* in the Zagros oak woodlands, Iran

Mohsen Arsalani (1)*, Achim Bräuning (2)

(1) Department of Physical Geography, Faculty of Geography, University of Tehran, Iran (2) Institute of Geography, University of Erlangen-Nuremberg, Germany.
Correspondence: arsalani_mohsen@ut.ac.ir

Drought as one of the most destructive consequences of climate change has especially intensive impacts on semi-arid regions. In this study, we used tree-ring widths of *Quercus brantii* to reconstruct drought events in the semi-arid Zagros Mountains of west Iran which experience severe drought events. Based on the strong climate-growth relationships between local precipitation and the standard ring-width chronology, we reconstructed regional October-May precipitation for the period 1850-2015. The linear regression model accounts for 35% of the actual October-May precipitation variance and indicates a declining trend of precipitation during the last decades. The Standardized Precipitation Index (SPI) was used to classify the drought events over the last two centuries. Extreme dry events occurred in 1870-71, 1898, 1960 and 1963-64. Dry periods occurred in 1868-1873, 1953-56, 1958-1973, 1984-88, 2008-2011, and 2013-2015. The average length of dry spells was 2.7 year over the period 1850-2015. Moreover, mild dry events lasted 1-5 years and showed the highest frequencies in comparison with other drought categories. Although the number of above-average values showed higher frequencies in comparison with below-average values over the whole reconstruction period, the number of below average values was higher from 1901-2015. The highest number of below-average values occurred in the1880s, 1950s, 1960s, 1970s and 1980s, with driest conditions occurring in the 1970s. The number of dry spells has strongly increased during 1935-2015, indicating an ongoing trend of aggravating drought situations that might challenge the future vitality of oak forests in western Iran.

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Dendrogeomorphological analysis of foothills' landslides activity – an example from Wiśnickie foothill

Dominika Wrońska-Wałach (1)*, Dawid Piątek (1), Maciej Bryndza (1), Agata Gołąb (1), Joanna Wąs (1), Anna Zielonka (1)

(1) Institute of Geography and Spatial Management, Jagiellonian University, Gronostajowa 7, 30-387 Kraków, Poland
Correspondence: dominika.wronska-walach@uj.edu.pl

Polish Carpathians foothill is an area with active landslides. A method based on analysis of tree-ring eccentricity was employed to analyse this process activity located in Wiśnickie Foothill. The study area is covered mostly by grasslands and arable fields. Mixed (deciduous and coniferous) forest are found on landslides and steep slopes. This type of study area requires an approach to the recognition of the eccentricity threshold for the landslide activation which excludes reference curve construction. Therefore, two objectives were considered: i) development a statistical method which allows recognising differentiation of eccentric grow initiated by landslide processes from the one produced by other processes based on trees located on landslides and ii) recognition of the precipitation condition which leads to activation of different types of landslides in foothills. For that reason, coefficients of differentiation (Cv) for samples taken from different tree species (ash, field maple, spruce and pine) were measured and xy graph has been constructed from Cv and eccentricity measured for particular years. Based on constructed graph eccentricity threshold were obtained. Precipitation has been analysed by data series from meteorological stations in Łazy (1987-2016) and Bochnia (1954-1986). We have considered years with three types of extreme rainfall characterised by Starkel (2012). Field sampling took place in years 2012-2015. The landslides were recognised as active if, within two years after rainfall, tree-ring eccentricity has risen above the calculated threshold. This approach is in line with osmomechanical theory created by Kojs et al. (2012). It was concluded that threshold of eccentricity-dependent on tree species and age (e.g. the youngest; less than 20 years old do not show eccentricity above the obtained thresholds). This kind of statistical approach allows to recognise years with remarkably different eccentricity and thus to show the activity of landslide processes. Our research shows slope's reaction in response to three different rainfall types: local, short-lasting downpours, continuous rains and rainy seasons depending on landslide size.

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On the track of extreme growth responses – a review and evaluation of methods for pointer year detection

Gottfried Jetschke (1)*, Marieke van der Maaten-Theunissen (2)

(1) Institute of Ecology and Evolution, University of Jena, Germany, (2) Chair of Forest Growth and Woody Biomass Production, TU Dresden, Germany.
Correspondence: bgj@uni-jena.de

The concept of "pointer years" is central in dendrochronology and deals with the identification of distinct growth responses, be it positive or negative. Pointer years can be used for crossdating purposes, by identifying common properties in individual time series (e.g. same trend). Alternatively, years of "extreme" growth can be defined and attributed to environmental conditions, especially remarkable climatic deviations.

Schweingruber et al. (1990) provided a comprehensive overview about the main idea of pointer year analysis and introduced a two-step approach in terms of "event years" for a single tree and "pointer year" for the whole stand population. Since the comparison of methods provided by Meyer (1998-1999) more than 140 papers have been published which explicitly refer to pointer years. Still a variety of different definitions and calculation methods is used which makes it difficult to compare results among papers.

We provide an up-to-date review and classification of the definitions used in the last two decades and a comparison of them with respect to (1) the aims of use, (2) their advantages or disadvantages under certain conditions, and (3) properties of the time series. Some suggestions with respect to a clear terminology are given.

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Do long-term nutrient imbalances contribute to drought-triggered forest dieback? Insights from tree-ring chemistry

Andrea Hevia (1, 2)*, Raúl Sánchez-Salguero (3, 4), José I. Querejeta (5), Gabriel Sangüesa-Barreda (3), Antonio Gazol (3), J. Julio Camarero (3)

(1) Forest and Wood Technology Research Centre (CETEMAS), Spain, (2) Universidad de Huelva, Spain, (3) Instituto Pirenaico de Ecología (IPE-CSIC), Spain, (4) Universidad Pablo de Olavide, Spain, (5) Centro de Edafología y Biología Aplicada del Segura (CEBAS-CSIC), Spain
Correspondence: ahevia@cetemas.es

Forest dieback is an important ecological and environmental issue affecting trees by reducing their growth and vitality, altering physiological and hydraulic mechanisms but also impacting their nutrient availability. Despite the relevant role of nutrients and their interaction to drought, there is a lack of knowledge on the relationships between drought-induced dieback and long-term nutrient imbalances (Gressler et al., 2017). Here, we combine wood traits (tree ring width and wood density), soil properties and long-term chemical information (1900-2010) from tree-rings by destructive and Micro X-ray fluorescence (µXRF) techniques, in two major European conifers with ongoing drought-induced dieback processes: silver fir (Abies alba, mesic site) and Scots pine (*Pinus sylvestris*, xeric site) in northeastern Spain (Camarero et al., 2015). We evaluate the role played by long-term nutrients imbalances by quantifying annual tree ring-chemistry elements in declining (D) and nondeclining (ND) coexisting trees in both species. To compare nutrient trends in wood of each species and tree vigor (D vs. ND trees), we used dendrochronology and applied generalized additive mixed models for wood traits and tree-ring nutrient contents. We found that D trees presented lower growth and higher minimum wood density, corresponding to smaller earlywood lumen tracheids, than ND trees. Moreover, differences in several nutrients between tree-vigor classes in both species were identified. First, most of the soil nutrients were higher in the D trees. Second, K, Mg, Mn and Zn tree-ring contents were higher in D trees, whilst Ca and Na were higher in ND trees during the last three decades included in the sapwood. Mn and the Mn/Al and Ca/Mn molar ratios showed the highest differences between tree-vigor classes for both species (Houle et al., 2007). Retrospective quantifications of Mn permits to forecast dieback 3 to 5 decades before growth decline started, in agreement with other early-warning proxies such as the reduction of tracheid lumen diameter prior to the dieback onset (Pellizzari et al., 2016). Our results by µXRF non-destructive technique provide a robust tool to reconstruct the long-term capacity of trees to withstand drought-induced dieback accompanied by nutrient imbalances.

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Growth and drought response of *Quercus pubescens* willd. In different soils of sub-mediterranean region

Martina Lavrič (1)*, Dominik Vodnik (2), Mitja Ferlan (3), Klemen Eler (2), Jožica Gričar (1)

(1) Department of Forest Yield and Silviculture, Slovenian Forestry Institute, Slovenia, (2) Department of Agronomy, Biotechnical Faculty, University of Ljubljana, Slovenia, (3) Department of Forest Ecology, Slovenian Forestry Institute, Slovenia.
Correspondence: martina.lavric@gozdis.si

Pubescent oak (*Quercus pubescens* Willd.) typically grows in Mediterranean areas where changing climate will lead to an increase in the frequency and severity of drought events. For that reason it is important to understand growth strategies and adaptive stress response mechanisms which enable Q. pubescens to survive in dry marginal areas. In our study these traits were investigated in pubescent oak trees growing on two different soil types – eutric cambisol on eocene flysch bedrock and rendzic leptosol on paleogenic limestone bedrock in Sub-Mediterranean climate region of SW Slovenia. In two years, 2015 and 2016, we monitored intra- and inter-annual xylem and phloem formation, leaf development and xylem sap flow. We found that cambial activity started at the end of March and ended at the beginning of August followed with development of entire xylem annual ring until the third week of September in both years and soils. Despite shorter cambial cell production period in 2016 than in 2015, the xylem and phloem increments were wider due to higher rate of cell production. Selected earlywood variables (i.e. vessel diameter, area and density, and percentage of water conductive area in earlywood and separately for the first ring of vessels) and early phloem variables (initial sieve tube diameter and area) were wider or greater in all cases on plot with deeper soil (eutric cambisol soil type), but they differed between years. Further, earlywood vessels of the first ring had wider mean diameter and greater mean area but smaller total area compared with all vessels in earlywood. Emergence of first leaves occurred in the second half of April in all cases and coincided with the beginning of the initial earlywood vessel formation. Leaf area index (LAI) increased with leaf development and reached average values of 4.03 ± 1.22 m2m-2 at the time of full leaf unfolding in mid-May. With abundant autumn leaf coloring at the end of October LAI values started to decrease and dropped to 1.87 ± 1.25 m2m-2 at the beginning of December when full leaf fall occurred. Sap flow increased contemporarily with leaf development at the beginning of the growing season. In contrast, during the growing seasons, sap flow was driven by climatic factors, especially vapour pressure deficit, air temperature and solar radiation. In the period April-September sap flow well reflected the difference in soil water availability between the research plots in both years. During drought period trees still reflect high water use efficiency (WUE) what confirms that *Q. pubescens* is well adapted to survive severe water shortage in the soil. Integrative structural-functional approach presented in this work revealed that climate is not the only driver of radial growth in *Q. pubescens* at the selected plots. Soil type is also important environmental feature that needs to be considered in such studies.

Reactions of rare native tree species in Germany to drought stress

Henriette Schmidt (1)*, Dr. Markus Schmidt (1), Candy Pflugmacher (1), Holger Hartmann (1), Dr. Bernhard Götz (1), Prof. Dr. Harald Schill (1)

Eberswalde University for Sustainable Development, Faculty of Forest and Environment, c/o Forstbotanischer Garten, Am Zainhammer 5, 16225 Eberswalde, Germany
Correspondence: henriette.schmidt@hnee.de

Climate extremes influence forest growth. For common species in Germany like beech, oak and pine these changes are well studied. Heinrich Cotta already foresaw that mixed forests are more resilient than pure plantations concerning a better and much faster growth and reduced vulnerability against insect calamities or extreme weather like wind or snow (Cotta, 1856, page 95 et seq). Our goal is to find suitable tree species for future biodiverse mixed forests with high drought adaptability and climatic plasticity.

For analyses we use a broad set of morphological, dendrochronological and ecophysiological parameters for the rare natives *Taxus baccata*, *Prunus avium*, *Malus sylvestris*, *Pyrus pyraster* and *Sorbus torminalis* and the secondary tree species *Acer campestre*, *Betula pendula* and *Carpinus betulus* in mixed forest field sites and laboratory drought experiments.

In Dendrochronology, the focus is with drought induced negative pointer years. Following a list of selection criteria, increment cores for all eight tree species were extracted to perform dendrochronology and isotope analyses. A site was considered suitable when the rare tree species occurred in specific dimensions and sufficient numbers (>20), with good vitality and no indication of high groundwater level.

The selected tree species belong to very different morphological groups. For example *B. pendula* is a fast growing pioneer species whereas *T. baccata* as a shade-tolerant conifer exhibits very different growth patterns. Nevertheless, first data collections were performed equally for all tree species. Due to the lack of clearly distinguishable tree rings or extreme tree-to-tree variation in radial growth patterns reliable dendrochronology sequences were not obtainable for all of the selected species. Further, statistically firm analyses of tree rings were performed for 2/3 of the selected sites only. Consequently, *C. betulus* and *M. sylvestris* were excluded from subsequent analyses.

Analyses of tree rings of the last five decades resulted in five negative pointer years for most of the species and sites. Using the Cropper-method with a 5-years moving window (Cropper, 1979; van der Maaten-Theunissen et al., 2015) the most common pointer years are 2003, 1976, 1989, 1992 and 2006 (in order of importance). In 2003 *P. avium*, *A. campestre* and *S. torminalis* showed limited resilience at all sites and could not recover to growth rates similar to those before the event year. *P. pyraster* reveals different extreme years than the other species. Possibly, the pointer years of *P. pyraster* are not linked to drought stress but site conditions and competition.

Climate data of negative pointer years shows prolonged periods of drought with less than 4 mm of precipitation per day, especially during spring. Further, low total precipitation during the growing season and late frosts intensify the observed negative effects on tree growth.

However, at this stage of our field data analyses, a generalization regarding the drought adaptability of these species lacks the insight of ecophysiology to gauge the range of their potential to cope with water stress. Currently, these rare native trees are strongly influenced by many additional limiting factors such as competition. In the past they rarely received the required silvicultural attention. By linking dendrochronological data with the results of the laboratory drought experiments we aim to better understand the growth potential of individual species in connection with site conditions.

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Forest vulnerability to a warmer 21st-century climate: Assessing climate extremes using process-based models of tree growth

Raúl Sánchez-Salguero (1, 2)*, J. Julio Camarero (1), Emilia Gutiérrez (3), Marco Carrer (4), Arben Q. Alla (5), Laia Andreu-Hayles (6), Antonio Gazol (1), Fidel González Rouco (7), Andrea Hevia (8, 9), Athanasios Koutavas (10), Elisabet Martínez-Sancho (11), Paola Nola (12), Andreas Papadopoulos (13), Edmond Pasho (5), Ervin Toromani (5), Gabriel Sangüesa-Barreda (1), Kristina Seftigen (14), José A. Carreira (15), Juan C. Linares (2)

(1)Instituto Pirenaico de Ecología–(IPE-CSIC), Spain, (2) University Pablo de Olavide, Spain, (3) University of Barcelona, Spain, (4) Università degli Studi di Padova, Italy, (5) Universiteti Bujqësor i Tiranës, Albania, (6) Lamont-Doherty Earth Observatory, USA, (7) Universidad Complutense de Madrid, Spain, (8) Forest and Wood Technology Research Centre (CETEMAS), Spain, (9) Universidad de Huelva, Spain, (10) City University of New York, USA, (11) Technische Universität München, Germany, (12) Università degli Studi di Pavia, Italy, (13) Technological Educational Institute of Stereas Elladas, Greece, (14) Swiss Federal Institute for Forest, Snow and Landscape Research (WSL), Switzerland, (15) CEAT-Universidad de Jaén, Spain
Correspondence: rsanchez@upo.es

Growth models can be used to assess forest vulnerability to climate warming. If global warming amplifies water deficit and extreme climate events as dry spells become more frequent, tree populations located at the driest and southernmost distribution limits (rear edge) or tree refugia could be particularly threatened (Camarero et al., 2015). Using a tree-ring width network of 75 Mediterranean fir forests, we analyzed and projected growth responses to observed and forecasted climate of Abies species forming rear-edges or climate refugia. We used the process-based Vaganov-Shashkin Lite growth model to understand changes in tree growth during the 21st century (Tolwinski-Ward et al., 2013). Warm and dry conditions during the growing season constrain growth of Mediterranean fir forests. Models anticipate that business-as-usual emission scenarios would lead to moderate growth reductions after 2050s in some rear-edges of drought-sensitive fir species (A. alba, −35.5%, A. cephalonica,−33.3%), whereas growth would increase in moist refugia of drought-tolerant fir species (A. cilicica, +30.7%) due to a longer and warmer growing season. Some fir species and subjected to warm and dry conditions (A. pinsapo, A. tazaotana or low-elevation A. borissi-regis and A. cephalonica) will be the most vulnerable against more arid conditions predicted for the late 21st-century (Sánchez-Salguero et al., 2017a, 2017b). Those scenarios are analogous to severe dry spells which caused recent dieback during the late 20th-century in some forests of the study species and which present a pronounced growth sensitivity to dry spells (e.g., A. alba, A. pinsapo). The projections of growth reduction in fir forests portend dieback and a contraction of their species distribution areas through potential local extinctions of the most vulnerable driest stands (Sánchez-Salguero et al., 2017a, 2017b). Our modeling approach provides accessible tools to project forest growth and to assess forest vulnerability under climate warming and more extreme climate conditions. The presented forecasts advocate for preparing conservation strategies to safeguard Circum-Mediterranean relict fir populations since many of their current refugia could be threatened by 21st-century dry spells.

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Introducing the Individualistic Growth Response network (IGR)

Allan Buras (1)*, Matyas Arvai (1), Szymon Bijak (1), Jesus Julio Camarero (1), Petritan Catalin (1), Any Mary Catalin (1), Roberto Cruz Garcia (1), Balasz Garamszegi (1), Urs Gut (1), Andy Hacket-Pain (1), Andrea Hevia (1), Hong Ling Hu (1), Weiwei Huang (1), Miriam Isaac-Renton (1), Ryszard Kaczka (1), Marko Kazimirovic (1), Wojciech Kedziora (1), Zoltán Kern (1), Marcin Klisz (1), Tomas Kolar (1), Michael Körner (1), Veronica Kuznetsova (1), Jirka Masek (1), David Montwe (1), Romy Rehschuh (1), Eva Rocha (1), Michal Rybnicek (1), Raul Sanchez-Salguero (1), Jens Schröder (1), Niels Schwab (1), Branko Stajic (1), Robert Tomusiak (1), Jan Tumajer (1), Martin Wilmking (1), Ute Sass-Klaassen (1)

(1) Virtual institute of Individualistic Growth Response including members from Canada, China, Czech Republic, Denmark, Germany, Hungary, Netherlands, Poland, Romania, Russia, Serbia, Spain, Sweden, Switzerland, and United Kingdom
Correspondence: allan@buras.eu

Individualistic growth response - i.e. the individual-specific and partlydiffering response of neighboring trees to environmental conditions - is gaining more and more attention. Within this context, recent studies are of interest since they have shown the expression of climate-growth relationships to depend on soil conditions (Lévesque et al., 2013, Rehschuh et al., 2017) as well as distance to the forest edge (Buras et al., 2017) which may help to better understand the mechanisms driving trees individualistic responses. However, the aforementioned studies represent rather local to regional spatial scales and do not encompass broad-leaved tree species. Thus, additional insights from other species and over larger scales are desirable - ideally following a systematic and uniform approach.

Here, we present the international Individualistic Growth Response network (IGR) which aims at deepening our understanding of individual-specific tree growth by including several species and sites to represent a wide range of ecological conditions. A central principle of IGR is to apply a standardized dendroecological approach across the network, which allows for lowering investigator-specific biases and thus addressing general questions systematically. Currently, the network comprises data from 14 countries (ranging from Canada to China, but with a special emphasis on Europe) representing eight coniferous and three broad-leaved species. The poster presents initial research questions along with corresponding results obtained at an international workshop which takes place at Wageningen University and Research in February 2018.

IGR is a steadily growing network and we invite everybody to participate since this will further strengthen our expressiveness. A meet and greet at our poster will provide a good opportunity to discuss further research avenues and clarify open questions related to network-participation. We are looking forward to see you there!

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The effect of the horse chestnut leaf miner (*Cameraria ohridella* Deschka & Dimić) gradation on the tree-ring width of horse chestnut (*Aesculus hippocastanum* L.)

Anna Cedro (1)*, Grzegorz Nowak (2)

(1) University of Szczecin, Faculty of Geosciences, 16 Mickiewicza St., 70-383 Szczecin, Poland
(2) West Pomeranian University of Technology in Szczecin, Department of Meteorology and Landscape Architecture, 3A Papieża Pawła VI St., 71-459 Szczecin, Poland
***Correspondence: anna.cedro@usz.edu.pl**

The aim of the study was to determine the effect of the horse-chestnut leaf miner (HCLM) gradations on tree-ring width of horse chestnut and calculation the year of the invasion of this pest. HCLM reduces the green surface of the leaves and prematurely drying them and fall down (often already in August). This disturbed developmental rhythm means that the trees do not enter the normal state of winter dormancy and are exposed to freezing, especially in the early and severe winter. The research was carried out in 2017 on trees of white chestnut (*Aesculus hippocastanum* L.), growing on the 400 m section of the municipal road near Buk village. Trees grow in avenue planting, on both sides of the road. The research area is located in north-western Poland, 12 km from Szczecin, about 400 m from the German border. Chronology, on the basis of which further analyzes were carried out, is 116 years old (1901-2016), based on 22 individual dendrochronological curves. The largest number of tree-rings was measured for the tree BU13 - 136 rings from the core zone to the bark, which allows to determine the age of trees at about 145 years, and the date of the foundation of the avenue to the eighth decade of the nineteenth century. The average tree-ring width is 3.54 mm. Dendroclimatological analyzes indicate the weather conditions of May and June as the dominant factor shaping tree-ring width of white chestnut. Low insolation and air temperature, precipitation above average positively affect tree-ring width of this species. The relative changes in growth calculated using the Nowacki-Abrams method (1997) indicate a series of periods with a downward and upward trend in changes. The largest decline begins in 2000, which can be linked to the beginning of the gradation of HCLM on the chestnut alley located in Buk village. However, despite such a rapid drop of tree-ring width, in the following years there is an increase in the width of annual growth and strong regeneration of trees (crown reconstruction, numerous young shoots at different heights of the stem, dynamic scarring of wounds).

Exploring the interaction between competition, climate, and management as drivers of radial growth in Beech and Oak stands in northeastern Germany

Roberto Cruz-García (1)*, Tobias Scharnweber (1), Martin Wilmking (1)

(1) Landscape Ecology and Ecosystems Dynamics working group, Institute of Botany and Landscape Ecology, Ernst-Moritz-Arndt University Greifswald, Germany
*Correspondence: rc133844@uni-greifswald.de

Elucidating how stand structure, competition, and management influence tree species´ adaptation to climate can improve sustainable forestry practice. Understanding how spatial competition for resources affects radial growth under management conditions in Central European forests could potentially reduce vulnerability of stands to climate change. While Beech (*Fagus sylvatica* L.) and Oak (*Quercus robur* L.) are the most important broadleaved tree species in central European forestry, the influence and interaction between climate, competition, and management on their radial growth is still not fully understood. In order to fill this gap, we modeled Basal Area Increment (BAI) as a function of climate, competition, and management quantifying the effect of these factors as well as their interactions.

   Oak and beech stands growing under similar site conditions in managed and unmanaged stands were selected from Rostock's City Forest (Rostocker Heide), a coastal lowlands forest located in northeastern Germany. Circular plots (1250 m²) where established and all trees within them were sampled, and their relative spatial position recorded. Competition indices were calculated based on size and distance between trees in a plot. The effect of climate, competition, and management, as well as their interactions were examined and quantified using a linear mixed effects model approach. The modeled radial growth (Basal Area Increment, BAI) for individual trees was evaluated for each species in its response to climate and how this factor interacts with a competition index, as well as with the differential management regime. Insights were gained regarding differences on competition and management affecting climate sensitivity in the two species, with oak presenting a larger effect of stand structure and dynamics in its radial growth, likely related to its ecology and light requirements.

Patterns of tree growth decline and mortality in two coexisting Mediterranean pine species of different drought tolerance

Macarena Ferriz (1)*, Dario Martin-Benito (1), Isabel Cañellas (1), Guillermo Gea-Izquierdo (1)

(1) Centro de Investigación Forestal, Instituto Nacional de Investigación y Tecnología Agraria y Alimentaria, Spain.
Correspondence: ferriz.macarena@inia.es

Rising temperatures trends have increased drought-stress globally, inducing forest dieback of different species in forest ecosystems worldwide over the last decades. Ecotones are particularly sensitive to this situation and changes in altitudinal and latitudinal species distribution can be expected. Given the climatic and land-use characteristics of the Mediterranean Basin, climate change may have increased the negative effects of intensive land-use in these forests. In the present work, we studied the possible factors influencing the decline and increased mortality of declining *Pinus pinaster* in relation to the growth dynamics and mortality patterns of coexisting and non-declining *Pinus pinea* under a Mediterranean-continental climate in central Spain. Plots around selected trees were established and sampled and cores extracted from focus trees, classified as either healthy, declining or dead. We compared growth patterns between the two species and the different health classes to evaluate the sensitivity of growth in response to climate, disturbance and stand competition in an ecotone for the two species. We discuss our results in the context of land-use legacies and climate change and how their interactions can affect species dynamics.

Exploring new dendrosciences proxies by Micro X-ray fluorescence (µXRF): Long-term wood chemistry variations in old-growth forests

Andrea Hevia (1, 2)*, Raúl Sánchez-Salguero (3, 4)*, J. Julio Camarero (3), Allan Buras (5), Gabriel Sangüesa-Barreda (3), J. Diego Galván (6), Emilia Gutiérrez (7)

(1) Forest and Wood Technology Research Centre (CETEMAS), Spain (2) Universidad de Huelva, Spain, (3) Instituto Pirenaico de Ecología (IPE-CSIC), Spain, (4) Universidad Pablo de Olavide, Spain, (5) Technische Universität München, Germany, (6) Ionplus AG, Switzerland, (7) University of Barcelona, Spain.
Correspondence: rsanchez@upo.es/ahevia@cetemas.e

Dendrochemical studies in old forests are still underdeveloped (Balouet et al., 2009). Old trees growing in remote high-elevation areas far from direct human influence constitute a promising biological proxy for the long-term reconstructions of environmental changes using tree-rings (Galván et al., 2012). Furthermore, centennial-long chronologies of multi-elemental chemistry at inter- and intra-annual resolution are scarce. Here, we use a novel non-destructive method by applying Micro X-ray fluorescence (µXRF) to wood samples of old *Pinus uncinata* trees from two Pyrenean high-elevation forests growing on acidic and basic soils. To disentangle ontogenetic (changes in tree age and diameter) from environmental influences (e.g., climate warming) we compared element patterns in sapwood (SW) and heartwood (HW) during the pre-industrial (1700–1849) and industrial (1850–2008) periods. We quantified tree-ring growth, wood density and relative element concentrations at annual (TRW, tree-ring) to seasonal resolution (EW, earlywood; LW, latewood) and related them to climate variables (temperature and precipitation) and volcanic eruptions in the 18th and 19th centuries. We detected differences for most studied elements between SW and HW along the stem and also between EW and LW within rings. Long-term positive and negative trends were observed for Ca and K, respectively (Vaganov et al., 2013). Cl, P and S showed positive trends during the industrial period. However, differences between sites were also notable. Higher values of Mg, Al, Si and the Ca/Mn ratio were observed at the site with acidic soil. Growing-season temperatures were positively related to growth, maximum wood density and to the concentration of most elements. Peaks in S, Fe, Cl, Zn and Ca were linked to major volcanic eruptions (e.g., Tambora in 1815) (Pearson et al., 2005). Our results reveal the potential of long-term wood-chemistry studies based on the µXRF non-destructive technique to reconstruct environmental changes (Hevia et al., 2018).

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Development of European beech chronology close to its upper altitudinal limit in the Western Carpathians

Marek Ježík (1)*, Denisa Sedmáková (2), Róbert Sedmák (2), Miroslav Blaženec (1), Ľubica Ditmarová (1)

(1) Institute of Forest Ecology, Slovak Academy of Sciences, Štúrova 2, Zvolen, 960 53, Slovak Republic, (2) Faculty of Forestry, Technical University Zvolen, T.G. Masaryka 24, Zvolen, 960 53, Slovak Republic.
Correspondence: jezik@savzv.sk

Understanding species responses and adaptability are increasingly important under new environmental conditions associated with on-going climate changes and more frequent extreme weather events. Ecosystems in mountain areas are considered to be especially sensitive to these changes, including trees, their distribution, production, and health status. European beech (*Fagus sylvatica* L.) is one of the most important tree species in European temperate forests. In the Western Carpathians, beech represents the most abundant tree species widely distributed from lowlands up to the mountains despite the fact, its natural representation was lowered by forest management practice due to preferring spruce in the past. It is a treeline species in many mountain areas, or it grows just below a treeline of mountain pine and spruce altitudinal belt, often penetrating the spruce cover at the bottom sites. We have focused our attention on this line where beech grows just on or close to its upper altitudinal limit. Using maps and forest GIS layers we identified suitable sites for this purpose and started to collect cores in 2011–2012. Cores from 7 sites are currently available. Core collection from the eighth site is planned in 2018. We preferred to take cores from 15 trees (2 cores per individual) at each site. Cores from three sites were already measured and successfully cross-dated until 1900. Basic chronologies, their statistics, and Cofecha outputs are presented. All three chronologies are highly sensitive with high inter-correlations within and between sites. Also, data from dendrometer measurements from the most profoundly studied site are presented. Based on preliminary results, it seems that mostly summer temperatures (June, July, and August) are reflected in tree ring width variability.

Impact of climatic factors on radial increment of English oak growing in different hydrological conditions in southern part of Belarus

Natalia Knysh (1)*, Maxim Yermokhin (1)

(1) Institute of Experimental Botany of National Academy of Science of Belarus, Minsk, Belarus
Correspondence: knyshnv@gmail.com

The main goal of our research was to identify the climatic factors which impact on radial increment of oak on different hydrological conditions in southern part of Belarus. The relief of Belarus is characterized by predominance of plains and lowlands and as well as river valleys. Two sub-formations of oak forests are singled out for Belarus. It is forests on mesotrophic soils that occupy about 90 % and floodplain forests that occupy 10 %.

The wood samples (440 pieces) were taken on seventeen places. As a result of cluster and correlation analysis we were identified dendrochronological regions in southwest, south and southeast part of Belarus. Each region was divided into two groups which differed from each other the hydrological conditions. Accordingly, six master chronologies for each group were created – for southwest region BYSW2o (mesotrophic conditions) and BYSW1o (drained forests), for south region BYS1o (annually flooded floodplain forests), BYS2o (sometimes flooded floodplain forests), for southeast region BYSE1o (annually flooded floodplain forests), BYSE2o (mesotrophic conditions).

The results of correlation analysis standardized chronologies showed that oak forests on floodplain forest type differ significantly from oak forests growing in drier conditions (BYSW1o and BYSW2o - t-test 5.17, BYS1o and BYS2o - t-test 7.4, BYWE1o and BYSE2o - t-test 4.7). The response functions explain a high variation BYSW2o (40.5%), BYS2o (48.0%), BYSE2o (33.5%) in more or less dry conditions. For stands that grow in typical floodplain or drained conditions the variation is BYSW1o - 21.5%, BYS1o - 37.9%, BYSE1o - 24.6%. It means that the influence of climatic factors is more pronounced in dry than floodplain conditions. As a result, it is difficult to identify the main climate factors that effect on radial increment of oak in floodplain conditions.

Response function showed that increment of oak trees in floodplain conditions positively connected with temperature at the beginning of the growing season. For trees that are growing in mesotrophic conditions the main importance is the regime of precipitation.

Relationship between remote sensing-based biomass activity and tree-ring index for *Picea abies* in Saxony

Michael Körner (1)*

(1) Public Enterprise Sachsenforst, Bonnewitzer Str. 34, 01796 Pirna
Correspondence: michael.koerner@smul.sachsen.de

The present study deals with the relationship between information of biomass activity from remote sensing data and time series of the tree-ring index. To describe the biomass activity satellite data from the sensor MODIS with a spatial resolution of 250 m were used. These data were utilized to extract time series of the vegetation index NDVI from the product MOD13Q1. This product is available as 16-day composite values resulting in 23 time steps per year. Due to data availability of remote sensing data the investigation was limited to the period from the year 2000 to 2015. After extracting the NDVI data at the spatial location of each stand a smoothing spline was fitted to the data points. To characterize the annual course of the NDVI, phenological metrics according to REED et al. (1994) were extracted. These metrics can be roughly subdivided into temporal and NDVI-based metrics. An example for temporal metrics is the start of the growing season that was defined by the point with the highest increase of the NDVI. Therefore the first derivative of the smoothing spline was used. The corresponding NDVI value at this time belongs to the other group. A total of eight metrics were derived from the NDVI data.

The terrestrial data base represents tree-ring index chronologies of 17 Norway spruce (*Picea abies* L.) stands from the western and eastern Ore Mountains and from the Zittau Mountains of the German federal state of Saxony. For the process of detrending a smoothing spline was used, too. The description of the autocorrelation was done by an autoregressive moving average model (AR(1)). Finally, PEARSON´s correlation coefficients between all plots and metrics were calculated. The results indicate no clear relationships between the NDVI metrics and tree-ring index information. However, for single stands a positive correlation could be established. These findings back the initial hypothesis that remote-sensing NDVI data may be used as representatives of annual variation in tree and forest growth.

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Short- and long-term climate-growth relations of a native and an introduced conifer in an inner-alpine dry valley

Nikolaus Obojes (1)*, Erich Tasser (1), Walter Oberhuber (2), Stefan Mayr (2), Ulrike Tappeiner (3)

(1) Institute for Alpine Environment, Viale Druso 1, 39100 Bolzano, ITA, (2) Institute of Botany, University of Innsbruck, Sternwartestrasse 15, 6020 Innsbruck, AUT, (3) Institute of Ecology, University of Innsbruck, Sternwartestrasse 15, 6020 Innsbruck, AUT
Correspondence: nikolaus.obojes@eurac.edu

To prevent further erosion on slopes degraded by deforestation and pasturing for centuries, the south slopes of the Vinschgau/Val Venosta valley were reforested from the 1900s to the 1960s. To cope with the dry and continental climate and poor soil, *Pinus nigra* which was introduced from the Mediterranean was predominantly used to this end, though small patches were also planted with native *Larix decidua*. Generally, *Pinus nigra* is considered as very drought resistant and shows a strongly isohydric behaviour. In contrary, *Larix decidua*, while also able to tolerate minor droughts, has an anisohydric behaviour. In this study we compare the water and growth relations of these to species by measuring sap flow, intra-annual stem radius changes with automatic dendrometers, and tree ring widths from stem cores at a side at 1160 m a.s.l. within the LTSER platform 'Matsch-Mazia' (LTER_EU_IT_097). Previous results showed that despite its anisohydric nature, *Larix decidua* clearly reduced its sap-flow/transpiration and also periodically decreased its stem radius during dry periods of two to three years. This led to reduced yearly radial growth of larch in dry years compared to more humid years or higher elevations. For *Pinus nigra* an even more sensitive short-term reaction of sap flow and presumably also stem radius to limited water availability should be expected. In the long-term however, *Pinus nigra* is usually showing a weaker response to precipitation and a stronger resilience and faster recovery from extreme events. Considering intentions of the regional forest departement to diversify the *Pinus nigra* stands on the south-slopes of the Vinschgau/Val Venosta, a comparison of climate-growth relations with a potential replacement species also has practical implications.

Impact of climate change on radial growth patterns of South Asian moist forest trees

Mizanur Rahman (1, 2)*, Mahmuda Islam (1, 2), Achim Bräuning

(1) Institute of Geography, Friedrich-Alexander-University Erlangen-Nuremberg, Wetterkreuz 15, 91058 Erlangen, Germany, (2) Department of Forestry and Environmental Science, Shahjalal University of Science and Technology, Sylhet 3114, Bangladesh
Correspondence: mizanur.rahman@fau.de

We developed standard ring width index chronologies (RWI) of three species from a South Asian moist tropical forest and evaluated their radial growth responses to the past and future climatic changes by using dendrochronological techniques in combination with a modelling approach. Climate-growth analysis of these species revealed that tree radial growth strongly negatively responded to mean, minimum and maximum temperatures. Precipitation also influenced tree growth either prior to the current growing season or during the current year post monsoon season depending on the species. Tree-growth was also influenced by Niño 3.4 region Sea Surface Temperature (SST) anomalies due to their control on the local climate. Climate-growth analysis results were used to project tree-growth up to 2100 AD under different climate change scenarios (Representative Concentration Pathways, RCPs). Tree growth was projected to decline by 20 % under high concentration scenario (RCP 8.5) followed by 11.3 % and 9 % under medium (RCP 6.0) and low-medium concentration scenarios (RCP 4.5). We found no inter-species variation in growth response to future climate change scenarios. Such decline in tree growth will likely influence the global carbon cycle by affecting carbon sequestration in moist tropical forests. Our findings suggest that moist tropical forests which are presumed to be a carbon reservoir are also vulnerable to climate change and may lose part of their carbon sequestration potential with severe consequences for the global carbon cycle and forest economy.

POSTER11

n/a

Intensive forest monitoring: describing stress from two sides

Tanja GM Sanders (1), Daniel Ziche (1) and Wolfgang Beck (1)

(1) Thuenen-Institute of Forest Ecosystems, Eberswalde,Germany
Correspondence: tanja.sanders@thuenen.de

Tree growth is influenced by a variety of factors. One, or the combination of two, is regularly used in dendroecology: temperature and precipitation. While other factors are known to have a possibly equally high impact, be it soil condition or biotic damages, climate-growth correlations are still standard. This might be due to easy availability of climate data at nearly every location, worldwide. However, the actual drivers of growth at any given site might not be revealed without knowing the stresses the tree experiences. While a negative pointer year or a growth decline tells us a clear story, the reasons might be various and most likely the answer will be in the unique combination of them. To really understand what drives tree growths, we need to understand its environment beyond the information from gridded climate data.

Using data of the intensive forest monitoring plots of ICP Forests2 (Level II) we have meteorological measurements in close proximity to the forest; but we also have information on the solid soil phase, deposition, phenology, water availability, biotic damage, competition and more. Based on tree-ring data, we determine pointer years, sensitivity, and recovery for several plots in Germany. Additionally, we looked at the site conditions to better understand the information provided by the chronologies. The benefit of the detailed site and stand description is shown at the example of two oak sites growing under very contrasting conditions; allowing us to gain a deeper understanding about the breadth of potential adaptation to site conditions for oak.

On a broader scale dendroecological studies at the ICP Forests Level II network and its various gradients, allow studies on site adaptation for many more species but also studies on the impact of the growing season or nitrogen deposition on tree-ring width.

PS: Please get in contact with icpforests-pcc@thuenen.de if you would like sample at the plots and for data access.

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1 The intensive forest monitoring is organized under the umbrella of the United Nations Economic Commission for Europe (UNECE) as the 'International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests' (ICP Forests); a programme within the 'Working Group on Effects' (WGE) of the 'Convention on Long-range Transboundary Air Pollution' (CLRTAP). The mission of ICP Forests is to "carry out multifunctional long-term monitoring of forests within the UNECE region and beyond and provide scientific knowledge on the effects of air pollution, climate change and other stressors on forest ecosystems" (Strategy of ICP Forests 2016–2023; to be adopted at the 32nd Meeting of the Task Force of ICP Forests).

Recent growth responses of Norway spruce and European beech indicate changes in their competition and health status in Poľana Mts., Slovakia

Róbert Sedmák (1)*, Denisa Sedmáková (1), Michal Bošeľa (1), Marek Ježík (2)

(1) Faculty of Forestry, Technical University in Zvolen, T. G. Masaryka 24, 960 53 Zvolen, Slovak Republic, (2) Institute of Forest Ecology, Slovak Academy of Sciences, Štúrova 2, 960 53 Zvolen, Slovak Republic
Correspondence: sedmak@tuzvo.sk

Long and medium-term changes in climate are expected to induce long and medium-term trends in tree growth, impact population size and the species' distribution. In our study, we assess the potential influence of varying site and climate conditions on the mid-term growth trends of *Fagus sylvatica* (L.) and *Picea abies* ([L.] Karst.) in the central part of the Western Carpathians, Slovakia. In the selected region, tree species were studied across their ecological gradient within the relatively small area – from zone dominated by beech-oak stands (lower altitudes) through beech and fir-beech zone (medium altitudes) up to spruce stands near the upper tree line (high altitudes).

For gradient analysis, sampling plots were selected randomly within each forest vegetation zone (FVZ) according to the principles of proportional-to-size sampling. The larger stands with a higher representation of targeted species had a higher probability to be sampled and one sampling point was situated near the centre of each sampled stand. At each sampling point, the mean and the top diameter out of ten trees nearest to the sampling point were determined for coring. Altogether, 234 spruces and 158 beeches were sampled on 196 sites (79 beech and 117 spruce plots). Quantification of medium-term growth changes was based on the ratio of mean values of tree ring indices (following the standardization of raw tree ring series in R environment) calculated for two time periods – reference period 1961–1990 and analysed period 1991–2012. The ratio values over one (positive difference) were interpreted as relative growth increase between the periods and ratio values under one (negative differences) were assessed as growth decrease caused by recent climate change. Moreover, the growth changes against long-term age-size related trends were evaluated in both periods separately (based on averages of annual tree ring indices calculated for each period).

Colder and somewhat drier climate in 1961–1990 in comparison to 1991-2012 significantly impacted the growth of beech in all FVZs. In lower (2nd and 3rd) FVZs, beech over-performed long-term growth trends, meanwhile colder climate limited its growth in the higher FVZs. Growth decrease (app. 5%) appeared already in the 4th FVZ, where beech has its growth optimum, further increased with increasing FVZ and reached 15% in the 7th FVZ. Similarly to beech, the growth of spruce in 2nd FVZ was improved by 6% compared to long-term age related trends and spruce trees performed slightly worse in 5–7th FVZ (2.7% growth decline) in 1961–1990. Unlike beech, spruce performance matched the long-term age related trends in the 3–4th FVZ. In the 1991–2012, rapid increase in mean temperature accompanied by small increase in precipitation sums resulted in systematic shifts in growth responses of beech and spruce according to FVZs. While in a previous time period the improved growth of beech and spruce in lower FVZs and worsened growth in higher FVZs was registered, the situation was reversed in the recent period 1990–2012 – the growth of both species was depressed in lower FVZs and significantly enhanced in higher zones against long-term growth trends. Comparison and indexation of growth responses between reference and recent time period revealed: (i) growth declines in the 2nd and 3rd FVZ (8 and 7% for beech; 10 and 2% for spruce), (ii) growth improvements in the 4th FVZ - beech by 11% and spruce by 4% and (iii) significantly enhanced growth from 5th to 7th FVZ – beech improvements ranged from 19% in 5th FVZ to 38% in 7th FVZ, spruce showed significant enhancement of growth ranging from 26% in the 5th FVZ to 20% in 7th FVZ. Recent climate change has already a significant impact on growth performance of both tree species. Comparison and quantification of growth changes according to FVZs showed that growth change is more pronounced in beech than in spruce and that beech responded to recent climate change more sensitively than spruce.

Responses to warming climate of Iberian beech forests is driven by tree DBH and biogeographical region

Xavier Serra-Maluquer (1)*, J. Julio Camarero (1), Antonio Gazol (1), Vicente Rozas (2)

(1) Instituto Pirenaico de Ecología (IPE-CSIC), Spain, (2) Área de Botánica, Departamento de Ciencias Agroforestales, EiFAB, iuFOR-Universidad de Valladolid, Campus Duques de Soria, 42004, Soria, Spain.
Correspondence: xaviserra92@gmail.com

European beech is a widely distributed broadleaved tree species in Europe that reaches its southern distribution limit in the Iberian Peninsula. Beech is considered to be drought sensitive, and the ongoing climate warming and aridification trend could exacerbate climate conditions for Iberian beech forests. In sight of a forecasted warmer climate accompanied by an increase on the frequency of extreme droughts, enlighten the beech growth capacity and the role of intrinsic factors which help beech to cope with these climate changes at its southern distribution limit is needed. Contradictory results have been found so far involving warming-related growth decline and also growth stability or enhancement. So that more clarifying research on the topic is needed.

Here we present a dendroecological study of 14 beech forests in the Iberian Peninsula, covering a large gradient of aridity conditions, from the Mediterranean to the Atlantic climates. We aim to determine if the pronounced warming trend observed in the area after the 1980s climate shift is causing a growth decline related to amplified drought stress and whether there is a biogeographical pattern in the growth response. We used different dendrochronological approaches, covering a 60 year long common period (1950-2008), to explore different time-scale effects. First, a study of pointer year's pattern was done in order to determine if post-drought growth decreases have increased, presumably due to more severe and longer droughts. Second, we evaluated the presence of abrupt growth changes that remains for at least 10 years. Third, we tested the long-term growth trends before and after the 80's climate warming shift. Fourth, linear mixed-effects models were used to test if tree diameter, age or biogeography had an effect on growth responses to drought before and after the 1980s.

Our results indicate differences in the number of negative pointer years, abrupt growth changes and growth trends before and after the 1980s. Tree DBH had an important role on the number of pointer years and breakpoints before the 1980 climate shift and also on the increment of pointer years after it. Differences in number of pointer years related to the biogeographical area where also found. Interestingly, long term growth trends varied among the sites, Pyreneean populations showed positive long term growth trends. Stable long term growth trends after 1980 where found in Atlantic populations. Finally Mediterranean populations showed a less stable growth trends with negative tendencies after 1990. These findings indicate different responses of Iberian beech forests to cope with drought and warming climate in its southern distribution limit depending on tree DBH and the biogeographical region.

The influence of climate conditions on the radial increment responses of larches from the Polish Provenance Experiment 1967

Norbert Szymański (1)*, Sławomir Wilczyński (1)

(1) Department of Forest Protection, Entomology and Forest Climatology, University of Agriculture in Krakow, Poland
Correspondence: szymanski.norbert@wp.pl

The aim of the study was to characterize of the variability of short-term radial increment responses of European larch (*Larix decidua* Mill.) of 20 Polish provenances growing in 52-year-old trial plots in Polish lowlands (Siemianice and Sękocin Stary) and uplands (Bliżyn), and also identify climate elements determining these responses.

The trial plots are parts of the Polish Provenance Experiment 1967. They help to perform provenance studies. The trial plots were established in 1967 on areas where climate and soil conditions were different. Each trial plot consists a collection of 20 larch provenances. The examined larch provenances are subjected to high stresses induced by the different local climatic conditions. It was assumed that the size of tree rings is a fundamental measurement of the larches' sensitivity to climate conditions. We put forward the hypotheses that the different larch provenances growing in the same climate conditions at each trail plot have different short-term radial increment rhythms and sensitivity to individual climate elements.

7-20 healthy dominate trees from each provenance growing in 3 trial plots were cored. The cores were scanned using an optical scanner. Tree-ring widths on images of the cores were measured using CooRecorder and CDendro computer program. The cross-dating and synchronisation of the tree-ring widths were done and verified using COFECHA program. The tree-ring widths in each year were calculated for incremental indices to remove long-term variability (trend) and exhibit short-term (annual) variability which was determined meteorological conditions. Each provenance were represented by 7-20 indexed series and one indexed chronology. I carried out analyses of climate-radial increment relationships considered such the most important climate parameters for plants as monthly average air temperature and monthly precipitations. The principal component analysis of tree-ring width indices of series and chronologies indicated differences in annual incremental rhythms of provenances. The response function analysis for indexed chronologies and climate parameters indicated which climate elements had a similar effect and which differentiated the annual incremental rhythms of the studied provenances.

This study indicated the most limiting element of the climate which had the strongest impact on the variation in the radial growth of larch. The output of the study were completing still limited knowledge of the intra-species variability of larch with regard to climate sensitivity. The study generated basic understanding of Polish larch provenances in respect of adaptation to climatic conditions in different regions of Poland.

Evidence of synchrony growth in croatian floodplain forests

Domagoj Trlin (1)*, Stjepan Mikac (1), Anja Žmegač (1)

(1) Department of Ecology and Silviculture, Faculty of Forestry, University of Zagreb, Croatia
Correspondence: dtrlin@sumfak.hr

Croatian floodplain forests are spread in the valleys of large rivers and their tributaries. The most preserved complexes are found in the middle and lower part of the Sava river (360487 ha), where two forest basins are particularly emphasized: Lonjsko polje in the west and Spačva in the east. The main species associated with this area are pedunculate oak and narrow-leaved ash. In this study dendrochronological methods were used to determine the influence of climate conditions on oak and ash tree ring growth over the last century. The study was conducted on 22 sites that include moisture gradients from permanent wetlands to dry habitats. Total of 716 cores - 411 oak and 144 ash trees were processed. Climatic data for the period 1950-2015 was downloaded from CRU TS3.21 database. Individual monthly correlations indicate a significant positive sensitivity of pedunculate oak to precipitation in February of the current year and negative sensitivity on temperature in April and March of the current year. There are also positive correlations with the Sava River water level in previous year September. Unlike oak, the narrow-leaved ash shows significant positive sensitivity to precipitation in April and the Sava water level in May and June of the current year. Synchrony trends show opposite values between oak and ash for the same period of analysis (1940-2007). It was established that changes in climate conditions in the second half of the 20th century had an impact on the increase in synchronization of growth of the narrow-leaved ash, while for the same reasons the synchrony of oak tree growth was reduced. Synchrony of ash growth is particularly intense in the period from 1960 to 1980. Generally, it can be argued that the synchronization of growth both species increases from dry to humid localities.

Growth pattern of autochthonous lowland spruce

Monika Vejpustková (1)*, Tomáš Čihák (1)

(1) Department of Forest Ecology, Forestry and Game Management Research Institute, Czech Republic
Correspondence: vejpustkova@vulhm.cz

The original range of Norway spruce in Europe extends, in addition to boreal zone, to the mountain massifs of the Alps, the Hercynian, Carpathians, Rhodope and Illyrian regions. However, historical information proves that spruce has been found frequently also at the lower altitudes on sites with permanent high soil moisture content and even on sites characterized by a high degree of waterlogging or on peat soils. Relict spruce stands of lower altitudes are considered to be the remnants of vegetation from the Atlanticum period of postglacial forest vegetation succession, which has remained on certain sites up to the present time.

The objective of the study was to analyse the growth of remnant populations of autochthonous lowland spruce and to compare it to the nearby artificially planted spruce monocultures on different sites. We hypothesized that not only site but also origin of the stands plays a significant role in the spruce growth pattern.

The study was conducted within the area of the Czech Republic, where nine populations of autochthonous lowland spruce were selected based on previous field survey. Populations were typically located in the deep valleys with more humid and cooler climatic conditions, in the altitude between 290 and 440 m asl. For the purpose of comparison, one spruce stand, preferably even-aged monoculture, was chosen in the close vicinity of each autochthonous population, the second stand was selected outside the valley position.

The increment cores were sampled and tree-ring series were obtained from 283 trees. The growth of relict populations was compared to that of allochthonous stands. The methods of cluster analysis and multidimensional scaling were employed to reveal the similarity in growth pattern. Moreover the signs of climatic extremes were traced in tree-ring series using pointer year analysis.

The results show that trees within particular autochthonous population are distinctly uneven-aged, in general the age ranging from 92 to 249 years. Both cluster analysis and multidimensional scaling grouped the series of autochthonous stands into one cluster despite their considerable geographical distance, the compared spruce monocultures were classified into two other groups. It indicates that growth pattern is substantially affected by tree origin. Identified negative pointer years correspond to the dry years which mean that even autochthonous spruce growing on natural ecotope is negatively influenced by drought. However, the frequency of pointers was significantly lower with stands growing in the valley position than with stands outside the valley.

The revealed difference in growth pattern between autochthonous and allochthonous stands substantiate a uniqueness of spruce lowland ecotype.

Tree and bush dynamics in African savannahs

Max Zacharias (1)*

(1) Department of Geography, University of Bonn, Germany
Correspondence: max.zacharias@uni-bonn.de

Savannah ecosystems undergo dynamics, such as bush encroachment, which may affect global livestock production negatively. Reconstruction of past bush dynamics is essential for the understanding of the causes of bush encroachment.

We present a new method to enable accurate age estimation of savannah bush species based on simple bush size parameters (stem circumference, height, and canopy diameter), which, in combination with repeated aerial photography (reconstruction of canopy diamters) and stem circumference measurements itself, could be used for the reconstruction and mapping of past bush encroachment.

In our research area near Kuruman, South African part of the Kalahari, wood samples were collected from the eight most dominant bush species growing on three communal and three commercial rangelands: Vachellia erioloba, Vachellia haematoxylon, Vachellia hebeclada, Senegalia mellifera, Diospyros lycioides, Grewia flava, Tarchonanthus camphoratus and Terminalia sericea. Tree-rings were counted on 482 stem discs of a total of 285 bushes to derive accurate age estimations for each bush.

Our results show that stem circumference is strongly related to bush age in all species. Bush ages can thus be accurately estimated based on stem circumference measurements. The relationships between bush height and age and between canopy diameter and age varied in strength across species, but were overall weaker. Strong age-stem circumference relationships allow for the precise reconstruction and mapping of bush encroachment in South African Savannahs on a broad to a fine scale. Using a geospatial Bush Encroachment Model (BEM), reconstruction of canopy diameters and thus bush encroachment was not possible, mainly due to the strong linear growth relationships of the model.

Overall dendroecological analyses of our study suggest that recent bush encroachment in our research area is likely regulated through infilling of canopy gaps by existing individuals, rather than through recruitment of new species. We assume South African savannahs to be understood as an ecosystem affected by pulsating bush patterns (encroachment and clear of scrub) through space and time.

Oak earlywood vessels can improve dendroprovenancing results

Akhmetzyanov L. (1)*, García – González I. (2), Groenendijk P. (2,3), Sass-Klaassen U. (1)

(1)Wageningen University and Research, The Netherlands, (2) University of Santiago de Compostela, Spain, (3) University of Campinas, Brazil
Correspondence: linar.akhmetzyanov@wur.nl

Nowadays identification of geographical and temporal origin of timber (dendroprovenancing) gets more and more important, not only for archaeological studies but also for detecting illegal forest logging activities. Traditionally, in dendroprovenancing studies the ring-width series (TRW) of a given timber is compared to time series from a network of local and regional chronologies from the same species, and by recognition of trends in distribution of the best matches, suggesting the likely source area of the material. But the spatial precision of provenancing provided by annual variation in TRW patterns can be improved by using other xylem features, as TRW contain information on yearly average environmental growing conditions, while most of the anatomical features (AF) depend on conditions during their formation, i.e. narrower time period. Thus AF and TRW chronologies differ from each other, and therefore using AF chronologies in provenancing studies would eventually help to improve the final results, i.e. narrow down potential wood source area.

   In the present study we analysed four oak species from eleven sites in Northern Spain and tested the added value of oak earlywood vessel chronologies (EV) for wood provenancing. We found that TRW chronologies allows us to discriminate between Eastern and Western sites and the main differentiating factor was average July temperature, while EV chronologies didn't show this sites separation. However, EV chronologies allowed us to separate between Northern and Southern site (winter and spring temperature as the main limiting factors), while TRW didn't show this kind of sites discrimination. These preliminary results suggest that "step-by-step" application of TRW and EV chronologies for our study sites would first identify potential wood geographical origin as coming from either from the "west" or "east" sites based on a TRW data; and as a second step, would provenance wood originating either from the Northern od Southern sites (based on EV chronologies). Our findings suggest, that progressive application of TRW and EV data would eventually enhance precision of classical dendroprovenancing studies.

Dendrochronological studies of indigenous and creole archaeological remains in the Argentinean pampas (19th and 20th centuries)

Stella Bogino (1)*, Alicia H.Tapia (2), Esteban Dussart (3), Andrea Medina (4), Virginia Pineau (5), Carlos Landa (6), Emanuel Montanari (5), Jimena Doval (5)

(1) Departamento de Ciencias Agropecuarias, Universidad Nacional de San Luis; Argentina, (2) Instituto de Arqueología, Facultad de Filosofía y Letras, Universidad de Buenos Aires; Departamento de Ciencias Sociales, Universidad Nacional de Luján; Argentina, (2) Facultad de Agronomía y Facultad de Ciencias Exactas y Naturales, Universidad Nacional de La Pampa; Argentina, (4) Asentamiento Universitario San Martin de los Andes, Facultad de Ciencias Agrarias, Universidad Nacional del Comahue, San Martin de los Andes; Argentina, (5) Instituto de Arqueología, Facultad de Filosofía y Letras, Universidad de Buenos Aires; Argentina, (6)vCONICET- Instituto de Arqueología, Facultad de Filosofía y Letras, Universidad de Buenos Aires; Argentina
Correspondence: stellabogino@gmail.com

The Pampas is a natural region that covers 750.000 Km² in Brazil, Uruguay and Argentina. Pampa is a Spanish name that comes from the quechua (indigenous language) and means "plain" or "flat area". The driest part of the Argentinean pampasis occupied by thorny forests dominated by Fabaceae species, mainly by caldén (Prosopis caldenia Burkart) trees together with Prosopis flexuosa DC (sweet mesquite) and Geoffroea decorticans (Gill. ex Hook. & Arn.) or chañar. Nowadays, caldén's woodlands cover approximately 8.438 km². The caldén's area was affected by large immigration processes that started in the 18th century up to the last century. Ranqueles native people, who came from the north of the current province of Neuquén in Argentina, were settled during the 1750-1879 period. Their occupation came to a halt in 1879 as a result of a military campaign date from which the countryside was occupied by Creole and European immigrants. In this study we dated poles of P. caldenia and P.Flexuosa collected from three archaeological sites at the north part of the caldén's area. Sampling sites were in the west temperate dry pampas with scarce rainfall and sandy soils (entisoils and molisoils). Due to semiarid climate conditions scarce water availability has been essential for human settlement. As a consequence, from the mean and late Holocene up to recent times evidences of human settlements had been detected near the lagoons and springs. Historical reports mentioned that Ranqueles were benefited from shallow water table by means of wells called "jagüeles". Jagüeles were placed near sweet water sources, encampments and circulation roads. These wells were enclosed with woody upright poles to avoid cattle entrance and consequently water contamination. During archaeological researches we detected three structures made with upright poles enclosing sweet water sources. Dendrochronological analysis was set on 16 samples. Cross sections were taken using a chainsaw and a transversal section was obtained from each pole. Samples were polished with sandpaper and subsequently identified in relation to which species they belonged to. Then, they were dated under a binocular microscope (Olympus SZ61). The accuracy of the datation process was analysed with the Cofecha software. Due to the poles were undated material they were compared with two master chronologies of P. caldenia of previous studies that belongs to the area. Master chronologies covered the 1738 - 2011 period (274 years, 11 samples) and the 1804 - 1996 period (192 years, 21 samples). Cross dating allowed us to determine that poles of one of the sampling sites had their last tree ring between 1810 and 1820, which was coincident with indigenous occupation being the first one to be dated from an indigenous structure of the 19th century in the area. Poles of the other two sampling sites were placed between 1918 and 1920 which was coincident with the first creoles and European occupation after Ranqueles extermination. These results showed the use other cultural groups as the Creole and European settlers of the traditional building strategies of the Ranqueles of useful value in the semiarid environments. These results reconfirm the dendrochronological potential of P. caldenia and for the first time its value for archaeological studies that open new challenge in order to reconstruct environmental and social past changes in the Argentinean pampas.

Dating archaeological woods excavated in Bangu-dong located at southern Korea based on the synchronization between a tree ring d18O chronology and local tree ring d18O chronologies in northwestern Japan

En-Bi Choi (1), Yo-Jung Kim (2), Jun-Hui Park (2), Jeong-Wook Seo (2)*

(1) Department of Cultural Heritage Science, Chungbuk National University, Republic of Korea, (2) Department of Wood & Paper Science, Chungbuk National University, Republic of Korea.

Correspondence: jwseo@chungbuk.ac.kr

Tree-ring research, so called 'Dendrochronology', in Korea began in 1990s and most researches were about the relationshipes between ring-width times series and corresponding climatic factors and/or the reconstruction of the climate in the past. The first tree-ring research for dating archaeological woods was published in 2000 by Park et al. (2001). After that, a lot of archaeological woods were dated based on the synchronization among their individual tree-ring chronologies and we could successfully establish an approximately 800-year long pine (*Pinus densiflora*) chronology which is the longest chronology in Korea. This 800-year long pine chronology plays very important role to data archaeological woods cut after 13th century. To date archaeological woods cut before 13th century, we are highly relying on the radiocaron dating method.

By numerous previous studies fulfilled using tree ring d18O chronologies, it is verified that they have stronger inter-correlations than ring-width chronologies not only within the same tree speceis but also between tree speices. It was great finding in dendroarchaeology for dating. In a recent study, we verified that tree ring d18O chronologies established from three dominant conifer tree speices (*Taxus cuspidata*, *Abies koreana*, and *Pinus koraiensis*) in subline zone of southern Korea have strong synchronization as well (Seo et al., 2017). And more, w e found that these tree ring d18O chronologies show similar inter-annual patterns as the chronologies in northewestern Japan.

In 2007 a large wooden fence facility was found in Bangu-dong, Ulsan, Korea. Its length is about 250 m and it is very meaningful as ancient remains showing the structure of ancient wooden fence certainly. Wooden columns and watchtowers were excavated here. Most of them have larger than 50 cm in diameter (Jeong, 2011). In the cross-dating with our master chronology, we could not find any result for dating. To date these archaeological wood therefore we fulfiled the radiocarbon dating and obtained a result between AD 829 and AD 929.

The current study was conducted to find answers about questions as follow: 1) is the cross-dating possible between tree ring d18O chronology from Bangu-dong excavation in southern Korea and the chronologies in northwestern Japan? and 2) if yes, how much does the dating result coincide with the radiocarbon dating result?

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The Jordaens Van Dyck Panel Paintings Project – first dendrohistorical insights

Johannes Edvardsson (1)*, Andrea Seim (2), Justin Davies (3), Joost Vander Auwera (4)

(1) Department of Geology, Lund University Lund, Sweden, (2) Institute for Forest Growth IWW, University of Freiburg, Freiburg, Germany, (3) University of Amsterdam (UvA), Amsterdam, Netherlands, (4) Royal Museums of Fine Arts Belgium (KMSKB-MRFAB), Brussels,Belgium.

Correspondence: johannes.edvardsson@geol.lu.se

For the first time, dendrochronology is being applied to a comprehensive and multidisciplinary study of the paintings on oak panel of two artists. The Jordaens Van Dyck Panel Paintings Project is an innovative multidisciplinary art historical initiative that is systematically examining the oil paintings of two famous Flemish painters, Jacques Jordaens (1593-1678) and Sir Anthony Van Dyck (1599-1641). An ongoing dendrochronological survey of nearly 300 oil paintings, combined with the study of the Antwerp panel makers' and Guild brand marks on the reverse of the panels, new archival research and traditional art historical scholarship, is achieving a better understanding of the lives, collaboration, and works of these artists and the origin and quality of the trees used for wood panels during the 17th century.

   The multidisciplinary approach is unique for this project, and its import from a dendrochronological perspective, because it provides opportunities to verify and specify the dates. So far, we can reveal results of non/micro-invasive dendrochronological analyses and the dating of 200 oak planks of ca. 100 paintings. The majority of the planks were absolutely calendar dated and the heartwood dating can be often pinpointed to a narrower period by combining the dendro-dates with current dating of Antwerp panel makers' marks and new archival findings. Moreover, most of the oak trees used for panel paintings by these artists originate from the Baltic region and some planks that support different paintings by the two painters were even taken from the same tree. These dendrochronological links have never been made before in art history.

The reorganization of dendrochronology in Bavaria under consideration of rafting and elevation-specific spruce and silver-fir regional-chronologies

Thomas Eißing (1)*

(1) Otto-Friedrich-Universität Bamberg, Germany
Correspondence: thomas.eissing@uni-bamberg.de

The dendrochronological laboratory of the University of Bamberg was established in 1993 as part of the DFG project "Dendrochronology and timber framing". For the first time, the methodical approach of building regional chronologies according to the historical raft transport routes has been successfully applied. Between 2008 and 2011, this methodology was transferred to Bavaria in the DFG project "Dendroprovenancing and Timber Transport in Bavaria". For this purpose, material that was not yet available digitally was re-measured, dated and a narrow grid of regional chronologies constructed. In addition, a model for the reconstruction of the elevation grades for spruce and fir in Bavaria was developed. The aim is to capture the wood supply for a city or region as well as possible. The regional chronologies allow a small-scale determination of the origin of wood (Dendroprovenancing). By 2017, more than 7,000 buildings with more than 67,000 samples had been recorded.

Closely situated dendro-sites tell distinct dendro-stories from the Mureş/Maros river, Romania

Zoltán Kern (1)*, Enikő Mihály (2), Balázs Nagy (2), János Mészáros (3), Petru Urdea (4), Fabian Timofte (4), György Sipos (5)

(1) Institute for Geological and Geochemical Research, Reserch centre for Astronomy and Earth Sciences, MTA, Hungary (2) Department of Physical Geography,Eötvös University Hungary (3) Institute for Soil Sciences and Agricultural Chemistry, Centre for Agricultural Research MTA (4) Department of Geography, West University of Timişoara, Romania (5) Department of Physical Geography and Geoinformatics, University of Szeged, Hungary
Correspondence: zoltan.kern@gmail.com

A wooden construction and in situ standing stumps have been emerged in short distance (~200 m) at an eroding meander bend of the Mures/Maros river near Zadareni (Arad county). An impressive (>5 m) fluvial sequence consisting gravel and sand cover both locality. Bark was found both on the stumps, suggesting a very rapid burial of the ancient wood, and on the construction wood. The wooden construction recalled the structure of a footbridge (including pillars and horizontal elements indicating the former walking surface). The basic questions were:

What could be the explanation for the very rapid fluvial sedimentation?

When did it happen?

Do the two localities belong to the same historical period?

Who and why did build the wooden construction?

The root collar of stumps (n=6), and top level of the horizontal elements of the bridge-like construction (n=19) have been precisely levelled at 04.09.2016. At the same time 7 disks were collected from the stumps and, similarly, 7 disks were sawn from the piles and beams for dendrochronological analysis.

The samples were processed following the standard dendrochronological protocol and ringwidths were measured to the nearest 0.01mm.

All but one of the sampled stumps was elm (Ulmus sp.) the exception was oak (*Quercus robur*). The species composition was reversed in the construction (i.e., 6 oaks, 1 elm).

The median elevation of the root collar level (100.4 m asl) and the walking level of the bridge-like construction (100 m asl) suggest that, surprisingly, the bridge represents a lower paleosurface compared to the buried forest.

Despite relatively few rings were counted in the samples from the construction (max. 43) the oaks could be synchronized into a 44 yr-long chronology, while the similarly few rings (max. 50) and the frequent growth anomalies challenged the synchronization of the ringwidth records of these obviously nearby grown stumps. None of the ringwidth records of the stumps could be crossdated with the 'bridge' chronology suggesting that its construction and the rapid fluvial sedimentation are probably subsequent events and do not belong to the same historical period. Crossdating attempts of the 'bridge' chronology against oak master chronologies available from the surroundings did not yielded unequivocal results. The likelihood of some weak crossdating results considering also historical cartographical evidence will be presented.

Tree-ring analyses on Bronze Age mining timber from the Mitterberg region, Austria

Thomas Pichler (1), Kurt Nicolussi (1)*, Jona Schröder (2), Thomas Stöllner (2), Peter Thomas (2), Andrea Thurner (1)

(1) Institute of Geography, University of Innsbruck, Austria, (2) Institute of Archaeological Studies, Ruhr-Universität Bochum, Germany.
Correspondence: kurt.nicolussi@uibk.ac.at

Wood was an essential raw material to maintain mining in historic and prehistoric times. During the Bronze Age the Mitterberg mining region in the Austrian Alps was one of the most important producers of copper and in further consequence a consumer of huge amounts of wood. Since the 1960s archaeological excavations at the dressing site Troiboden at the Mitterberg main lode have uncovered mining timber namely both single finds as well as box-shaped wooden constructions like wet-tyes, which were used to wash and concentrate crushed copper ore. Dendrochronological analyses on a set of mining timbers yield calendar dates for these mining activities suggesting a boom phase of ore exploitation in the 14th and 13th century BC. I.e., two felling phases, one in the 1370s and a second from the 1290s to 1270s years BC, can be proven so far. As a consequence of the activities, wood supply from the nearby forests might have been exhausted soon, which is confirmed by palynological records from bogs in the vicinity of the excavation site Troiboden. By utilising a tree-ring growth – elevation model developed by Dittmar et al. (2012) on the base of tree-ring data of the Northern Alps and its foreland the elevations of growing sites were estimated to detect where the mining timbers might come from. To examine the model outcomes we used tree-ring data with known origin, i.e. series from living trees and subfossil samples from the Troiboden and its vicinity. The results for the mining timbers suggest that the prehistoric miners utilised trees from the vicinity of the mining site in the 14th century but at least partly sought wood from growing sites of lower elevations to continue mining during the first half of the 13th century BC.

Missing link in Late Antiquity? A critical examination of Hollstein's Central European Oak Chronology

Andreas Rzepecki (1)*, Mechthild Neyses-Eiden (1)

(1) Rheinisches Landesmuseum Trier, Germany.
Coresspondence: andreas.rzepecki@gdke.rlp.de

In 1980 Ernst Hollstein, head of the Laboratory of Dendrochronology at the Rheinisches Landesmuseum Trier (Germany) from 1970 to 1983, published his Central European Oak Chronology, which covers a period from 690 BC to 1975 AD. Besides a later correction of the end date of the sampling site chronology Kirnsulzbach (Germany) from 443 BC to 514 BC (Neyses 1991) this master chronology has since not been changed and still is one of the most important bases for dendrochronological dating in western Germany. It stands out in so far as it provides tree-ring width curves for each individual sampled site integrated in this comprehensive chronology.

In particular due to the fact of Hollstein's chronology being publicly available, it has frequently been criticized for its insufficient data to bridge the Late Antiquity between 350 and 400 AD with only three sampling sites (tomb near Beerlegem, Belgium; tomb inside of Cologne Cathedral, Germany; subfossil trees near Broichweiden, Germany) and that these site chronologies cover those decades with inadequate correlation coefficients (r = 0,220; GLK=61,1% for mean curve Beerlegem and Cologne vs. Saar-Mosel-Chronology). With regard to recent statistical threshold values for crossdating Hollstein's Late Antiquity bridging needs to be reconsidered.

Therefore, in a combined effort, the dendrochronological laboratories at Rheinisches Landesmuseum Trier, the University of Cologne and Albert-Ludwigs-University Freiburg reevaluated Hollstein's findings for Late Antiquity by including the respective dendrochronological examinations conducted in Rhineland-Palatinate, North Rhine-Westphalia and northeastern France during the past 40 years. A total of 64 site chronologies were compiled to establish a new Late Antiquity chronology. 13 of these site chronologies could be used to support Hollstein's original bridging curves between 350 BC and 400 BC mentioned above. Furthermore, this new bridging chronology could be validated by comparing it to an independent chronology from southern Germany (courtesy of Franz Herzig, Bayerisches Landesamt für Denkmalpflege, Dienststelle Thierhaupten).

This study thus proves
- that the integrity of Hollstein's Central European Oak Chronology is not compromised by a flawed Late Antiquity bridging
- that dating based on the Roman part of this chronology can still be considered as absolute
- that there is no floating part within this master chronology.

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Using «blue intensity» method for dating historical sites in West Siberia (Russia)

Maya Sidorova (1, 2)*, Anna Taynik (1), Valentin Barinov (1) , Igor Slyusarenko (2), Vladimir Myglan (1)

(1) "Siberian dendrochronological laboratory", Siberian Federal University, Russia; (2) Institute of Archaeology and Ethnography SB RAS, Russia.
Correspondence: mayasidorova12@gmail.com

Nowadays a number of historical sites (including the unique archaeological monument Suzun plant) have been preserved in Novosibirsk region (south of West Siberia). Historical sources do not determine exactly when they were constructed. Based on tree-ring width measurement, sites were not dated too. Due to the fact that limiting factors are absent, a growth of trees changes little in Novosibirsk region. Here we use the new parameter which is more sensitive to environmental change. It is optical wood density ("blue intensity").

   A number of articles have already shown its efficiency in dendroecology (Babst et al., 2009; Bjorklund et al., 2013; McCarroll et al., 2013, Wilson et al., 2014; Rydval et al., 2014; Dolgova, 2016). Nevertheless "blue intensity" method has recently become to apply for dating historical sites and archaeological monuments (Mills et al., 2013; Wilson et al., 2017).

   This study presents first results of "blue intensity" method application in cross-dating timbers from archaeological monument Suzun plant and historical sites in Novosibirsk region (south of West Siberia).

A new dendrochronological laboratory in Mannheim (Germany)

Thorsten Westphal (1)*

Dendrochronological Laboratory on the Klaus-Tschira-Center Archaeometrie, Curt-Engelhorn-Centre Archaeometry gGmbH Mannheim (CEZA), Germany.
Correspondence: thorsten.westphal@cez-archaeometrie.de

The Curt-Engelhorn-Centre Archaeometry gGmbH (CEZA) is a nationally and internationally operating research institute in the field of scientific analysis. The institute (founded in 2004) currently comprises two departments: the Laboratory for Material Analysis - providing services such as material characterization, technology, authenticity, origin, nutrition and mobility research - and the Klaus-Tschira-Center Archaeometrie– providing dating services by radiocarbon, luminescence and (since the beginning of 2015) tree-ring analyses too.

The main activities of the Dendrochronological Laboratory Mannheim currently are:

1. Transfer of the so-called "Hohenheim Tree-Ring Collection" (approximately 50.000 wood samples) from the Institute of Botany, University of Hohenheim to Mannheim, in order to preserve the pieces for future scientific investigations and to ensure its long-term and professional treatment. The collection is currently being repackaged into sturdy plastic boxes, inventoried and photographed.

2. Age determinations of recent, historical, archaeological and subfossil wood samples for scientific collaboration in research projects or analytical services for public institutions, companies and private clients. In addition, own research is carried out to create and improve chronologies for different species of wood and regions.

3. Close collaboration within the institute to develop new or refine existing analytical methods, e.g. collaboration with the 14C-AMS-laboratory for high resolution radiocarbon analysis of difficult sections of the radiocarbon calibration curve or regarding stable isotope analysis for determination of the origin of wooden artefacts (Dendroprovenancing).

Measuring intra-annual dynamics of carbon sequestration from anatomical measurements on three contrasting species

Anjy Andrianantenaina (1)*, Cyrille Rathgeber (1)

(1) SILVA, University of Lorraine, AgroParisTech, INRA Grand-Est, France
Correspondence: anjynandrianina.andrianantenaina@inra.fr

Wood density and tree ring width are crucial variables to estimate biomass. But less is known about their seasonal patterns to accurately quantify when and how much carbon is daily sequestered by trees within a growing season. We aim to better understand the underlying mechanism of wood formation and consequent seasonal dynamics of xylem increase in size and in biomass for three growing intermixed species with contrasting wood anatomy. We question whether contrasting species would show similar patterns of growth in size and in biomass.

Here, we present a new approach to measure the apparent density and the radial increase of forming xylem along a growing season, and to estimate the biomass production from anatomical measurements. During the 2015 growing season, microcores containing phloem, cambial zone, and developing xylem were weekly collected on seven dominant trees of three species: *Fagus sylvatica* (L.), *Quercus petraea* (Mattuschka) Liebl, and *Picea abies* (L.) Karst, grown intermixed in a flux tower site (Hesse, France). The microcores were prepared in the laboratory to allow the observation of the developing xylem under light microscopy, and to measure their radial increment. Image analysis were performed to measure apparent density and to estimate biomass production in forming xylem. Allometry equations were applied to estimate individual tree biomass production. For spruce, quantification of the daily xylem radial growth and biomass production were compared from two approaches: based first on kinetics of wood formation and tracheidogram; and second on xylem apparent density and radial width measurements.

The three species showed contrasted timing of xylogenesis phases: oaks started earlier enlargement and showed earlier functional mature xylem cells compared to beech and spruce. But cessation of the wall-thickening occurred at similar dates, early October, independently of species, marking the end of carbon sequestration within xylem tissues. The two approaches permitted to capture the rates of xylem size increase with accuracy, but with an underestimation for the second approach. This could be because of not taking into account the contribution radial increase due to cambial cell division. Both approaches lead to similar pattern of woody biomass production, quickly increasing from late April onward to peak on mid-June, then slowly decreasing till cessation in late September. Applying also the second approach on beech and sessil oak, we showed that the apparent density increased within the growing season, along with xylem formation. Consequently, using a constant density delayed from 10 to 30 days the estimation of the seasonal dynamics of woody biomass production for the three species. Spruce, beech and sessil oak showed also contrasted patterns of growth in size and in biomass. Spruce and beech showed a bell-curve of radial growth, starting in late April onward to peak between late May and early June, and slowing down till cessation from late July to early August. While for oak, the seasonal dynamics of radial growth showed a first peak in late April corresponding to earlywood vessel formation, followed by a slowing down in late May, then showing a second and higher peak in mid- June, and slowing down till cessation in early September. The intra-annual dynamics of woody biomass production followed a bell-curve skewed to the left for beech and spruce, starting to increase in late April onward to peak between late May and early June, while skewed to the right for oak, onward to peak in July.

Our work provide a unique approach to accurately quantify the seasonal dynamics of woody biomass production. Regarding the contrasting intra-annual dynamics of radial growth and biomass production between the three species, it questions their relative contribution to the course of stand carbon uptake and the accurate quantification of daily carbon sequestration at stand level.

Key words: conifers, deciduous, xylogenesis, carbon.

Oxygen isotopes in tree rings of Canary Pine as recorders of fog interception on La Palma

Jose Carlos Miranda (1, 2)*, Giovanna Battipaglia (3), Simona Altieri (3), Kerstin Treydte (2), Luis Gil (1)

(1) Technical University of Madrid, ETSI Montes, Grupo de Genética, Fisiología e Historia Forestal, Spain, (2) Research Unit Landscape Dynamics, Swiss Federal Research Institute WSL, Zürcherstrasse 111, CH-8903 Birmensdorf, Switzerland, (3) Department of Environmental, Biological and Pharmaceutical Sciences and Technologies, University of Campania L. Vanvitelli, via Vivaldi 43 81100 Caserta, Italy

Correspondence: jc.miranda@upm.es

Climatic variations in the transition zone from temperate to tropical regions determine the fate of local ecosystems. In some of these regions, the lack of climate records limits predictions of future climate conditions. The Canary Archipelago is such a transition zone, where atmospheric stratification caused by the Azores High and humid trade wind influence causes distinct altitudinal gradients in vegetation. A stratocumulus cloud layer ("sea of clouds" as locally named) is formed under atmospheric stability conditions, leading to increased and isotopically heavier water supply for vegetation due to fog water droplets interception, compared to precipitation occurring under atmospheric instability conditions. Thus, the altitude, thickness and annual frequency of the sea of clouds determines the amount of local water input on the islands. These specific climatic conditions are, however, only scarcely recorded due to the lack of climatic stations in general and the absence of instruments for quantification of water interception in particular. In order to obtain a long-term register of the influence of the sea of clouds on vegetation, we combine dendrochronology and stable oxygen isotope analysis in plant tissues of *Pinus canariensis*. This species is endemic on the Canary islands and dominates vegetation between 200 and 2000 m asl, particularly on the island of La Palma. Trees damaged during volcanic eruption allowed us to obtain past oxygen isotope signatures on different recovery stages from crownless to fully crown recovered trees and to compare them to pre-eruptive tree-ring values. Four pine trees from 1780 to 1915 m asl damaged by an eruption in 1949 were felled and 5 slices were taken from each tree. Dendrochronological measurements were performed following standard procedures. Oxygen isotope ratios were analyzed in tree-ring cellulose extracted from pools of 5 tree rings. Trees damaged by volcanic eruption showed high δ18O values, ranging from 36.29 to 40.27 per mil. The first tree rings formed after the volcanic damages showed, however, significantly lower isotope values compared to pre-eruptive rings and the following post eruptive rings. High δ18O values may be related to the uptake of isotopically enriched water from fog interception. Fog interception by vegetation is dependent on leave surface, thus interception in our studied trees was minimum after volcanic damages, and increased with recovery of the foliar surface. Therefore, lower oxygen values of the first post-eruptive formed rings corresponded with a lower fog intercepted water input. Besides tree-ring width indices were positively correlated with δ18O values, i.e. heavier isotope values were related to wider rings, as higher quantities of fog water may have been intercepted, increasing the water availability for pine that is its limiting resource at this altitude.

Tree species diversity improves beech growth and alters its physiological response to drought in Belgium

Astrid Vanoppen (1)*, Kerstin Treydte (2), Pascal Boeckx (3), Vincent Kint (1), Quentin Ponette (4), Kris Verheyen (5), and Bart Muys (1)

(1) Division Forest, Nature and Landscape, Department of Earth and Environmental Sciences, University of Leuven, Belgium, (2) Dendrosciences Group, Research Unit Forest Dynamics, Swiss Federal Research Institute WSL, Birmensdorf, Switzerland, (3) Isotope Bioscience Laboratory, Faculty of Bioscience Engineering, Ghent University, Gent, Belgium, (4) Earth and Life Institute, Université catholique de Louvain, Louvain-la-Neuve, Belgium , (5) Forest & Nature Laboratory, Ghent University, Melle-Gontrode, Belgium
Correspondence: astrid.vanoppen@kuleuven.be

The predicted increase in drought frequency and severity is expected to affect forest growth. Common beech, a widespread and economically important tree species in Europe, is known to be drought sensitive. It is thus important to increase our understanding about the effect of drought on the growth of beech in interaction with management. Diversifying forests has been proposed as a useful management strategy to mitigate the effects of increasing drought on forest growth. In order to study if beech trees growing in more diverse forest patches are more resistant and resilient to drought compared to those growing in monoculture patches, a unique observational platform was set up in Belgium. Beeches growing along a tree diversity gradient (from monocultures to forest patches with up to three species) were selected. Combining dendrochronological and stable carbon and oxygen isotope data allowed for studying the effect of tree species diversity on beech growth and its reaction to drought regarding stem radial growth and isotope proxies for physiological performance. Enhanced stem radial growth and higher resistance to drought was observed for beech trees growing in diverse patches. During drought years the increase in δ 13C compared to the years prior to drought in more diverse stands was less pronounced compared to beech trees growing in monocultures, indicating enhanced stomatal conductance and growth continuation of trees growing in mixtures. Until now the positive effect of diversity on beech growth and resistance seems to still outperform negative effects induced by drought; though increasing drought frequency and severity might override this in the future.

Linking climate, physiology and intra-annual secondary growth in a intraspecific competition trial of *Pinus pinea* L. in central Spain

Marta Pardos (1)*, Javier Vázquez-Piqué (2), Reyes Alejano (2), Guillermo Madrigal (1), Sara Pascual (1), Rosario González-Cascón (4), Sven Mutke (1), Javier Gordo (3), Rafael Calama (1)

(1) INIA-CIFOR, Madrid, Spain (2) Department od Agroforestry Sciences, University of Huelva, Spain (3) Servicio Territorial de Medio Ambiente, Valladolid, Spain (4) INIA, Dpto. Medio Ambiente, Madrid, Spain
Correspondence: pardos@inia.es

The simultaneous analysis of the temporal dynamics of intra-annual secondary growth and the physiological status in forest tree species allows to give deep insight on important topics on forest ecology as tree phenology, seasonal response to climate events, net primary productivity, biomass allocation and mobilization of nutrient reserves. Apart from climate, both processes are highly controlled by individual tree-level competition, which defines the total availability of resources - water, light, nutrients - to be invested in the photosynthesis, and subsequently, in vital processes as respiration, root growth, primary and secondary growth reproduction.

   In the present study we aimed to analyze the temporal relations among climate, tree physiological status, and secondary growth in a Mediterranean stone pine (*Pinus pinea* L.) forest in central Spain. Our main questions to answer were (i) is there a direct temporal relationship between physiological status and subsequent secondary growth? (ii) are physiological parameters and secondary growth more linked to climate or to competition?. Observations were carried out during the three-year 2014-2017 period on a 20-years old thinning trial, including two thinning intensities (150 stems/ha, 250 stems/ha) as well as a control treatment (500 stems/ha). Tree physiological status was measured monthly in ten trees per treatment, including measurements of gas exchange, stomatal conducance, clorophyll fluorescence, water potential and specific leaf area. Intrannual secondary growth was monthly recorded by means of band dendrometers installed in the same trees. Our results give evidence of a large climate control over the seasonal changes in the physiological activity and secondary growth phenology, while competition is mainly ruling the between-tree differences and the maximum rates of secondary growth.

Dendrochronological analysis of subfossil driftwood excavated from the alluvial deposit of the Drava river at the Croatian - Hungarian border

Mátyás Árvai (1)*, Enikő Mihály (2), Zoltán Kern (3)

(1) Institute for Soil Sciences and Agricultural Chemistry, MTA ATK, Budapest, Hungary, (2) Department of Physical Geography, Eötvös Loránd University, Budapest, Hungary.(3) Institute for Geological and Geochemical Research, MTA CSFK Lendület 2ka Palæoclimate Research Group, Budapest, Hungary
Correspondence: arvai.matyas@agrar.mta.hu

This paper presents preliminary results of dendrochronological analyses of the first occurrence of subfossil tree trunks from Drava alluvial sediments.

The driftwoods have been emerged at an outer bend of the Drava river near the village of Babócsa. The locality of the samples was covered by a significantly thick (>6 m) fluvial sand deposit, and it laid roughly in the same horizon situated at a stratigraphical border separating massive gravel and sand sequences.

All together 14 samples had been collacted within a relatively short distance (~100m) from three separated sets. The species of the excavated wood remains are vary. The half of the samples were oak (*Quercus robur* L., n=7), fewer samples belonged to beech (*Fagus sylvatica*, n=3) and elm (Ulmus sp., n=3) finally a single sample was found to be Norway spruce (*Picea abies*, n=1).

The samples were processed following the standard dendrochronological protocol and ringwidths were measured to the nearest 0.01mm.

Despite the most likely origin of the samples is the riverbank; the oak trunks had narrow tree-rings sequences and one of the oak trunks contained more than 250 rings and other three oak samples preserved around 200 rings. Naturally, these samples dispose the greatest potential to the succesful synchronization.

Tree-ring indicators of streamflow for south-central Tibet, China

Feng Chen (1)*, Yujiang Yuan (1), Huaming Shang (1), Shulong Yu (1)

(1) Key Laboratory of Tree-ring Physical and Chemical Research, Institute of Desert Meteorology, China Meteorological Administration, China.
Correspondence: feng653@163.com

In a warming world, water scarcity is one of the main concerns for sustainable development and human well-being in Asia. Due to the lack of instrumental streamflow records, the natural variability of the water supply from high Asian rivers is not well understood from a long-term perspective. Here, we have reconstructed the streamflow of Lhasa River and Salween River, based on the tree-ring width indices. The reconstructions explain over 42 % of the instrumental streamflow variance over the common period. In the Lhasa River Basin, remarkable periods of low streamflow occurred during 1588–1608, 1629–1642, 1651–1678, 1754–1785, 1820–1844, 1873–1887, 1922–1934, 1941–1964 and 1970–1991, while the high streamflow periods at 1548–1587, 1609–1628, 1679–1688, 1696–1719, 1740–1753, 1797–1819, 1845–1872, 1888–1910 and 1992–2004. In the Salween River Basin, remarkable periods of low streamflow occurred during 1500–1509, 1534–1548, 1563–1573, 1592–1613, 1628–1656, 1731–1774, 1793–1832, 1863–1899, 1906–1930 and 1961–1979, while the high streamflow periods at 1510–1533, 1549–1562, 1574–1591, 1614–1627, 1657–1730, 1775–1792, 1833–1862, 1931–1942, 1950–1960 and 1986–2011. The streamflow reconstructions are representative of regional moisture conditions over the south-central Tibet. Some significant spectral peaks are identified, and suggest the influence of natural forcing on the streamflow of the Rivers, such as ENSO and solar activity. The linkages of our reconstructions with sea surface temperature in the northern Indian Ocean and western equatorial Pacific Ocean suggest the connection of regional streamflow variations to large-scale atmospheric circulation. We also find that there is the relationship between streamflow variations of high Asia and the Asian summer monsoon. Our streamflow reconstructions provide a long-term perspective on current and twentieth century wet and dry events in the south-central Tibet, is useful to guide predictions of future variability, and aids future water resource management.

Cloudy stories from ancient trees; the palaeocloud signal in stable carbon isotope records

Mary Gagen (1)*, Eduardo Zorita (2), Danny McCarroll (1), Giles Young (1), Neil Loader (1), Iain Robertson (1)

(1) Department of GEography, Swnsea University UK, HZG – Helmholtz Zentrum Geesthacht (2)
Correspondence: m.h.gagen@swansea.ac.uk

The long term relationship between cloud cover and temperature is one of the most important climate feedbacks contributing to determining the value of climate sensitivity. Climate models still reveal a large spread in the simulation of changes in cloud cover under future warming scenarios and clarity might be aided by a picture of the past variability of cloudiness. Stable carbon isotope ratios from tree ring records have been successfully piloted as a palaeocloud proxy in geographical areas traditionally producing strong dendroclimatological reconstructions (high northern latitudes in the Northern Hemisphere) and with some notable successes elsewhere too. An expansion of tree-ring based palaeocloud reconstructions might help to estimate past variations of cloud cover in periods colder or warmer than the 20th century, providing a way to test model test this specific aspect. Calibration with measured instrumental sunshine and cloud data reveals stable carbon isotope ratios from tree rings as an indicator of incoming short wave solar radiation (SWR) in non-moisture stressed sites, but the statistical identification of the SWR signal is hampered by its interannual co-variability with air temperature during the growing season. Here we present a spatio-temporal statistical analysis of a multivariate stable carbon isotope tree ring data set over Europe to assess its usefulness to reconstruct past solar radiation changes. The interannual co-variability of the tree ring records stronger covariation with SWR than with air temperature. The resulting spatial patterns of interannual co-variability are strongly linked to atmospheric circulation in a physically consistent manner. However, the multidecadal variations in the proxy records show a less physically coherent picture. We explore whether atmospheric corrections applied to the proxy series are contributing to differences in the multi decadal signal and investigate whether multidecadal variations in soil moisture perturb the SWR. Preliminary results of strategies to bypass these problems are explored.

POSTER36

Climatic response dynamics in larch and spruce chronologies on the upper treeline in Subarctic

Arina Galimova (1)*, Nadezda Devi (1), Andrey Grigoriev (1), Pavel Moiseev (1) and Vladimir Kukarskih (1)

(1) Institute of Plant and Animal Ecology Russian Academy of Sciences, Ekaterinburg, Russia
Corresponence: arina_galimova93@mail.ru

For the Subarctic areas (Kola Peninsula and Putorana Plateau), long (290-350 y.) generalized tree-ring chronologies of Dahurian larch (*Larix gmelinii* (Rupr.) Kuzen.), Siberian spruce (*Picea obovata* Ledeb.) and European spruce (*Picea abies* (L.) H. Karst.) have been made. All the chronologies feature high sensitivity indicating a strong climatic signal. Despite the considerable distance between the sites, the chronologies' response on climate is similar and typical of subarctic region. Major factors determining the tree growth are thermal conditions of summer months. The analysis of the climate signal temporal discontinuity highlighted the periods of maximal and minimal limitations to the species radial growth caused by climatic conditions. Significant changes in the growth response to climate variables have been determined, the most pronounced of which have been observed since the mid-twentieth century.

Spatial variability of Scots pine response to climatic extremes in Central Europe over the last 50 years

Ryszard J. Kaczka (1)*, Karolina Janecka (2), Tobias Scharnweber (2), Martin Wilmking (2)

(1) Faculty of Earth Sciences, University of Silesia in Katowice, Sosnowiec, Poland, (2) Institute of Botany and Landscape Ecology, University of Greifswald, Greifswald, Germany.
Correspondence: ryszard.kaczka@us.edu.plr

Recent climate change is commonly recognized as one of the most significant challenges for the environment and humans at local and global scale. The proper mitigation to climate change is problematic due the lack of sufficient knowledge about the processes which are continuously unfolding, for example the reaction of forest ecosystems and individual trees to current climate change. Central Europe, including the middle part of the European Plain, the Bohemian Massif, the Western Carpathians and the Great Hungarian Plain is a region where local climate varies from humid oceanic to continental, which is especially pronounced in the Northern European Plain of Germany and Poland. Here, we present preliminary results of dendroclimatic analyses focused on Scots pine (*Pinus sylvestris* L.) as the most common tree species in the region and on specific years of extreme weather in the last five decades (1970s – 2010s). From instrumental climate data we know that during that period the climatic changes were very pronounced and several extreme years (1976, 1984, 1992, 2003, 2010, 2015) and/or short periods (1976-1982) occurred. Five sites located along an ~800 km long transect from NW (Germany) to SE (Poland) were analysed. All stands are characterised by similar sandy podzolic soil of rather dry conditions, minimal or moderate human impacts due to past logging and air pollution. The site-orientated sampling strategy was employed and 50 to 100 trees were sampled per site. Several parameters (tree ring widths, wood density, blue intensity, intra-annual wood density fluctuation) were measured and identified. Therefore core preparation was rather complex including resin extraction, cutting 1.2 mm thick wooden laths for x-ray density measurements of selected samples, sanding and scanning (2400 DPI, IT8 calibrated flatbed scanner). X-ray wood density was measured with an Itrax multiscanner (Cox co.), the blue intensity, annual, early- and latewood widths were measured with CooRecorder software and intra-annual wood density fluctuations were studied under optical microscope using standard classification of type and location of anomalies (E, E+, L, L+). The chronologies of all proxies were built based on optically and statistically cross-dating the time series using respectively CDendro and Cofecha programs. The main climate factors controlling pines' growth were identified using stationary and running correlations between standard chronologies and climate parameters including temperature, precipitation, and drought indices SPEI and PDSI. The rings from particular years (climatic extreme years) were compared with the general pattern of the site and local growth using all proxies. The reaction to extreme climatic years varied not only along the transect but also within stands. The individual and stand reactions depend very strongly on the effective date when abnormal weather occurred during the growing season. Further analyses will include more sites and possibly more coniferous species resulting in establishing the network which allows to perform better spatial analyses.

Solar evidence in tree rings from Kola Peninsula (Northwestern Russia)

Elena Kasatkina (1), Oleg Shumilov (1)*, Mauri Timonen (2), Alexander Kanatjev (1)

(1) Kola Science Centre RAS / Polar Geophysical Institute, Russia, (2) Natural Resources Institute (LUKE), Finland.
Correspondence: oleg@aprec.ru

The Sun's role in climate variability is now a subject of debates, especially in the context of understanding contribution of solar forcing to modern global warming. Besides, there are some evidences of the approaching new Grand Solar Minimum with Little Ice Age climatic conditions (K.G. McCracken and J. Beer, JGR, 119, 2379-2387, 2014; N.-A. Morner, Natural Science, 7, 510-518, 2015). This expectation is based on the occurrence of the extended solar minimum of 2006-2009 (McCracken and Beer, 2014). To investigate the possible Sun-climate connection we analyzed the regional tree-ring chronologies covering the period from 1445 to 2005. A total of 36 timber cores of scots pine were sampled near the northern tree-line at Loparskaya station (68.6 N, 33.3 E), including the oldest living pine with more than 560 years of age. Ring widths were measured with a precision of 0.01 mm by using a self-developed image analysis system (scanner and relevant software) (Kanatjev et al., Instruments and Experimental Technicues, 57, 214-217, 2014). The data were processed using modern methods adpoted in dendrochronology (cross-dating and standardization) with the help of COFECHA and ARSTAN programs. The analysis revealed significant cooling events, coinciding with the Spoerer (1400-1540), Maunder (1645-1715), Dalton (1790-1830), and Gleissberg (1880-1910) Grand Solar Minima. The application of MTM-spectrum analysis and continuous wavelet transform for the Loparskaya tree-ring chronology identified the existence of the main cycles of solar activity (11, 20-25, and ~ 100 years). The main solar factors acting on climate and atmosphere are solar radiation and cosmic rays, influencing the cloud cover of the atmosphere. As solar and cosmic ray proxies we used sunspot number and Be^10 cosmogenic isotope records respectively. To examine the relationship in time-frequency scale between tree-ring growth and solar activity, the cross wavelet transform and wavelet coherence were applied to the time series. The wavelet coherence analysis revealed a strong coherence in the 8-13 and 20-30 year bands indicating a possible link between solar activity and climate change on a regional scale. Our results demonstrate the possibility of using polar tree-ring widths as indicators of solar and climate changes in the past.

Are tree rings proper proxies for nonlinear past climate variability?

Jaqueline Lekscha (1, 2)*, Jasper G. Franke (1, 2), Reik V. Donner (1)

(1) Potsdam Institute for Climate Impact Research, 14473 Potsdam, Germany, (2) Department of Physics, Humboldt University, 12489 Berlin, Germany.
Correspondence: jaqueline.lekscha@pik-potsdam.de

In present-day paleoclimate research, tree ring archives have become one of the most important sources of information on past climate variability at interannual-to-multidecadal time scales. Understanding and interpreting tree rings and associated dendroclimatic proxies as recorders of past climate changes is however challenged by the non-uniqueness of climatic factors possibly influencing tree growth (e.g., precipitation vs. temperature) and interference with other non-climatic environmental factors at the local scale. Moreover, the climate system itself is inherently complex and exhibits non-trivial, possibly nonlinear and non-stationary, dynamics at multiple temporal and spatial scales. Beyond characterizing its gradual variability patterns, identifying and attributing abrupt shifts in the associated climate dynamics is of foremost interest for improving our knowledge of the fundamental processes underlying past climate changes, including both internal and externally forced variations. The latter case comprises, among others, changes induced by varying solar irradiation and volcanic eruptions, which differ in the spatial and temporal signatures of their climatic effects potentially reflected by anomalous tree growth.

Under these conditions, traditional statistical methods have natural limitations in their capability to characterize and attribute variations of characteristical properties of tree rings. During the last years, nonlinear methods of time series analysis have been proposed as considerable alternatives for studying paleoclimate proxy records. Among other approaches, recurrence network analysis has demonstrated its value as a tool for studying past climate variability as recorded in sedimentary sequences or speleothems [1,2]. However, when applied to tree ring data, the results are found to be typically far less robust with respect to the choice of the method's intrinsic parameters than for other previously studied paleoclimate archives. Possible reasons for this behavior could include specific response times of trees to climate stressors as well as a peculiar spectral profile of tree ring data that differs from that of other paleoclimate proxies and thus raises the question at which time-scales one can infer meaningful information on climate variability.

To shed some light on the aforementioned problems, in this work we systematically study how recurrence network analysis of tree ring chronologies represents abrupt changes in past climate variability. Beyond investigating the nonlinear variability properties of selected tree ring chronologies from different regions, we employ pseudo-proxy models for tree rings and evaluate whether and in which cases different types of dynamical anomalies and regime shifts can be detected within this analysis framework. Subsequently, we compare the results to corresponding analyses of other archives, such as lake sediments and ice cores. Possible relations to previous results obtained with other nonlinear methods like visibility graphs are discussed [3]. The obtained results provide important information regarding the question in which cases recurrence network analysis and other modern time series analysis techniques can yield meaningful results when applied to dendroclimatic records.

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Summer hydroclimate deficit variability in Northern Romania since 1440 A.D.

Constantin Nechita (1)*, Ólafur Eggertsson (2), Ionel Popa (1)

(1) National Institute for Research and Development in Forestry "Marin Drăcea", Romania, (2) Icelandic Forest Research Mógilsá, Iceland.
Correspondence: nechitadendro@gmail.com

Drought induce significant environmental changes and in our days, and represent one of the most important natural threats affecting temperate ecosystems in Europe (Vicente-Serrano et al., 2015). According to the Kreibich et al., (2014) the world will experience major environmental hazadrs caused by climate changing during the next decades. The Maramures county, in Northern Romania, represent a specific case in South East Europe region in respect to the response of oak radial growth to climate parameters clarified in previous study by Nechita et al., 2017. This was one of the main reason for constructing a long chronology for that region, even if the area is relatively restricted. Even so, the Maramures region offers a large potential to prolonging the chronology further back in time, using subfossil wood existing in large deposits along the Iza river. The oak chronology for Maramures covers to day the period from 1406 to 2016 AD. The weakest replication period (14 samples) of the chronology is between 1770-1830, lack of historical buildings and old growth trees covering this period. But even so the EPS value does not fall below 0.86. Tree-ring widths were used to reconstruct July SPEI4 patterns for the period 1440-2015. According to the findings, drought events in the Maramures region persisted of no more than 2 years, and extreme dry events occurred only in 1-year intervals. The historical records of drought events verifies the data obtained by the tree-rings analysis. The major drought events occurred in 1519, 1525, 1532, 1538, 1603, 1610, 1616, 1660, 1675, 1704, 1773, 1802, 1827, 1854, 1855. We discuss the relevance of July SPEI4 features for the growth of oak trees and the possibility of its effect on social and cultural activity in the region.

Rowan (*Sorbus aucuparia* L.) growth response to climate and growth phenology in Eastern Carpathians

Ionel Popa (1)*, Anca Semeniuc (1), Andrei Popa (2)

(1) National Research and Development Institute for Silviculture Marin Dracea, Câmpulung Moldovenesc, Romania, (2) University Stefan cel Mare of Suceava, Faculty of Forestry, Romania.
Correspondence: popaicas@gmail.com

Timberline and treeline ecosystems are one of the most sensitive to climate warming. Rowan (Sorbus aucuparia L.) tree ring chronologies and growth response studies are scarce. The study area is located in the Eastern Carpathians (Calimani Mts.) in the transition zone from compact forest to treeline. Vegetation is represented by a mixture of Norway spruce, stone pine and rowan in a matrix of mountain pine.

Tree cores from 23 trees (2 cores per tree) and weekly microcores from 2007 to 2009 were used to derive the climate-growth pattern for rowan. Daily climate data were obtained from grid database EOBS (0.25°x0.25°). Tree ring width of rowan from Eastern Carpathians capture a strong temperature signal from previous autumn (end of September to middle of October), spring (March) and summer (end of June to end of July). First informations on intra-annual wood formation for rowan were provided. Wood formation monitoring reveals an onset of cambial activity at the end of May. The first cells in enlargement phase are observed in the first decade of June. The lignification phase begins on the second part of June and ends in the first week of September. Growth cesation, in terms of formation of new cells, is recorded at the end of July.

Our preliminary results highlight that rowan growth is climate sensitive and for a better understanding of climate changes impact on subalpine ecosystems is necessary to combine long-term (tree ring width) and short-term (wood formation monitoring) data for secondary wood species.

Are solitary trees the better climate archives?

Tobias Scharnweber (1)*, Lisa Heinze (1), Marieke van der Maaten-Theunissen (1, 2), Martin Wilmking (1)

(1) Institute of Botany and Landscape Ecology, University of Greifswald, Germany, (2) Chair of Forest Growth and Woody Biomass Production, TU Dresden, Germany.
Correspondence: tobias.scharnweber@uni-greifswald.de

In temperate environments, where tree growth is not at its physiological limit, dendroclimatology usually is concentrated on samples from closed canopy forests. Here, competition effects and possible disturbances -be it natural or anthropogenic- can exert strong influences on ring-width patterns. This makes a rather flexible detrending of raw ring-width data indispensable before extracting any climatic information. However, detrending creates difficulties as it comes to precisely differentiating between climatic and non-climatic signals (noise).

   Surprisingly, only very few studies are conducted with solitary trees. These lonely giants have never experienced any competition for light or have been released from competition and therefore possibly preserve a much clearer climatic signal in their ring-width patterns. We tested this hypothesis by comparing growth patterns from 33 solitary oaks (*Quercus robur* L.) that grow on agricultural fields or meadows with chronologies of the same species from adjacent closed canopy forests in northern Germany. Contrary to our expectations, the long-term growth trends of the solitary oaks show clear deviations from the theoretical negative exponential decline of ring width with age. Although climate correlations were slightly higher for the solitary trees compared with the closed canopy forests, this difference was not as clear as expected. We explain this with the influence of fertilization and (or) changes in agricultural practices throughout the last century on growth of these trees and conclude that the analyses of solitary trees only partially helps to disentangle effects of competition, disturbance and climate.

Trees as Indicators of the Urban Heat Island (UHI)

Sebastian Schneider (1, 2)*, Stefanie Elsholz (1), Burkhard Neuwirth (3), Ingo Heinrich (1, 4), Daniel Balanzategui (1, 4), Christoph Schneider (1)

(1) Geography Department, Humboldt-Universität zu Berlin / Germany, (2) Department of Earth Sciences, Freie Universität Berlin / Institute of Geographical Sciences, Germany, (3) DeLaWi-TreeRing Analyses, Windeck / Germany, (4) Helmholtz Centre Potsdam GFZ German Research Centre for Geosciences / Department 5 Geoarchives, Germany.
Correspondence: sebastian.schneider.8@geo.hu-berlin.de

The project "Trees as Indicators of the Urban Heat Island" investigates different tree species in Berlin, the city with the most pronounced UHI in Germany. The main goal of the project goal is the reconstruction and modeling of spatial distribution and spatiotemporal evolution of the urban heat island using dendroecological parameters (tree-ring width, pointer years, wood anatomical features). In a first step, the climate-growth relations were analyzed for 13 urban tree sites along a UHI-gradient in the district Neukölln of the City of Berlin and compared with 10 tree sites in the north (Müritz Nationalpark), southwest (Potsdam-Telegrafenberg), and southeast (Stadtforst Köpenick) hinterland of Berlin. The urban tree sites cover various levels of UHI-intensity expressed by so called local climate zones and include urban (acer, ash, and lime) as well as basic forest tree species (beech, oak, pine, and others) to prevent visible urban-rural diversities from being blurred by species-specific differences.

Two cores each from about 350 trees were sampled with increment corers and prepared by applying established dendroecological measurement and data processing techniques. Indexations of tree-ring width measurements based on moving averages with 5 or 13 years bandwidths were applied to all mean tree curves to eliminate long term growth trends and to underline the year-to-year variations. Linear correlations between various temperature and precipitation data derived from various climate stations (Berlin-Dahlem, Berlin-Alexanderplatz, and Potsdam, DWD) provided the basis for climate-growth analyses and the calculation of z-transformed Cropper values for the extreme year analyses. The approach aims at determining and prioritizing the growth factors for mean climatic and extreme weather conditions (dry seasons, heat waves, excess precipitation) at different sites.

Besides the sampling approach and the data processing the poster will present first dendrochronological and -climatological results by illustrating species-specific growth patterns at urban sites in comparison to non-urban sites.

Climate signal in tree-ring features of black pine (*Pinus nigra* Arn.) trees from the Rhodope Mts. in South Bulgaria

Velislava Shishkova (1)*, Achim Bräuning (2), Momchil Panayotov (1)

(1) Dendrology Department, University of Forestry, Sofia, Bulgaria, (2) Institue of Geography, Friedrich-Alexander University of Erlangen-Nuremberg, Germany
Correspondence: ivelvell@gmail.com

The Mediterranean region is often described as especially vulnerable to climate change. Model projections predict future warming and drying with increase of heat waves and dry spells. Such conditions may have strong negative effects on the environmental and socioeconomic state of the region. The southern parts of the Rhodope mountains in Bulgaria are strongly influenced by the Mediterranean climate, having higher average temperatures than the central and western parts of the mountain range, and a precipitation maximum during winter. Precise knowledge on past climate can help us to better understand the origin and changing frequency of drought events and to mitigate their negative effects on forest ecosystems. Yet, there are still regions (like the interior part of the Balkan Peninsula) that are not well studied in this respect due to the scarcity of proxy climate reconstructions. Hence, there is a knowledge gap of the local climate of the Rhodope mountains in the past.

Black pine (*Pinus nigra* Arn.) is one of the long-living tree species in the region that is sensitive to climate conditions and has been used to produce reliable tree-ring based reconstructions. Moreover, there are old-growth black pine forests in the Rhodope Mts., with high conservation value. Thus, improving our knowledge on their response to climatic stresses is important.

With the recent technical development and perfection of wood anatomical methods , the number of dendroclimatic analyses utilizing quantitative wood anatomy has strongly increased. The variation of wood anatomical features within the tree rings is expected to have a greater potential for reconstructing past environmental conditions than using tree-ring width chronologies alone. However, detailed wood anatomical analyses have rarely been applied to long-term climate reconstructions. No analyses concerning the climate response of wood anatomical parameters have been done for *Pinus nigra* in the Rhodope Mts. region.

Our study sites are located in the Trigrad region of the Rhodope Mts. We collected samples from living trees, growing on relatively steep, rocky slopes with southern and south-eastern exposition, where drought is expected to be the limiting growth factor. Besides measuring tree-ring widths and building a standard tree-ring width chronology, we prepared transverse thin-sections of selected cores and measured tracheid cell wall thickness and cell lumen area. Our aim was to build tree-ring width and wood anatomical cell features chronologies and to compare them with existing meteorological data from the region in order to obtain detailed information how climatic factors affect radial tree growth and wood structure. Preliminary results show high mean correlations between the tree-ring width series for each study site (between 0.469 and 0.645) as well as common climate signals in the developed chronologies - statistically significant positive correlations between tree-ring width and summer precipitation (r>0.45) as well as negative correlations with summer temperatures. The longest chronology (420 years) had strong and stable through time correlation with June-July precipitation and was used as a proxy for early summer precipitation reconstruction.

Volcanic signatures in polar tree rings from Kola Peninsula (Northwestern Russia)

Oleg Shumilov (1)*, Elena Kasatkina (1), Mauri Timonen (2), Alexander Kanatjev (1)

(1) Kola Science Centre RAS / Polar Geophysical Institute, Russia, (2) Natural Resources Institute (LUKE), Finland.
Correspondence: oleg@aprec.ru

Solar and volcanic activities are considered to be the two most important forcings for climate variability throughout the Holocene prior the industrial period. Volcanic eruptions emit huge amounts of volcanic dust, sulfur dioxide and water vapor into the atmosphere, which, through the formation of an aerosol layer, can change the radiation balance of the atmosphere, thus impacting climate. Sulfate aerosols that enter the stratosphere after powerful volcanic eruptions exist there for several years. The aim of this study is to verify a hypothesis concerning the possible climatic response in polar region (Kola Peninsula and Finnish Lapland) to the most powerful volcanic eruptions (VEI>4) during the last millennium. The analysis was based on the Kola (1445-2005) and Finnish supra-long (~ 7500 years) tree-ring chronologies. These chronologies were developed from scots pine samples collected near the northern tree line at Loparskaya station (68.6 N, 33.3 E) and Finnish Lapland (68-70 N, 20-30 E), respectively. A superposed epoch analysis indicated a significant decrease in polar tree-ring growth over 7 years after the eruptions with subsequent recovery to its normal level. It was revealed that the level of tree growth in polar region is affected by most powerful low-latitude volcanic events. For example, the 1600 Huaynaputina eruption (VEI=6), which was the largest volcanic eruption in South America over the past 2000 years, caused the most significant (by 25% relative to the previous year) depression in tree growth. By contrast, eruptions of high-latitude Icelandic volcanoes (Katla (1721, 1755); Laki (1783); Askja (1875)) had no significant impact on the climate of Kola Peninsula and Finnish Lapland. As it concerned the 1783 Laki eruption, in accordance with some evidence (Thordarson and Self, JGR, 2003; Sonnek et al., Nat. Hazards, 2017), one can assume that a stable blocked high-pressure air pattern over Europe concentrated volcanic gases near the Earth's surface and prevented them to spread into the Kola Peninsula. The results open new possibilities of using polar tree-ring widths as indicators of volcanic activity above the Arctic Circle.

Oxygen isotopes in tree rings as atmospheric moisture proxy

Kerstin Treydte (1)*

(1) Swiss Federal Research Institute WSL, Research Unit Landscape Dynamics, Birmensdorf, Switzerland
Correspondence: treydte@wsl.ch

Climate models project a marked increase in heat waves and droughts even in high rainfall areas of Europe for the 21st century. Such projections, however, still contain huge uncertainties, and empiric proxy data are required to reduce model uncertainties. Furthermore insight into the trees' physiological response to climate change is of high relevance for predicting how tree growth and thus the terrestrial carbon and water cycle will respond to future environmental conditions. Oxygen isotopes in tree rings can provide valuable insight into the water uptake by trees and their physiological response to hydroclimatic variation. This holds particularly in temperate, low elevation regions where traditional tree ring parameters such as tree-ring width or maximum late wood density are limited in recording strong climatic signals. This poster presents an integrative mechanistic and paleoclimatic perspective on recent work that convincingly demonstrates the applicability of oxygen isotopes in tree-rings as recorders of hydroclimatic, and particularly atmospheric moisture variability. Examples range from seasonal, local scales to multi-century continental scales.

Provenance-specific growth reaction of Scots pine

Wrzesiński P.(1)*, Wilczyński S. (2), Klisz M. (1)

(1) Department of Silviculture and Genetics of Forest Trees, Forest Research Institute, Sekocin Stary, Poland, (2) Department of Forest Protection Climatology and Enthomology, Faculty of Forestry, University of Agriculture, Krakow, Poland
Correspondence: P.Wrzesinski@ibles.waw.pl

The frequency of weather disturbances attributable to climate change, increasing over the past decades, contributes to increasing frequency of fluctuations in tree-ring growth pattern in different climatic zones. Consequently, information about local responses to past changes in climate and its variation through tree ontogeny is urgently needed to predict future species responses under global climate change. Radial growth of trees reflects the interactions between environmental and genetic factors. Testing the populations of forest trees in provenance experiments allows determining their adaptation potential the context of forecasted and observed climate changes, directions and range of possible migration, as well as assessing the plasticity of origins in a changing environment. The aim of the study was to gain knowledge about provenance-specific adaptation potential of Scots pine to thermal and pluvial condition of southern Poland. The study was carried out in Polany provenance plots established in 1966 (Beskid Sądecki, Carpathians). The research covered 15 provenances of Scot pine from the whole area of Poland. The populations originated from different climatic regions with climate of origin different from the climate of the provenance plot. We selected and cored 15 trial trees representing each of the provenance. The choice of trees was made for the biosocial status of trees (Kraft I and II class) and their health status. The research material comprised 450 core samples (two cores per tree). The tree rings widths were measured using the Coorecorder and CDendro software. The accuracy of the ring dating and the homogeneity of the series were verify using the COFECHA program with the DPL package. To remove the age trend, the tree–ring widths values were standardized to annual sensitivity indices. Then, in each year, the values of the sensitivity series of trees of a given origin were averaged, creating for each population a chronology of average annual sensitivity indices. Response function analysis was used to determine climate–radial increment relationships. In order to classify provenances in terms of incremental rhythm traits, and to identify climatic elements shaping their short-term incremental reactions, the principal components analysis was used. The genetic basis of radial growth, suggests that the selection of provenance of pine appropriately adjusting the length of the individual stages of xylogenesis to unfavorable growth conditions may improve their adaptation to climate change.

The precipitation reconstruction developed from treerings at the upper treeline in the eastern Himalaya

Hui Zhang (1, 2)*, Haifeng Zhu (1), Eryuan Liang(1)

(1) Key Laboratory of Alpine Ecology and Biodiversity, Key Laboratory of Tibetan Environment Changes and Land Surface Processes, Institute of Tibetan Plateau Research, Chinese Academy of Sciences, China
(2) College of Resources and Environment, Linyi University, China
Correspondence: Zhanghui@itpcas.ac.cn

In the eastern Himalaya, little is known about the climate change in decadal and centennial scales for the lack of the meteorological data, especially near the glacier area. Treeline is sensitive to the climate change and is less disturbed by human activities. The aim of this study is to investigate the limiting factors of treeline and the climate change in decadal time scales in eastern Himalaya in past few hundreds years. We took Sabina tibetica Kom. samples from the upper treeline of Langxian which is in the leeward of the eastern Himalaya and is also near the glacier area, and developed a width chronology started in A.D. 1619. The correlation between the STD chronology and the climatic factors showed that the precipitation in May and June was significant positive correlated with the chronology, indicating precipitation in late spirng and early summer was the main limiting factor of radial growth in treeline. The hindering effect of the Himalaya is very strong for the airflow from the southern Asia, thus it is much drier for trees in treeline in pre- and the early time of growing season in study area. The reconstruction of total precipitation in May and June explained 38.1% of China Meteorological forcing Data sets (CMFD) during1979-2015, and showed 4 wet phases (1780-1790, 1797-1810, 1899-1936, 1990-2008) and 4 dry phases (1815-1830, 1864-1874, 1964-1989. 1896-1936) during 1720-2014. 1896-1936 was the wettest period, and 1864-1874 was the driest period over the past around 300 years. The precipitation was decreased since A.D. 2000, while the temperature in this area was increased. Comparation with other reconstructions in adjacent area showed good consistency, suggested our reconstruction had good spatial representation. Our reconstruction could make up for the lack of the meteorological data and provide more information about climate change in rural area of the eastern Himalaya, especially near the glacier area.
Keywords: Climate change; Sabina tibetica Kom.; Treeline; the eastern Himalaya

Adjusted tree ring latewood width holds potential for summer climate reconstruction in subtropical South China

Yesi Zhao (1, 2), Jiangfeng Shi (1)*, Shiyuan Shi (1), Bowen Wang (1), Huayu Lu (1), Jian Yu (3)

(1) School of Geographic and Oceanographic Sciences, Nanjing University, China, (2) Department of Geography and Geosciences, University of Erlangen-Nuremberg, Germany, (3) College of Forestry, Beijing Forestry University, China
Correspondence: Shijf@nju.edu.cn

Summer climate variability in South China at decadal scales is not well understood due to the relatively short meteorological records and the scarcity of paleo-proxies. Herein, we explore the potential of using tree-ring latewood width (LWW) from Tsuga longibracteata to reconstruct summer climatic factors. Latewood usually forms in the mid- to late growing season, at least partly during summer. Tree-ring samples were collected at three sites (HS, QSZ, and SJD) close to the northern boundary of Guangxi province. We built three LWW chronologies and three adjusted LWW chronologies after the removal of the influence of earlywood on latewood growth. Bootstrapped correlation and response analyses indicate that the LWW chronologies are significantly correlated with summer climatic factors, and the adjusted LWW chronologies show much higher correlations. The extent to which summer climatic signals can be extracted from adjusted LWW is site-dependent. At the well-drained sites (QSZ and SJD) with abundant sunshine, adjusted LWW shows significant positive correlations with July–August Standardised Precipitation-Evapotranspiration Index (SPEI), owing to the positive response to precipitation and the negative response to temperature. In contrast, adjusted LWW only exhibits positive responses to July temperature on north-oriented slope (HS) with high water-holding capacity. Nearly 37% of the variance in the regional SPEI can be explained by the adjusted LWW chronology from the forest stand (QSZ) on well-drained southeast-facing slope with less endogenous disturbances. These results indicate that there is a great potential of using adjusted LWW to reconstruct summer SPEI in South China when suitable sampling sites are selected.

Dendrecological investigations on timber from mines at "Rammelsberg" near Goslar and "Beerberg" near St. Andreasberg (Harz Mountains)

Andreas Bauerochse (1)*, Hanns Hubert Leuschner, Barbara Leuschner, Julia Weidemüller

(1) Lower Saxony State Service for Cultural Heritage
Correspondence: andreas.bauerochse@nld.niedersachsen.de

As Europes northernmost low mountaine range, the Harz Mountains are famous for their ming, going back to – at least – the Iron Age period. From the beginning wood was an important raw material, used multifariously: first to produce charcoal for smelting processes, as timber for constructions, gallery support systems and mine headgears as well as for fire driven ore mining.

Today wodden remains are often found in abandoned mines and overburden stockpiles. They are conserved by heavy metals, mineral salt crusts (sinter) as well as in flooded galleries. As this wood belongs to the period of the last about 2500 years, it is an unique archive containing former environmental and – as it is arteficial – anthropogenic information.

Its dendrochronologically and dendrecologically analysis provides insights in the history of mountain mining, forest management, and (climate induced) environmental change of the Harz mining district. Here we focus on two mines, the world heritage site ´Rammelsberg` near Goslar and the mine ´Beerberg` near St. Andreasberg (upper Harz region).

At Rammelsberg excavations at a late medieval overburden stockpile started in 2012, discovering a great number of woodden artefacts. First dendro-dates of these subfossil timber – oak and pine, belonging to the entrance of a burried gallery and an adjacent lumberyard – dates to the middle and the second half of the 15th century. It is the lumberyard, whose samples documents human activities over a period of at least 50 years, from AD 1448 until AD 1491, while the timber of the excavated entrance of the gallery construction works date to the 1470´s. However, only a few timber from the first meters of this construction could be dated up to now. As the excavation site is situated at a (late) medieval overburdon stockpile, we expect more and older timber in deeper layers as well as from gallery sections situated further ahead in the mountain. A comparison of these first tree ring curves show simularities that document a) several timber belong to the same trees, and b) several trees probably come from the same forest district.

At the Beerberg mining district wodden artefacts could be dated to the period from the late 17th/early 18th century. Most of these artefacts originate from under ground catwalks. Up to now the oldest date belongs to the rest of a water pipe made of spruce, cut AD 1700.

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Growth variability of two native pine species on Corsica as a function of altitude

Martin Häusser (1)*, Sonja Szymczak (1), Achim Bräuning (1), Emilie Garel (2), Frédéric Huneau (2), Sébastien Santoni (2)

(1) Institute of Geography, FAU Erlangen-Nuremberg, Germany, (2) Hydrogeology Department, University of Corsica, CNRS UMR 6134 SPE, France
Correspondence: martin.haeusser@fau.de

The island of Corsica, France, poses a unique study area. The fourth largest island of the Mediterranean Sea is dominated by a north-south oriented mountain range that peaks at 2700 metres. In previous studies *Pinus nigra* subsp. *laricio* proved to be a reliable source of robust ringwidth chronologies at tree line sites. But the characteristics of tree growth in other parts of the island are yet to be unveiled. Due to the distribution of two pine species (*Pinus pinaster* in lower areas and *Pinus nigra* subsp. *laricio* in higher regions) it is possible to cover the altitudinal range of the island from alpine environments to Mediterranean coasts.

By means of tree-ring analysis, the relation between tree age and temporal growth changes was evaluated via growth trajectories for pines in different age classes at various sites across the island, ranging from 1600m asl to sea level. We hypothesize that tree growth in high altitudes is limited by temperature whereas the growth limiting factor in the lowlands is summer drought. First analyses on differences and similarities in growth trajectories depending on altitude, species, and east or west slope of the mountain range will be presented.

The common juniper wood traits network – a tool for environmental reconstructions from the Arctic to the Mediterranean

Jiří Lehejček (1), Allan Buras (2,3), Rohan Shetti (3), Marco Carrer (4), Jesus Julio Camarero (5), Martin Wilmking (3)

(1) Department of Environmental Security, Faculty of Logistics and Crisis Management, Tomas Bata University in Zlín, nám. T.G. Masaryka 5555, 760 01 Zlín, Czech Republic, (2) Forest Ecology and Forest Management, Wageningen University and Research, Droevendaalsesteg 3a, PB 6708 Wageningen, Netherlands., (3) Institute of Botany and Landscape Ecology, University of Greifswald, Soldmannstr. 15, 17487 Greifswald, Germany, (4) TeSAF Department, Università Degli Studi di Padova, Legnaro, Italy, (5) Instituto Pirenaico de Ecologıa (IPE-CSIC), Zaragoza 50059, Spain

Juniper (*Juniperus communis*) is the most widespread coniferous species in the world. It can serve as a sensitive environmental proxy archive (e.g. summer temperature, or ice-sheet melt reconstructions) covering time scales to several centuries. This combination of large spatial and long temporal coverage provides unique opportunities to I) reconstruct and study the paleo-environment in remote regions and II) infer important feedbacks and future consequences to global climate dynamics.

To tap this resource over large scales, we are currently building the common juniper wood traits network (Fig. 1). So far, 17 locations – mainly along the Northern Atlantic coast and in the Mediterranean – have been sampled. In the network, we intend including existing data-bases such as the shrub-hub and the tundra trait data-bases. However, concerted field campaigns covering Asia and N. America are still missing and thus desired.

Here, we invite the scientific community to contribute to the common juniper wood trait network with the benefits of co-authorship and network access for each data contributor. We have developed a sampling procedure to guarantee the comparability of the collections. Sampling per site takes approx. two person days, and involves measurements of basic plant traits and stem sections for dendro-ecological and wood anatomical analyses.

Fig. *1 Juniperus communis* northern hemisphere distribution (green area, small map) and location of field sites currently included in the network (black stars, main map). Field sites from west to east: Kobbefjord, Greenland; Hólasandur, Iceland (2018); Pennaroya + Villaroya de los Pinares, Spain; Finse, Norway; Devero + Ventino + Sella Nevella, the Alps; Abisko, Sweden; Kevo, Finland; North Kola Peninsula, Norway; Pollino, Calabria; Polar + Northern + Southern Ural, Russia

A history of the oscillations of Schiaparelli glacier since the Little Ice Age derived from tree-ring based moraine dating

W. Meier (1)*, M. Braun (1), J.C. Aravena (2), J. Griesinger (1), P. Hochreuther (1)

(1) University of Erlangen-Nurnberg, (2) University of Magallanes, Punta Arenas
Correspondence: wolfgang.jh.meier@fau.de

Since the availability of satellite data and airborne photography, glacial mapping is facilitated, but besides historical records, information about former glacial extents are very scarce. Knowledge about prior glacial dimensions is indispensable to quantify the consequences of recent changes in surface under future climate change scenarios. Especially in remote areas which are difficult to access, historical records are rare. Dating glaciermoraines offers the opportunity to derive information about the former glacial maxima and also about timing and speed of glacial oscillation. The germination date of trees on moraines can be used as a minimum age for a maximum glacier advance or the start of glacier retreat. Newly acquired tree-ring data (*Nothofagus betuloides*) from the glacier forefield of Schiaparelli Glacier is linked to previous studies from Cordillera Darwin, Tierra del Fuego. The former extend of Glacier Schiaparelli is discussed with regards to historical records. The time between stabilization of an initial soil surface and settlement of first trees ('ecesis time') was estimated by sampling 60 trees at the lateral moraine which was still glaciated in 1986 as documented by satellite data. Recolonization with trees was found to occur within 10 years, revealing that many studies overestimate this process up to 50 years. We identified three major frontalmoraines with declining age towards the recent glacier tongue, dating to 1750, 1775 and 1880, respectively. Additionally, 14C ages of buried trees (1750 +/- 35 BP) in the glacier forefield located between the dated moraines and the glacier tongue suggest an advance of the glacier before 1750. Besides moraine dating, tree-rings provide a suitable climate proxy with yearly resolution. For instance, at our sampling site tree-ring width is strongly related to increasing minimum temperatures since 1900 and reveal an above average growth after 1850.

Alien Plant Species in the city – trouble or opportunity?

Maks Merela (1)*, Angela Balzano (1), Denis Plavčak (1)

(1) Biotechnical Faculty, Department of Wood Science and Technology, University of Ljubljana, Slovenia
Correspondence: maks.merela@bf.uni-lj.si

Invasive Alien Plant Species (IAPS) are one of the biggest challenges in European ecosystems. They displace local vegetation, destroy agricultural land and cause damage to European economy in billions of euros every year. Many of them are daily removed and mainly burned. Department of Wood Science and Technology together with City of Ljubljana and partners work at the Applause project that addresses unsolved questions regarding invasive alien species in terms of the zero-waste approach and circular economy. Nowadays people are composting or incinerating these plants. Pilot projects for processing plants into paper at a semi-industrial level proved that they can be utilized for other useful purposes. By recognizing the potential of IAPS, Applause aims to introduce sustainable production processes for transforming the biomass of collected plants into useful products made of wood and paper. First of all we want to make it easier for the citizens to recognize and identify invasive non-native plant species and then remove and process them into useful products. One of the biggest challenges is to develop successful and trustworthy circular economy model, finding new use for all parts of collected IAPS and upcycling the residual materials. The project addresses the widest possible circle of stakeholders: kindergartens, schools, pupils, students, households, property owners, companies, tourists, professional organizations…

During research a list of appropriate IAPS for paper, wood and food products, dyes and home-made formulations against plant harmful organisms will pre prepared. For innovative high added value products it is necessary to know raw material (wood) properties. For this purpose 17 different woody plant species will be examined (anatomy, physical-mechanical properties, basic chemical composition, machinability, gluing properties, durability, resistance and impregnability). Analyze results will enable developing a greener way of pre-treating the pulp for paper production – processing with enzymes. We are also going to find a solution for wood waste which now serves as an energy-generating product but can also be processed into other useful products.

Applause is a project of UIA (Urban Innovative Actions) as Initiative of the European Union that provides urban areas throughout Europe with resources to test new and unproven solutions to address urban challenges. Three year project is financed by European Regional Development Fund.

Spatial heterogeneity of Phosphorous concentrations within tree rings – results from LA-ICP-MS measurements

Jörg Niederberger (1)*, Adrian Wichser (2), Martin Kohler (1), Davide Bleiner (2), Jürgen Bauhus (1)

(1) Chair of Silviculture, Institute of Forest Sciences, University of Freiburg, Germany, (2) Swiss Federal Laboratories for Materials Science and Technology (Empa), Ueberlandstrasse 129, 8600 Dübendorf, Switzerland
Correspondence: joerg.niederberger@waldbau.uni-freiburg.de

Many European forests have become phosphorus (P) limited in recent decades, possibly due to increased nitrogen deposition, soil acidification and improved tree growth. Dendrochemical analyses of P might enable a retrospective analysis of P nutrition of trees and provide valuable information about the effects of short-term changes (recycling efficiency) as well as of long-term environmental trends on the P availability in forest ecosystems.

We elaborated and further developed the Laser Ablation ICP-MS methodology to measure P in individual year rings. Our ongoing work has shown that the recovery of P in wood samples using the LA-ICP-MS approach is very good. However, owing to the relatively small area captured (we used laser shots producing holes of 100 μm), single shots may not adequately represent the spatial heterogeneity of P distribution within tree-rings. This spatial variation increases the noise in our data and makes the identification of signals from environmental effects more difficult.

So far we focused on spatial patterns of P within tree rings that might have been caused by temporal variation in P through different seasonal uptake or immobilization strength. However, the difference in P content between early wood and late wood was not significant. Therefore, we will test approaches to capture the spatial variation in circumferential direction within tree rings. In addition, we analyze wood anatomical structures like parenchyma rays of deciduous and conifer trees. Here we want to see how these nutrient rich tissues differ from the surrounding woody biomass and if there is also a variation within this structures e.g. in radial direction.

We found for *Picea abies* stronger radial variability in element concentration, in sapwood as well as in heartwood, compared to circumferential direction. In contrast, for *Fagus sylvatica* we found reverse results, here the variability was stronger in circumferential than in radial direction. This stronger variability for *F. sylvatica* seemed to be caused by parenchyma rays. At *F. sylvatica* parenchyma rays showed for all nutrients higher element concentrations than the surrounding wood, in sapwood as well as in heartwood. Additionally, we found that P concentrations in F. silvatica tree rings are considerably higher than in *P. abies*.

Exploring the growth response of Norway spruce (*Picea abies*) along a small-scale gradient of soil water supply

Inken Rabbel (1)*, Bernd Diekkrüger (2), Burkhard Neuwirth (3)

(1) Department of Geography, University of Bonn, Germany, (2) Department of Geography, University of Bonn, Germany, (3) Dendro-Labor Windeck, Tree-Ring-Analyses, Windeck, Germany
Correspondence: irabbel@uni-bonn.de

Tree growth is closely linked to local site conditions and dynamic environmental factors, from which temperature and precipitation are the most prominent in long-term observation studies. Studies on the drought response of forest trees often treat drought as the lack of precipitation over a defined period of time. However, actual plant water supply is not only dependent on incoming precipitation amounts, but strongly varies with local soil conditions and related water retention characteristics.

By combining tree ring data of different even-aged microsites under homogeneous climatic conditions with long-term soil hydrological simulations in HYDRUS-1D, we explore the growth response of Norway spruce (*Picea abies*) along a small-scale gradient of soil water supply. Based on a comparative time-series analysis of tree-ring width, temperature, precipitation and soil water status, we try to disentangle the effects of climate factors and actual water shortage on the observed growth signal.

The study area is located in the low mountain ranges of western Germany (Eifel National Park, close to the Belgian border) and covers an area of 0.27 km². The elevation of the test site ranges between 595 and 628 m a.s.l., with a mean slope of 3.6% and a maximum slope of 10.4%. Each microsite consists of 8 to 22 spruce trees that were sampled from two sides parallel to the slope. After quality check, the tree mean curves were detrended on the basis of a high-pass filter (binomially weighted 5 -year running means) and averaged to microsite chronologies. These represent the growth reponse of Norway spruce along the prevailing small-scale gradient of soil water supply from comparatively dry to permanently nearly saturated. For soil moisture monitoring, a wireless sensor network was installed in 2009 consisting of 900 sensors at 150 locations. Based on the soil moisture measurements, we inversely estimated the soil hydraulic properties of the selected microsites and simulated soil water supply in terms of root-zone water potential over a time period of 60 years after planting. We compare the simulated soil moisture dynamic as well as long-term temperature and precipitation data with the tree-ring chronologies of the corresponding microsite with the aim to identify the growth limiting factors in the investigated plant-soil-vegetation system.

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Lost in translation? On the relations between tree-ring index and remote-sensing time series across an ecological gradient in northeast Germany

Jens Schröder (1)*, Michael Körner (2)

(1) Thünen Institute of Forest Ecology, Eberswalde, Germany, (2) Staatsbetrieb Sachsenforst, Graupa, Germany.
Correspondence: jens.j.schroeder@thuenen.de

Changes in biomass productivity in forest ecosystems are supposed to be closely related to changes in the annual growth rates of the trees in these forests. Annual growth rates are stored in the tree-ring index (TRI) chronologies of the respective stands and can be accessed in retrospect by means of dendroecological analyses. This approach delivers reliable and precise data but requires considerable efforts and thus cannot be applied on a large scale. To generate biomass productivity estimations on the landscape level, many studies have recently focused on remote-sensing data, particularly on the Normalized Difference Vegetation Index (NDVI) derived from optical satellite data. This index can be obtained at a temporal resolution of 16 days for a pivel size of 250 m.

The poster summarizes a methodological study aimed at testing the assumption that NDVI data are representative of biomass productivity in forests as expressed in tree growth. We analyzed the correlation of single and compound NDVI values with increment variation in forest stands as derived from borer core samples. These were taken from samples of 20 representative Scots pine (*Pinus sylvestris*) trees each in three plots of three reference regions on a geographic and age gradient in northeast Germany. Remote-sensing data as supplied by the MODIS sensor of the Terra satellite system were used to extract the necessary NDVI information as indicators for annual changes in productivity. The analyses focused on dominant and co-dominant trees to capture as closely as possible the influence of climatic conditions on the variation in both TRI and NDVI.

The relations between the two data levels were quantified by Pearson's correlation coefficient for all combinations of different NDVI images with singe-plot and average TRI information. According to our results there is a close relation between local and regional NDVI and variation in tree-ring width indices. The derived linear models can be transferred across the plots in the reference region but lose some explanatory power when applied in another region. The most relevant temporal intervals to explain TRI variance are located at the beginning and the end of the vegetation period. The integration of a robust NDVI-based model across all plots delivering reliable TRI estimations with average accuracy could deliver more precise productivity estimations, especially for extreme growth conditions such as drought years. Further studies should analyse mixed stands of different species and the relationships between other remote-sensing indices such as EVI and TRI or basal-area increment indices.

Precise dating of *Dryas octopetala* L.: Possible or impossible?

Giulia Fontana (1)*, Markus Egli (2) and Holger Gärtner (1)

(1) Swiss Federal Research Institute WSL, Switzerland, (2) Department of Geography University of Zurich, Switzerland.
Correspondence: giulia.fontana@wsl.ch

Debris flows are natural hazards highly affecting large high mountain regions. In the alps they represent a danger not only for infrastructure but also for human life. It is therefore important to study historical and recent events to learn more about the processes occuring before, during and after such an event. In the frame of a master thesis the dwarf shrub Dryas octopetala L. (mountain avens) was first utilized to reconstruct the minimal age of debris flow events in the Marlt-Graben (Sulden, South Tyrol, Italy). During the analysis of 150 plants no correlation to the climate data of Sulden was found. To better understand the growth of this shrub and the environmental influences on the plant, a detailed and punctual study of one shrub was implemented. Six sections along the growth axis were dated using 1, 2, 8, 16 and 32 radii, chronologies were build and the correlation with climate data of two weather stations was attempted. The results of this detailed analysis showed that the correlation with precipitation as well as temperature data is random. Further the different cross-dating approaches reveal similar minimal ages, but different positioning of inserted missing rings (MR) and therefore different chronologies. The high number of partially missing rings (PMR) further influenced the challenging cross-dating process. Based on the current analysis, a precise dating of the annual rings of this small shrub does not seem to be applicable without further methodological testing.

Effects of threshold variations for the Earlywood/Latewood border on BI-based tree-ring parameters

Thomas Frank (1)*, Kurt Nicolussi (1)

(1) Institute of Geography, University of Innsbruck, Austria.
Correspondence: Thomas.Frank@student.uibk.ac.at

Tree-ring measurements based on the absorption of light in the blue spectrum (the Blue Intensity method) have been proven to be helpful tools for extracting climate information from trees. Compared to density measurements via x-ray densitometry, BI measurements feature reduced costs as well as lesser times for processing making it available for many tree-ring laboratories. Consequently, the past years have seen an increasing amount of publications based on BI data. In the tradition of x-ray densitometry studies, most of these papers focus on maximum BI. However, some image analysis programs necessary for the realisation of BI measurements produce several, i.e. the following seven parameters: Maximum BI (MXBI), minimum BI (MNBI), earlywood density (EWBI), earlywood width (EWW), latewood density (LWBI), latewood width (LWW) and total ring width (TRW). Additionally, one can calculate delta-BI (dBI) as introduced by Björklung et al. (2014) and the average density of the whole tree ring (TRBI) manually. Five of the above mentioned parameters (EWBI, EWW, LWBI, LWW, delta-BI) rely on earlywood or latewood information and thus have one thing in common: The values acquired depend on the definition of the earlywood/latewood border. Regarding BI measurements, that is done by setting a percental threshold of delimitation which defines which parts of a tree ring are considered earlywood and which ones latewood. The threshold impacts on all further processing steps because it influences the raw data heavily. This paper aims to analyse how different thresholds impact on correlation results of different tree-ring parameters with instrumental temperature data. The tree-ring samples utilized for this study are 30 cores of spruce (*Picea abies*) trees from a high-elevated site (ca. 1700 m asl) in the northern Alps. Results show that correlations of all threshold sensitive parameters are influenced by different delimitations with LWW`s and EWBI`s results showing most pronounced differences. Correlations for the same parameters can range from insignificant to pretty good, depending on what threshold was chosen. E.g., the smaller the LWW was chosen, the higher the LWW-temperature correlations are. Regarding delta-BI, best correlations with climate data were achieved with the lowest percentage tested, i.e. 30%, for the EW/LW delimitation.

Are only scanner-based tree-ring measurements reliable enough for tropical dendrochronology?

Aster Gebrekirstos (1)*, Mulugeta Mokria (1, 2), Abrham Abiyu (3), Achim Bräuning (2)

(1) World Agroforestry Centre (ICRAF), United Nations Avenue, P.O. Box 30677-00100, Nairobi, Kenya
(2) Institute of Geography, University of Erlangen-Nuremberg, Wetterkreuz 15, 91058 Erlangen, Germany, (3) Amhara Agricultural Research Institute (ARARI), Amhara region, Ethiopia
Correspondence: A.Gebrekirstos@CGIAR.ORG

Tropical dendrochronology is a rapidly advanicng field of tree-ring research. Howerer, there are still challenges concerning the methodological approaches useful to unequivocally delineate tree-ring boundaries in different species and sites. There are some claims that scanner-based tree-ring analyses are preferable over traditional microscopic inspection because digital images can be analysed with software-based semi-automatic techniques and can easily be shared between laboratories. We suggest, however, that a combination of traditional microscope-based wood anatomical analysis and scanner-based tree-ring analyses is more appropriate in tropical dendrochronology, since multiple tree-rings with sharp wood-anatomical appearance are often uncritically accepted by image-analysing approaches as annual rings. Based on regional studies in northern Ethiopia we provide evidence that scanner-based tree-ring analyses (e.g. on *Juniperus procera*) alone is not a reliable tool to confirm the annual nature of anatomically distinct tree-ring boundaries. Using a combination of traditional dendrochronology including radiocarbon dating, we show that under some local climatic conditions, two anatomical tree-rings per year are usually formed, hence the solely use of image analysis of scanned wood images may be strongly misleading in the construction of regional tree-ring chronologies.

Disentangling moisture origins in δ18O tree-ring time series from Perito Moreno Glacier/Argentina

Jussi Grießinger (1)*, Lukas Langhamer (2), Christoph Schneider (3), David Steger (3), Ana M. Srur (4), Philipp Hochreuther (1), Wolfgang Meier (1)

(1) Institute of Geography, Friedrich-Alexander-University of Erlangen-Nürnberg, Germany; (2) Department of Atmospheric and Cryospheric Sciences, University of Innsbruck, Austria; (3) Department of Geography, Humboldt Universität zu Berlin; (4) IANIGLA, Mendoza, Argentina.
Correspondence: jussi.griessinger@fau.de

Glacier mass balance on the eastern part of the Southern Patagonian ice sheet is predominantly influenced by precipitation variability. As the spatio-temporal availability of meteorological time-series extending back more than 50 years is scarce and humidity conditions vary largely in high mountain areas, there is a strong need for proxy data providing insight into the local and regional hydroclimatic history as well as the long-term climatic variability. The isotopic δ18O signal in tree-ring cellulose is strongly influenced by soil water, which is dependent on the amount and origin of meteoric (precipitation) water (source water δ18O). Within this study, we combine tree-ring δ18O analysis on southern beech (*Nothofagus pumilio*) with backward trajectory modelling to test the potential for reconstructing long-term atmospheric circulation patterns and their contribution to local precipitation changes. Trajectory modelling is accomplished through applying the Lagrangian integrated trajectory model LAGRANTO, driven by gridded reanalysis data (ERA-Interim). Individual trajectories are extracted from a vertical motion field based on horizontal wind components (u, v), temperature, pressure level, and surface pressure. Moisture sources were calculated and corrected in respect to rain out effects during the transport pathways to the target area. Within a first test, we focus on years with extraordinarily high/low δ18O values, which are expected to reflect the strongest changes in air mass origin. To ensure synoptical plausability, further analyses with regional predominant mean weather types were performed. This approach enables us to determine the mean annual airflow direction for the past two centuries, and accordingly the variability of historic moisture flows contributing to the glacier mass balance at Glaciar Perito Moreno.

A new electric device for sampling increment cores

Akira Kagawa (1)*, Takeshi Fujiwara (1)

(1) Wood Anatomy and Quality Laboratory, Forestry and Forest Products Research Institute, Japan
Correspondence: akagawa@ffpri.affrc.go.jp

Here we report a newly developed, portable device for automated sampling of tree-ring cores. The device employs a battery-powered electric wrench and the complete system to drive the boring operation weighs less than 10 kg. It is capable of sampling both 5-mm and 12-mm diameter cores of up to 80-cm length from the hardest hardwood. Compared to equipment used in previously published articles, this device demonstrates a superior torque-output/total-weight ratio. The device is also capable of facilitating the starting operation of a 12-mm increment borer.

Increment borer is a preferred way of sampling wood because it can take core samples without destroying the living tree. For measurement of tree age, ring widths, and density, the smaller 5mm cores are preferred. For analyses of stable isotopes, radioisotopes such as radiocarbon and 137Cs, a larger mass of wood is required and large diameter cores (12 mm) are preferably used. The objective of this study was to design a mechanical core-sampling system that is useful in the fieldworks.

Our automated tree-ring sampling device consists of five major components: power wrench, gearbox, reaction bar, winch socket and increment borer. A Makita electronic wrench drives the input of the gearbox to generate low-speed, high-torque output on the other side. The gearbox contains either one gear, or combination of the two gears connected coaxially, to shift the gear ratio from 1:24 to 1:118. We normally start increment borer by pushing the electric wrench and the reaction bar to insert the threaded part (the first 3cm of the tip). When pushing force from one operator is not sufficient to start the borer, we set the reaction bar in horizontal direction so that two or three persons can push the reaction bar to increase the pushing force of the borer bit against the bark. By simply reversing the rotation setting of the electric wrench, we can rotate the bit counter-clockwise and extract the bit out from the stem. When the bit became stuck by passing into a rotten wood part in the tree stem, the "Decorum extractor" worked effectively in combination with Smartborer. The biggest advantage of Smartborer is manifested in its reaction bar design. No other device developed so far has the reaction bar designed to absorb reaction force with the operator's leg and arm. Driving a 12 mm borer bit into a tree requires a large torque, especially when sampling a long core from hardest hardwood, such as oak and teak. When sampling cores for wood quality research, where the next tree to be sampled is close, we were able to increase the sample throughput by more than three times compared to the manual procedures.

Reference:
Kagawa, A. & Fujiwara, T. (2017) Smart increment borer: a portable device for automated sampling of tree-ring cores. Journal of Wood Science, https://doi.org/10.1007/s10086-017-1668-6

Further notice
To watch the videos that show our device in action, please search "increment borer three minutes" on Google. You will be able to experience our device at our demonstration booth, which should be opening during lunch break each day and the poster session. Near our booth, I will put up a signup sheet for an intensive course to learn how to use our device. If there is a strong interests among the participants, we will organize the intensive course during the mid-conference excursion.

A Harder, Better, Faster, Stronger device for sampling increment cores

Akira Kagawa (1)*, Takeshi Fujiwara (1)

(1) Wood Anatomy and Quality Laboratory, Forestry and Forest Products Research Institute, Japan
Correspondence: akagawa@ffpri.affrc.go.jp

In this poster presentation, we will compare the specifications of our new device for sampling increment cores with the previous ones. We will focus on (1) how hard the sample can be (e.g. dried oak), (2) how better the portability has become, (3) how much faster the sampling has become, and (4) how much stronger output our device can generate.

For these comparisons, we tested our device on large (DBH > 60cm) Himalayan cedar (*Cedrus deodara*) and Japanese oak (*Quercus crispula*) and small (DBH < 30cm) Japanese larch (*Larix kaempferi*) and Japanese cedar (*Cryptomeria japonica*).

According to these testing, improvements of our device can be summarised as follows

(1)   Able to core harder hardwood: the device could successfully extract core samples from the hardest hardwood, such as oak.

(2)   Better portability: Our device can be carried by hand or back-packed to more inaccessible woodland areas. In a typical field trip, we used two-three 6.0Ah-0.7kg batteries per day. In an exceptional case, where we had to sample 12-mm x ca. 600-mm cores from large trees growing close to each other, we had to use six batteries per day.

(3)   Faster sampling: When sampling cores for wood quality research, where the next tree to be sampled is close, we were able to increase the sample throughput by more than three times compared to the manual procedures.

(4)   Stronger torque: Despite its light weight (less than 10 kg), our device can generate sufficient torque to drive 12-mm borers. So far, no previous devices have achieved both high torque output (980 N*m) and lightweight (less than 10 kg) at the same time. At this torque, sampling 12-mm x 800-mm core from oak was possible.

Reference:
Kagawa, A. & Fujiwara, T. (2017) Smart increment borer: a portable device for automated sampling of tree-ring cores. Journal of Wood Science, https://doi.org/10.1007/s10086-017-1668-6

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Long slide holder for microscope stage

Marcin Klisz (1)*, Adam Miodek (2, 3), Paweł Kojs (3), Holger Gärtner (4)

(1) Department of Silviculture and Forest Tree Genetics, Forest Research Institute, Poland (2) Department of Biosystematics, University of Opole, Poland (3) Polish Academy of Sciences Botanical Garden – Centre for Biological Diversity Conservation in Powsin, Po land (4) Swiss Federal Research Institute WSL, Switzerland.
Correspondence: m.klisz@ibles.waw.pl

Dynamic development of automatic techniques dedicated for time-series tracheid-lumen formation allowed to use Quantitative wood anatomy (QWA) in dendroecological studies on a larger scale. The key stage preceding anatomical measurement of cross-sections is the their digitization with a light microscope coupled to a digital camera. When digitazing long slides, problems with stabilizing and positioning them apperas. To solve this problem light microscopes equipped with holders for standard slides should be replaced by one equiped with dedicated, long slide holder. As a result of cooperation with a Tech-Form company two high precision adapters were created for stabilizing long slides (400 mm) on the microscope stage during the digitization process. The construction of the holders comprises a plastic and aluminum profiles connected by hexagon bolts. Both adapters allow to adjust their construction to different dimensions of long slide, making them more universal. While both holders allowing stabilization of long slides whereas only an advanced version gives the opportunity to mechanically shift them with dedicated micro-screw. Future development of this project requires interaction with potential end-users of the holders, therefore we strongly encourage dear conference participants to visit the poster session and to look at both prototypes.

A comparison of landslide dating results from compression wood and ring eccentricity among Norway spruce – analysis of landslide hazard

Katarzyna Łuszczyńska (1)*, Ireneusz Malik (1), Małgorzata Wistuba (1)

(1) Department of Reconstructing Environmental Change, Faculty of Earth Sciences, University of Silesia, Poland.
Correspondence: katarzyna_luszczynska@o2.pl

Dendrochronology allows analysing activity of landslides in the past, during the last decades and even centuries. Each tree growing on a landslide is a separate sensor of ground movement which enables the analysis of the temporal and spatial variability of mass movements. Tree stems are tilted and bent by landsliding. Normal radial growth of wood is disturbed: tree-ring eccentricity and reaction wood are developed, features of wood anatomy diagnostic for active landslides. We have analysed appearance of eccentricity and reaction (compression wood among Norway spruces growing in a mountain area where landsliding is common. We applied dendrochronological methods and GIS analysis to reconstruct spatial variability of landslide activity and related hazards in the study area. The aim of the study was to compare the results of landslide hazard mapping conducted with the use of tree-ring eccentricity and with the use of compression wood.

46 sampling points have been selected in the Sucha Mt massif (3.75 km², max 1040 m a.s.l., southern Poland, Western Carpathians). In each point we have sampled 1-3 Norway spruces. Two cores were sampled from each tree: one from the upslope and the other from the downslope side of a stem. Samples were a subject of standard dendrochronological processing and tree-ring widths were measured (0.01 mm accuracy). Based on ring widths measured for each tree percentage eccentricity index was calculated to date landslide events (method after Wistuba et al., 2013). At the same time, the occurrence of compression wood was analysed based on visual quantitative assessment (thicker and more rounded cell walls, smaller cell lumens and presence of intracellular spaces, criteria after Yumoto et al., 1983, but without gradation of compression wood). Obtained results of dendrochronological dating allowed us to determine the mean frequency of landsliding at each sampling point (separately for eccentricity and for compression wood). Using a GIS-based approach, landslide frequency values were interpolated to two landslide activity maps: one based on eccentricity and another based on compression wood. Conducted studies have shown that dendrochronological analysis of growth disturbances (tree-ring eccentricity and compression wood) in coniferous trees is a promising approach for determining landslide hazards in whole vast mountain massifs.

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Tree rings as a source of data on flood occurrence and water levels in small ungauged catchments (Sudeten Mts., Poland)

Ireneusz Malik (1)*, Małgorzata Wistuba (1), Katarzyna Łuszczyńska (1), Damian Absalon (1)

(1) Faculty of Earth Sciences, University of Silesia in Katowice, Poland
Correspondence: irekgeo@wp.pl

In vast, monitored catchments of large rivers development of floods can be analysed and forecasted based on data from numerous gauging stations. However, flood hazard also occurs an poses threat to people and settlements in small ungauged catchments, in upper parts of larger basins. In such catchments, besides lack of monitoring data, historical records are often scarce. Thus the only source of data are palaeogeographic reconstructions and among them dendrochronology seems to be the most promising approach. Studies based on wood anatomy of roots can provide data on flood occurrence with annual or even seasonal accuracy.

During floods, due to lateral bank erosion, roots of trees are often exposed from under soil cover and/or injured by transported debris. Change of growth conditions after exposure (in particular: increased daily and annual temperature ranges) results in the change of wood anatomy: roots of coniferous trees start produce smaller cells (decrease of lumen in earlywood to 50%). Sudden appearance of late wood in tree rings following the exposure can also be observed. Root injury can be dated based on scars, callus tissue, resin ducts and concentrations.

The goal of our study was to date flood occurrence in 2 small, ungauged mountain catchments based on tree roots exposed in stream banks during flood events. In catchments of Łomnica and Łomniczka (Karkonosze Mts., Western Sudetes, Poland) we sampled roots of Norway spruces (*Picea abies* Karst.) exposed in stream banks, at diverse elevations above normal water level. Root samples were sanded to expose wood structure. Their cross sections were analysed in reflected lights, under a stereomicroscope in search for anatomy features diagnostic for root exposure and/or wounding. If necessary thin sections were also prepared to be analysed under optical transmission microscope. In all samples we dated flood events by counting annual rings developed after root exposure and wounding. Besides having dated major flood events which covered large areas, including valleys of main rivers (e.g. 1997, 1998) we were able to detect events of local character and smaller magnitude (e.g. 1970, 1978, 1986, 1991). For each stream and each single flood event we analysed elevation of roots exposed and/or injured in relation to normal water level and local topography (in particular: channel and valley cross-section at a sampling site). Through combining results of dendrochronological study with hydrological and meteorological data from the nearest gauging stations we estimated water levels of streams under study during past flood events.

Multidimensional tree-ring models: on-line interactive parameterization

Pavel Peresunko (1)*, Artem Sazonov (2), Sergey Videnin (3), Ivan Tychkov (4), Viktor Ilin (4), Vladimir Shishov (4)

(1) Computer Science Department, Siberian Federal University, Russia, (2) Artificial Intelligence Systems Department , Siberian Federal University, Russia, (3) Information Systems Department, Siberian Federal University, Russia, (4) Mathematical Methods and IT Department, Siberian Federal University, Russia

Correspondence: pperesunko@sfu-kras.ru

There are a number of process-based models simulating tree-ring growth. In most cases to run the models a number of model's parameters should be reasonably estimated taking into account environmental conditions for growing trees. The process of parameter's estimation is identified here as a parameterization of multidimensional model. As an example of such parametrization new VS-oscilloscope on-line is developed as a parametrization tool of Vaganov-Shashkin process-based model (VS-model). The VS-model explains how climate affects on tree-ring formation as a function of daily temperature, precipitation, solar irradiation and environmental variables.

Previous desktop version VS-oscilloscope has some difficulties to use, i.e. 1) Potential user needs to download and install corresponded software taking into account computer OS; 2) Potential user needs to keep a track of new versions of the application; 3) Potential user needs to use third-party applications (i.e. graphical editor) to present VS-model results.

The VS-oscilloscope on-line is developed to solve those problems based on R-code and JavaScript technology. The developed web-application allows researcher to use the last version of the VS-model without installation and using other third-party applications.

To test the new on-line application dendrochronological data of 20 sites and daily climatic observation of 12 stations located in different environmental conditions in Russia (Central and Eastern parts of Siberia) were used. Results of the on-line simulations were compared to the simulated results of the desktop version of VS-oscilloscope as. Mean absolute error between simulated growth curves was less than 0.001 and differences between the simulated data was statistically insignificant (p-value >>0.05).

Different landslide activity recorded within silver fir (*Abies alba* Mill.) and pine (*Pinus sylvestris*) tree-rings – an example from Wiśnickie foothill

Dawid Piątek (1)*, Maciej Bryndza (1), Agata Gołąb (1), Joanna Wąs (1), Anna Zielonka (1),Dominika Wrońska-Wałach (1)

(1) Institute of Geography and Spatial Management, Jagiellonian University, Gronostajowa 7, 30-387 Kraków, Poland
Correspondence: dawidpt23@gmail.com

Recently landslide activity in terms of climate change is one of major concern. In last few decades the Polish Flysch Carpathians has been highly affected by mass movements. Therefore, investigation of landslides is of high relevance. Two landslides were sampled: permanently active with visible surface changes and theoretically more stable landform. Both landslides are located in the Wiśnickie foothills (the Polish Carpathians foothill) and differ in size and formed colluvium. The aim of this work was to recognize the tree-ring width changes recorded in silver firs (*Abies alba*) and pines (*Pinus sylvestris*) growing on landslides representing different activity. Dendrogeomorphological method involving eccentricity measurements and coefficients of differentiation (Cv) were applied. In total 18 silver firs and 18 pines were sampled. 90-year chronology (1925-2015) was obtained from silver firs and 87-year chronology (1928-2015) from pine trees. Two eccentricity thresholds were taken under consideration: i) lower - could indicate minimum activity of the landslide, ii) higher - could indicate stronger activity of landslide. During that time pines from stable landslide reached 115 times (in average 7 times/tree) eccentricity indicating minimum activity of landslide and 15 (in average 0,8 times/tree) value of Cv which indicate stronger activity of the landslide. Silver firs from active landslide reached eccentricity indicating minimum activity 160 (in average 9 times/trees) and stronger activity 39 (in average 2,1 times/tree). This results led us to the conclusion that the use of an excessively low eccentricity threshold may lead to an overestimation of the landslide activity and lower threshold indicate more creeping processes then activation of the slide surface.

Different climatic signal inferred by tree-rings and Maximum Late-wood Density for *Pinus cembra* in the Southern Carpathians

Catalin-Constantin Roibu (1)*, Andrei Mursa (1), Ionel POPA (2) and Mihai-Gabriel Cotos (1)

(1) Forest Biometrics Laboratory, Faculty of Forestry, "Stefan cel Mare" University of Suceava, (2)National institute for Forest Research "Marin Dracea".
Correspondence: catalinroibu@usm.ro

National Park of Retezat Mountain is located in the South-Western Romania. Here, *Pinus cembra* is highly spread, forming compact forests that reach the upper limit of it's distribution. The purpose of this study is to show if there are major differences in the climate response induced by the two proxy data sources.

The realization of a dendrochronological series, feasible for climatic reconstitution, required the extraction of core samples from living trees and discs from dead wood during 2012-2016. Samples were extracted and processed according to the standard dendrochronological methodology.

The maximum density series were obtained using WinDendro density version software, which determines the density on radiographic images scanned using an ITRAX multiscanner. Both dendrochronological series were detrended using the same method, a 300-year spline function.

Tree-climate analysis showed that the tree-ring widths (TRW) are very poorly influenced by the main climatic parameters, with a correlation coefficient, between growth index and summer temperatures (JJA), below $r=0.3$ ($p <0.05$). We can conclude that for the Southern Carpathians area the ring width receives limited information from the climate. Growth processes are influenced by several climatic factors (including rainfall). In the studied area there is a strong influence of the Mediterranean climate, which brings long dry periods during the summer.

Regarding maximum density series (MxD), it has been shown that lignification processes are strongly influenced by the temperatures of the second half of the vegetation season, with correlation coefficients exceeding 0.70 ($p <0.001$).

Temporal stability of the two tree-climate analysis highlighted in the case of TRW strong fluctuations, with a interesting change of response to climate during 1970-1990, when trees responded negatively to summer months temperatures. In the case of MxD series, the correlative link remains significant for the entire analysed period.

Spatial stability of the tree-climatic response, using MxD series showed a very strong influence not only on the Retezat National Park but on almost the entire country, obtaining very high correlation coefficients ($r=0.6-0.7$). It can be noted that the tree-climate relationship is spatially stable and representative of South-West Europe, covering also the Italian Alps area. In our country, the spatial correlation is stable across the West, Center, and South, decreasing towards Eastern part of Romania.

Individual based methods for the assessment of tree-ring datasets

Mario Trouillier (1)*, Marieke van der Maaten-Theunissen (1, 2), Martin Wilmking (1)

(1) Institute of Botany and Landscape Ecology, University Greifswald, Germany, (2) Chair of Forest Growth and Woody Biomass Production, TU Dresden, Germany.
Correspondence: trouillier@posteo.de

Averaging tree-ring measurements of multiple individual trees to build population chronologies is one of the fundamental techniques applied in dendrochronology. As in other disciplines of science, repeated measurements serve to filter out individual noise, particularly if the environment cannot be controlled. In addition, this procedure serves to avoid pseudoreplications. While various statistical measures have been developed to control for the quality of population chronologies (signal to noise ratio, expressed population signal, mean sensitivity, etc.), the cause and distribution of variance is only seldom investigated. Most studies look for one specific signal and disregard all other variance as noise. This is also why dendrochronologists often follow certain non-random sampling strategies by selecting marginal sites (e.g. tree lines) and only open-grown, tall and (or) dominant trees, to increase a certain signal and to reduce the "noise" which might originate from biotic interactions like competition.

But the quote by Edward W. Ng: "one man's noise is another man's signal" nicely illustrates that noise may contain hidden information. Here, we outline various approaches that apply dendrochronological methods to individual trees rather than mean population chronologies. We show that the correlation of individual tree growth with climatic drivers may vary a lot, that this variance can differ between climatic variables, and that differences can sometimes be attributed to variables like competition indices or height/dbh. Plotting the spatial distributions of climate sensitivity can identify site heterogeneities or environmental gradients. Often many climate and other variables are available for each month, which means that sometimes >100 correlations can be calculated for each tree. So many results can be tricky to illustrate. The t-SNE method (t-Distributed Stochastic Neighbor Embedding; originating from machine learning to plot and cluster multidimensional data) can be used to identify clusters or gradients of trees with similar climate sensitivities. The effect of meta data (age, size, competition index, etc.) on this clustering can then be assessed.

In general, we show how additional information can be obtained with individual based assessments. This approach can help dendroecologists to gain a deeper understanding of population dynamics, site heterogeneities and causes for different environmental sensitivities, while dendroclimatologists might extract a clearer signal after knowing and accounting for tree's different sensitivities.

Xylogenesis of *Picea abies* in treeline ecotone: results from six seasons and multiple sites in the Krkonoše Mts., Czech Republic

Jakub Kašpar (1, 2)*, Hana Kuželová (2), Václav Treml (2)*

(1) Department of Forest Ecology, Silva Tarouca Research Institute, Czech Republic, (2) Department of Physical Geography and Geoecology, Charles University, Czech Republic.
Correspondence: jakub.kaspar@vukoz.cz, treml@natur.cuni.cz

Wood formation represents a critical temperature-limited process of tree growth at the treeline. Here, we present an overview of the timing of wood phenology and growth rates of *Picea abies* from multiple sites and growing seasons of 2010-2015 in the Krkonoše Mts, Czech Republic. The main goal was to compare inter- and intra-site variability in basic parameters of wood phenology. The onset and ending of wood-formation phases (cell enlargement, cell-wall thickening, formation of mature cells), duration of xylogenesis, as well as timing of maximum cell-production rate were recorded. Our data set was represented by 14 site/years (six seasons with observations at two to four sites). We assumed that phenological characteristics showing high inter-site/year variability are influenced by environmental factors such as temperature or soil moisture, whereas the phenological characteristics with similar timing across sites and years are influenced by day length.

In average, the cell enlargement starts in the middle of May, and the cell wall thickening phase commences approximately two weeks later at the beginning of June. First mature cells usually occurred at the end of June. The last enlarging cells were observed in mid-August and the formation of the tree-ring was completed about three to four weeks later. The highest cell production was typical for a short interval around the summer solstice.

The intra-site/year variability in the studied phenological parameters was similar among all the variables characterizing phase onsets, endings and production-rate. Substantially higher intra-site variability was observed for phenological phase duration (duration of cell enlargement and cell wall thickening, duration of xylogenesis) because of the correlation between onsets and endings of phases (the earlier onset, the later ending). Small differences in onset dates thus result in greater differences in the duration of corresponding phases.

The highest inter-site/year variability was determined for durations of individual phases and for the onset of the cell enlargement phase. On the other hand, parameters such as ending of cell enlargement, onset of cell wall thickening, occurrence of first mature cells and the timing of maximum cell production rate showed low variability across sites and years.

In conclusion, durations of individual phases of xylogenesis are highly variable and probably also very sensitive to environmental conditions (both large-scale and local) and to competition status of the tree. The onset of xylogenesis is generally driven by large-scale environmental conditions (temperature) while the highest cell production rate is synchronized with the day length peak.

Xylem anatomical responses to climate variability in Himalayan birch trees at one of the world's highest forest limit

Sudip Pandey (1)*, Marco Carrer (1), Daniele Castagneri (1), Giai Petit (1)

(1)Università degli Studi di Padova, Dip. Territorio e Sistemi Agro-Forestali, viale dell'Università 16, 35020 Legnaro (PD), Italy
Correspondence: environ.sudip@gmail.com/sudip.pandey@studenti.unipd.it

The Himalayas is one of the most ecologically sensitive and fragile areas in the world. Climate of the region is dominated by the monsoon seasonality, with typical dry winters and abundant summer precipitations. Here, forest vegetation spreads up to the world's highest elevations, where cold temperatures and early spring droughts represent the main limiting factors for growth. In this study, we applied a dendro-anatomical approach to assess xylem trait chronologies and their association to local climate variability in the diffused broadleaved Betula utilis D Don close to the treeline (above 3900 m a.s.l.).

 We measured tree-ring width on increment cores from 73 trees. In addition, we cut thin sections of a subset of seven cores, and analyzed them with ROXAS for the assessment of ring-based parameters of vessels and fibres. We then built up the corresponding trait chronologies and analyzed them against the time series of monthly temperatures and precipitations. Mean ring width (MRW), mean vessel area (MCA_V) and ring-specific hydraulic conductivity (Kr) positively correlated with summer temperatures in the previous and current year. In addition, MCA_V was significantly associated to March precipitations. Instead, fibres showed a diffuse negative correlation only with temperatures during the previous and current season suggesting that fibres shrink when vessels enlarge.

 These results revealed that Himalayan birch is well adapted to the monsoon seasonality and is responding positively to atmospheric warming, thus suggesting the potential for this species to further expand in altitude under the forecasted climate change scenarios.

Keywords: Betula utilis; climate change; dendroanatomy; treeline; tree rings; xylem; vessels; fibres

Monitoring seasonal cambial activities of four dominant conifer tree species in subalpine zones of Deogyusan National Park in Korea and correlation of degree-days with their initiations

Jun-Hui Park (1), En-Bi Choi (2), Hong-Chul Park (3), Jeong-Wook Seo (1)*

(1) Department of Wood & Paper Science, College of Agriculture, Life, and Environment Science, Chungbuk National University, Republic of Korea (2) Department of Cultural Heritage Science, Chungbuk National University, Republic of Korea (3) Korea National Park Research Institute, Korea National Park Service, Republic of Korea.
Correspondence: jwseo@chungbuk.ac.kr

Since the Industrial Revolution, the air temperature has been rapidly increased due to the greenhouses gases released from burning fossil fuels. According to meteorological data collected around the world over the last 100 years between 1880 and 2012, the average global temperature increased up to around 0.85°C and during the same period the temperature in Korea increased up to around 1.7°C. It means that the warming speed in Korea was two times faster than the average around the world. It is very necessary therefore for us to understand the influences of the warming to the ecosystem to protect and/or preserve it.

Korean fir (*Abies koreana*) is one of the woody plants distributed only in Korea. Its natural distribution is very restricted to subalpine zones in Korea. In the reason, the International Union for Conservation of Nature (IUCN) assessed Korean fir as endangered species (EN) in 2011. And more IUCN reported, if the natural distribution area is decreased to less than 10km², it is expected to become a critically endangered species (CR). Except this species, most tree species in subalpine zones are growing under harsh growing condition. Therefore, it is important to understand an influence of warming to the tree growth therein. This study aimed to monitor the seasonal cambial activities of principle conifer tree species (*Abies koreana, Pinus koraiensis, Picea jezoensis, Taxus Cuspidata*) in subalpine zone of Deogyusan National Park and to investigate the associations of heat sums with the initiation of cambial activities.

Before start samples we select five trees per each tree species. Sampling was fulfilled weekly between April and September in 2017 in using Trephor (⌀1.9 mm) at breast height from the ground. To avoid wound effect by sampling, the sampling points are at least 2.5 cm apart from each other. All samples were embedded in PEG2000 (polyethylene glycol) and then cut their cross sections of 7-12 μmin thickness using a sliding microtome to investigate the cambial zone under a light microscope. To calculate heat sums (so called 'degree-days') we employed the model developed by Sarvas (1972).

As the results, it was verified that the durations of cambial activities of AK, PK, PJ, and TC were 135.8 (±8), 117.6 (±20.0), 98 (±13.1), 107.8 (±6.3), respectively. And the degree-days induced the initiation of cambial activity of AK and PK were 78.4 (±14.3), 105.8 (±25.9), respectively, whereas PJ and TC were the same as 127.6 (±34.7). The monitoring data and results could be used as a fundamental data to establish a strategy to protect and/or preserve principle conifer tree species in subalpine zones in Korean.

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How simulated growth rates detect the climate effects in the tree-ring structure of conifers

Margarita Popkova (1)*, Vladimir Shishov (1), Patrick Fonti (2), Sergio Rossi (3), Marina Fonti (1), Elena Babushkina (4), Eugene Vaganov (1)

(1) Siberian Federal University, Russia, (2) WSL Swiss Federal Research Institute, Switzerland, (3) Département des Sciences Fondamentales, Université du Québec à Chicoutimi, Canada, (4) Khakassian Technical Institute, Siberian Federal University, Russia
Correspondence: popkova.marg@gmail.com

A better understanding of the link between environment, wood formation and structure is necessary to assess the ability of tree species to acclimate and endure a changing environment requires tools allowing projecting growth under future climatic scenarios. Novel methods over the last decades have extended interests into the processes of tree-ring formation towards higher intra-annual resolution and deeper mechanistic understanding of environmental impact. Process-based models of tree-ring growth provide this additional perspective for simulating intra-annual growth. The Vaganov-Shashkin model (VS-model) is an environmental driven tree-ring growth model that has proven to provide reliable estimates under strong limited conditions.

This study demonstrated that the VS-model successfully generated realistic tracheidograms of tracheid cell diameter for *Pinus sylvestris* trees. Based on the simulated integral growth rates a new block of the Vaganov-Shashkin model has been developed for that purpose and applied to derive the linear dependency between the average cell growth rate and the tracheid size. The strong association between the growth rate of the dividing cambial cell and the tracheid size was used to predict wood structure from daily climatic condition. This relation is then inversely applied to estimate tracheid size (TD) from the growth rate obtained from the model. The VS-model also provides convincing intra-annual output typical of summer drought-limited environments of South Siberia characterized by a bi-modal growth and a radial ring pattern with the occurrence of numerous IADF. The growth rates modelled for the 2013 growing season were synchronous in timing and proportion with the number of cambial and enlarging cells observed on micro-cores collected in the field (r = 0.93 and 0.84 for cambial and enlarging, respectively).

Ten years of wood and phloem formation studies in *Fagus sylvatica* and *Picea abies* in Slovenia

Peter Prislan (1), Jožica Gričar (1), Angela Balzano (2), Maks Merela (2), Luka Krže (2), Martin De Luis (3), Katarina Čufar (2)*

(1) Slovenian Forestry Institute, Slovenia / (2) Biotechnical Faculty, Department of Wood Science and Technology, University of Ljubljana, Slovenia / (3) Departamento de Geografía, Universidad de Zaragoza, Spain
Correspondence: katarina.cufar@bf.uni-lj.si

Temporal dynamics of cambial activity and xylem as well as phloem formation have been monitored over a decade in European beech (*Fagus sylvatica* L.) and Norway spruce (*Picea abies* (L.) Karst.) at two sites in Slovenia; a lowland temperate Panška reka near Ljubljana (400 m a.s.l.) and an Alpine site on Menina planina (1200 m a.s.l.).

Samples (micro cores) for analyses have been collected from mature tree stems with a Trephor tool at weekly intervals during the growing seasons. Permanent slides of cross-sections were prepared for light microscopy. The numbers of cells in the cambium, as well as current xylem and phloem increments were determined. Phenological phases of xylem and phloem formation were recorded as well; e.g. onset of cell enlargement or post-cambial growth (bE), onset of secondary wall formation and lignification (bW), first mature cells observed (bM), cessation of cell enlargement (cE), cessation of lignification (cW) and transition from early to late phloem (tEP).

Comparison of data between sites and years helped us to evaluate weather-growth relationships. The results suggest that phloem formation seems to be less subjected to fluctuations in environmental conditions than the xylem formation. The dynamics and phenology of xylem formation process are affected by local weather conditions, predominantly temperature. However, average weather conditions before occurrence of observed phenological phases significantly differed between sites indicating high intra-specific plasticity of beech and spruce (Prislan et al. 2013a; Gričar et al. 2014). Results also show that precipitation is not a limiting factor for xylem growth in beech and Norway spruce at the two temperate sites with relatively abundant and uniformly distributed precipitation (Gričar et al. 2015; Prislan et al. 2018).

Detailed cellular and ultrastructural observations with transmission electron microscopy (TEM) and UV-microspectrophotometry (UMSP) allowed us to reconstruct the dynamics of cell wall deposition and lignification in wood and bark. Using proper tissue fixation and TEM enabled us to follow seasonal changes in cambium cell ultrastructure. We observed that the changes in cell organelle size, distribution, number and shape took place one month before occurrence of newly formed xylem cells. These results indicated that classical methods of wood formation studies based on fixation with FAA and observations under the light microscope allow us to follow cambial cell production rather than real cambial activity (Prislan et al. 2013b).

Long term monitoring of wood and phloem formation is experimentally demanding and time consuming. Nevertheless, the obtained data provide an enormous potential for studying tree behaviour including tree productivity and survival in changing climate.

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Xylogenesis of trees (*Picea abies*) and shrubs (*Pinus mugo*) in treeline ecotone

Václav Treml (1)*, Tomáš Hejda (1)

(1) Department of Physical Geography and Geoecology, Faculty of Science, Charles University, Czech Republic.
Correspondence: treml@natur.cuni.cz

Shrubs are better adapted to cold environments than trees and can thus thrive at lower growing season isotherms than trees. However, it remains uncertain which mechanisms or their combinations shrubs employ to complete growth at substantially colder temperatures than trees. Among possible candidates one can consider the following: (1) low stature of shrubs is reflected in their better thermal environment compared to tall trees; (2) relatively narrow tree-rings of shrubs allow earlier completion of xylogenesis in comparison with xylogenesis of trees with wider tree-rings; (3) there might be differences in temperature thresholds of wood formation between shrubs and trees. Wood formation of six *Picea abies* individuals and six *Pinus mugo* ramets (each coming from different individual) growing on the identical site was studied during 2016 and 2017 in treeline ecotone in the Krkonoše Mts., Czech Republic. To characterize differences in temperature conditions we measured air temperature near tree (shrub) tops, temperature of stem parts where wood phenology was analysed and soil temperature in root zone.

Our preliminary results show that the first assumption related to differences in temperature is not supported by measured data. Air temperature near apical parts was similar for shrubs and trees with an exception of winter and early spring, when shrubs were covered by snow. Both stem temperatures and soil temperatures of trees were slightly higher than the same temperature metrics of *Pinus mugo* shrubs. Cell division and enlargement started slightly earlier for trees, whereas cell maturation was completed earlier for shrubs. The poster further presents the progress of xylogenesis of *Picea abies* and *Pinus mugo* and dicusses validity of our assumptions.

Phenology of the secondary growth of stone pine (*Pinus pinea* L.) under contrasting climatic conditions in Spain

Javier Vázquez-Piqué (1)*, Rafael Calama (2), Marta Pardos (2), Almudena Vázquez-Campillo (1), Luca Mion (1), Guillermo Madrigal (2), Javier Gordo (3), Reyes Alejano (1)

(1) Department of Agroforestry Sciences, University of Huelva, Spain. (2) CIFOR-INIA Research Institute, Spain. (3) Servicio Territorial de Medio Ambiente de Valladolid, Junta de Castilla y León, Spain
Correspondence: jpique@uhu.es

The detailed knowledge of the secondary growth of forest species and their phenology has a wide application both to forest management and to the prediction of strategies for adapting species to global change. In this work, the secondary growth and phenology of stone pine in two contrasting populations in Spain (Cartaya -Huelva, SW Spain- and Nava del Rey -Valladolid, central Spain-) are analysed in a three years period. The analysis is carried out at three scales: monthly by measuring band dendrometers in 50 individuals per plot; daily, by electronic dendrometers in 3 individuals per plot and at histological scale, by extracting microcores biweekly in six trees per plot. The species has a maximum of spring growth, summer contraction and autumnal growth. The cessation of cambial activity in winter is not evident in the SW of Spain. The climatic variables most influential in the growth are the average and minimum relative humidity and precipitation, which correlate positively with growth in all the phenological phases, the radiation, with negative correlation in all the phenological phases, and the minimum and average temperature of air and soil temperature, which correlate positively with growth in the autumn expansion phase.

ROXAS – Quantifying xylem anatomy in angiosperms and conifers

Georg von Arx (1)*, Marco Carrer (2), Angela Prendin (2,3)

(1) Swiss Federal Institute for Forest, Snow and Landscape Research WSL, Switzerland, (2) TESAF Department, University of Padova, Italy, (3) Department of Bioscience, University of Aarhus, Denmark
Correspondence: georg.vonarx@wsl.ch

Tree-ring anatomical features such as conduit size, density and cell wall thickness are nowadays recognized as valuable archives of past growth conditions. Compared to ring width that integrates conditions over an entire growing season, dendroanatomy, i.e. the analysis of anatomical features in time series of decades to centuries, can provide information about past growth conditions in an intra-annual resolution. Despite these promising perspectives, the wide use of dendroanatomy has been mostly limited by technical constraints, because measuring anatomical features is often very cumbersome and time consuming. This is why time series of wood anatomical features have been either short or based on a small subset of the sample such as a few radial files.

In this poster we present ROXAS: a specialized image-analysis tool that has been developed to overcome many of the previous constraints. ROXAS can be used for angiosperms and conifers, for (circular) branch and root samples as well as (linear) tree cores. It is designed to process large images of large samples and produce output for all conduits, even in conifers (up to 1,000,000 tracheids per sample). After automatic recognition of conduits and (with some limitations) ring borders, the user can efficiently improve the automatic output directly in the image. Besides the ring width amd conduit lumen area, data output includes many additional parameters such as size distribution of conduits, mean hydraulic conduit diameter (Dh), conduit position within the ring, theoretical hydraulic conductivity, conduit grouping (angiosperms), cell-wall thickness of each conduit (conifers) and Mork's index. ROXAS can be obtained at www.wsl.ch/roxas for free within the scope of the user policy, but depends on the commercial software Image-Pro Plus.

Identification of strong volcano eruptions by light rings in larch in the northern Siberia

Marina Gurskaya (1)*, Ilka Beil (2), Martin Wilmking (2)

(1) Institute of Plant and Animal Ecology UD RAS, Ekateriburg, Russia, (2) Institute of Botany and Landscape Ecology, University of Greifswald, Greifswald, Germany.
Correspondence: e-mail: mgurskaya@yandex.ru

One potential driver of a temperature drop during the summer months is a large volcanic eruption (Robok, 2000). After the eruption, the temperature of the vegetation period can decrease by 1.5-1.8°C in large areas (Sigl, 2015). The intensity of eruptions is estimated by the VEI (volcanic explosivity index), which integrate emission of volcanic debris, dusts, gazes, and aerosols amount. It varies from 1 to 8, with 8 being the most severe (Newhall, Self, 1982).

A cold and/or short vegetation period is the main driver of the formation of light rings in conifers in the North of Siberia (Gurskaya et al., 2012), usually as a result of reduced carbon deposition processes in tracheids walls.

The aim of this work is to compare a spatio-temporal distribution of light rings in *Larix* in northern Siberia with large volcano eruptions according to their VEI and geographical position. Site and spatial chronologies of light rings based on 18 sites distanced in 300-350 km from each other over north of Siberia were built as a percentage of light ring number from total number of ring. Common length of the developed chronologies is 1600-1992, and in Eastern Siberia is 1550-1995.

The years with mass formation of light rings (more than 50% of the total number of rings) and over large areas (more than 50% of sites) have been identified. Most of these years with light rings in larch, namely 1580, 1601, 1885, 1992, followed major volcanic eruptions with a VEI ≥6. However, the strongest eruption with VEI = 7 (Tambora, Apr 1815), was manifested only by a moderate number of light rings over Siberia during the period 1816-1818, with the maximum light ring formation 1817. However, the eruption of Santa Maria, Oct 1902 had little effect on the formation of light rings in the following 1-3 years, and the eruption of Novarupta, Jun 1912 led to the formation of light rings only in trees in Western Siberia, but not over whole Siberia. So the volcano – light ring connection can be weak at times. Also, years with a mass formation of light rings over a large territory without previous eruptions: 1731-1732, 1735, 1772-1773, 1809 have been identified.

Spatially, the signature of volcanoes with eruptions VEI = 6, leading to a mass formation of light rings in larch all over northern Siberia, were localized within 20° N and 20° S. Despite their high VEI, volcanoes located at high latitudes, have less influence on the formation of light rings. The impact of volcanoes located within 20° N and 20° S is related to the gradual transfer of air masses from the tropical belt to polar area (from Hadley cell to Polar cell). The most of unregistered by light rings eruptions with VEI=5 belong to volcanoes located at the western Pacific coast: Kamchatka and Japan. Volcanoes located in other parts of the planet (Indonesia, America, and Iceland) had eruptions recorded by light rings, but their effect was negligible. Thus, the mass formation of light rings over a large territory in northern Siberia is a very complex process: It depends not only on the VEI value, but also on the geographic location of volcanoes and can also be the result of unknown large volcanic eruption or no volcanic activity.

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Growth responses to drought across Europe: first analysis of the European Beech Tree Ring Network

Andrew Hacket-Pain (1)*, Christian Zang (2), Claudia Baittinger (3), Niels Bonde (3), Franco Biondi (4), Allan Buras (2,5), Liam Cavin (6), Hugues Claessens (7), Christoph Dittmar (8), Isabel Dorado Liñán (9), Igor Drobyshev (10), Balazs Garamszegi (11), Michael Grabner (12), Claudia Hartl (13), Weiwei Huang (14), Jon Kehlet Hansen (14), Alistair S. Jump (6), Alexander Land (15), Nicolas Latte (7), François Lebourgeois (16), Tom Levanic (17), Juergen Kreyling (18), Martin de Luis (19), Luis Alberto Longares (19), Ernst van der Maaten (18), Marieke van der Maaten-Theunissen (18), Edurne Martinez del Castillo (19), Annette Menzel (2), Lena Muffler (18), Ionel Popa (20), Catalin-Constantin Roibu (21), Tobias Scharnweber (18), Willy Tegel (22), Robert Weigel (18), Martin Wilmking (18)

(1) Geography and Planning, University of Liverpool, UK (2) TUM School of Life Sciences, Technical University of Munich, Germany (3) Environmental Archaeology and Materials Science, The National Museum of Denmark, Denmark (4) Department of Natural Resources and Environmental Science, University of Nevada, USA (5) Forest Ecology and Forest Management, Wageningen University, Netherlands (6) Biological and Environmental Sciences, University of Stirling, UK (7) BIOSE Department, Gembloux Agro-Bio Tech-Liège University, Belgium (8) c/o CZ, TUM School of Life Sciences, Technical University of Munich, Germany (9) Forest Research Centre, INIA-CIFOR, Spain (10) Forest Research Institute & Southern Swedish Forest Research Centre (SLU), Sweden (11) Forest Research Institute, National Agricultural Research and Innovation Centre, Hungary (12) Institute of Wood Science and Technology, University of Natural Resources and Life Science, Austria (13) Department of Geography, Johannes Gutenberg-University Mainz, Germany (14) Department of Geosciences and Natural Resource Management, University of Copenhagen, Denmark (15) Institute of Botany, Hohenheim University, Germany (16) Agronomy, Forestry, Water and Environmental Science and Technology, AgroParisTech, France (17) Department of Forest Yield and Silviculture Slovenian Forestry Institute Ljubljana Slovenia (18) Institute of Botany and Landscape Ecology, Greifswald University, Germany (19) Department of Geography and Regional Planning, University of Zaragoza, Spain (20) National Research and Development Institute in Forestry, Romania (21) Forest Biometrics Laboratorory, Faculty of Forestry, "Stefan cel Mare" University of Suceava, Romania (22) Forest Growth and Dendroecology, University of Freiburg, Germany

Correspondence: andrew.hacket-pain@liverpool.ac.uk

A growing number of studies have used publically available tree ring datasets, such as the International Tree Ring Databank (Grissino-Mayer and Fritts, 1997), to address ecological questions. These databases include chronologies from climatically stressed trees sampled for climatic reconstruction. Typically, these trees do not originate from closed-canopy forest conditions. Consequently, attempts to characterise regional variability of tree growth from tree ring data may be impeded, particularly analysis that combines tree ring datasets with model output at the landscape scale (e.g. Babst et al 2013). Here, we present a new tree ring network focused on European beech (*Fagus sylvatica* L.), and provide examples of applications to ecological questions. The network includes data from 418 sites across Europe, incorporating the full geographic and climatological distribution of the species. All data were sampled from closed-canopy stands considered to be representative of locally typical beech forests.

Drought years were associated with low growth across the species distribution, although some regions showed lower sensitivity. Growth-climate analysis revealed spatial variation in the main drivers of this drought effect across the species' geographic distribution. Low early summer precipitation limited growth in most regions, except in northern populations. Summer temperature was a key driver of growth in beech populations from lowland forests in eastern Europe. Additionally, the response of growth to drought was strongly dependent on preconditioning of growth by high temperatures or drought stress in the previous year. The importance of climatic preconditioning helps to explain observed spatial variation in growth response to extreme climate events, such as the 1976 drought in north-west Europe, and the 2003 summer heatwave in central Europe.

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Long-term resilience and growth responses to drought in old-growth, rear-edge Mediterranean pine forests

Andrea Hevia (1)*, Raúl Sánchez-Salguero (2), J. Julio Camarero (3), Javier Vázquez Piqué (1)*, Reyes Alejano (1)

(1) Universidad de Huelva, Spain, (2) Universidad Pablo de Olavide, Spain, (3) Instituto Pirenaico de Ecología (IPE-CSIC), Spain.
Correspondence: jpique@uhu.es / andrea.hevia@dcaf.uhu.es

In southern Europe, old-growth conifer forests are scarce and fragmented, and they are often restricted to cold and wet mountainous areas located near the southernmost species distribution limit (rear edge). Climate warming and increasing aridity may negatively impact those unique forests, particularly near the rear edge or in the most xeric sites (Sánchez-Salguero et al., 2017). A better understanding of growth responses to climate and drought could provide insight on the long-term vulnerability of those old-growth forests to ongoing temperature rise and aridification (Linares and Tiscar, 2010). Furthermore, we could expect that youngest trees are more resilient to the new climate conditions than old trees which were born and grew during cool-wet decades. Here, we investigate how tree age and climate trends drive growth resilience and recovery to droughts in three *Pinus nigra* subsp. *salzmanii* old-growth, rear-edge forests (Sierra de Cazorla, Sierra María, La Sagra) located in Andalusia (southern Spain). We sampled 60 trees on each site using dendrochronological methods and then we grouped trees in three age classes (young trees, age < 100 years; mature trees, 100 < age < 200 years; and old trees, age= 200-700 years old). Tree-ring width chronologies were built for each age class and site and then related to monthly climatic variables (temperatures and precipitation) and drought during the 20th century. We also quantified the variation between age groups and sites (Navarro-Cerrillo et al., 2014) in terms of long-term growth resilience to three severe droughts which occurred during the late 20th century (1994-1995, 1999, 2005, 2012). We found that drought is the main driver of growth of P. nigra forests, but differences between sites aridity and ages classes were also observed according to Camarero et al. (2013). The resilience in these old-growth forests depends on the drought severity during the growing season (spring-summer), whereas the post-drought recovery was linked to site precipitation and tree age. Old trees from dry sites were less resistant but also recovered lower than trees of similar age from wet sites. Mature and young trees responded more to drought severity than old trees. If droughts become more severe and frequent as predicted in the Mediterranean region, old and mature trees from stands in the driest regions will be increasingly more sensitive to intense dry spells.

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Changes in radial growth and xylem anatomical features of *Chukrasia tabularis* in response to extreme climatic events

Mahmuda Islam (1,2)*, Mizanur Rahman (1,2) Achim Bräuning (1)

(1) Institute of Geography, University of Erlangen-Nuremberg, Wetterkreuz 15, 91058 Erlangen, Germany, (2) Department of Forestry and Environmental Science, Shahjalal University of Science and Technology, Sylhet 3114, Bangladesh
Correspondence: mahmuda.islam@fau.de

Multiple sources of evidence suggest an increasing frequency of extreme climatic events during the past century. In Bangladesh, a South Asian country influenced by Asian monsoon climate, drought in 1999 and 2006 were the most severe drought among the ten drought events identified over the last four decades. We investigated the impact of these two drought events on radial growth and xylem anatomical features of diffuse porous *Chukrasia tabularis* tree in a moist tropical forest in Bangladesh. We developed standard chronologies of ring-width and Xylem anatomical features of Chukrasia tabularis and calculated how radial growth and anatomical characteristics changed during drought events based on the average of previous two years. Tree radial growth declined by 53% during 1999 and 48.7% during 2006 drought events. Among the anatomical features, number of vessel (NV) total vessel area (TVA) and Mean vessel area (MVA) decreased by 44%, 36% and 7% respectively. Vessel density (VD) increased by 12% during 1999 while during 2006 it only marginally increased. A decreasing vessel area and increasing vessel density however indicate xylem hydraulic adaptation of *C. tabularis* to avoid hydraulic failure during the extreme events. Our analysis suggest that tree growth and xylem anatomical features of *C. tabularis* are highly sensitive to extreme drought events in Bangladesh.

Is climate a primary and stable factor controlling tree growth in a mixed forest? An example from the Upper Silesia region, Poland

Karolina Janecka (1)*, Ryszard J. Kaczka (2), Tobias Scharnweber (1), Barbara Spyt (2), Martin Wilmking (1)

(1) University of Greifswald, Institute of Botany and Landscape Ecology, Germany, (2) University of Silesia, Faculty of Earth Sciences, Poland
Correspondence: karolinaejanecka@gmail.com

Upper Silesia (south Poland) is a region where human impact has significantly influenced forest structure and conditions of tree growth. In this study we examine the influence of climate on the radial growth of trees and draw comparisons to other environmental factors including pollution.

Fifty individuals from three coniferous (silver fir, Scots pine and Norway spruce) and two deciduous tree species (European beech and European oak) were sampled using an increment borer. Tree-ring width chronologies of each species were constructed and three types of growth changes were identified: negative and positive pointer years, and growth declines (>3 years). The climate response was characterized for single- and multiple-monthly climate variables over the 1917-2015 AD period using gridded temperature and precipitation climate data. The stationary and running correlations (31-year moving window) were calculated.

We detected a total of 28 negative pointer years and 18 positive pointer years among the three coniferous species. The spruce chronology recorded the greatest number of pointer years and some negative pointer years occurred synchronously among coniferous species (e.g. 1929, 1930, 1964, 1984). Four growth declines were identified in the fir chronology, while a single decline was found in the spruce and pine datasets. In the beech chronology we identified seven negative and one positive pointer year and a singular growth decline. Only two negative pointer years were detected in oak. Among all species, many negative pointer years coincided with unfavourable weather conditions (e.g., severe winters, droughts) and some growth declines for coniferous species coincided with high industrial emissions in this region.

Investigation of climate-growth relationships revealed a strong signal in almost all species except oak. For the common period of 1917-2015 AD, stationary correlations revealed that the radial growth of fir was positively related to January-July precipitation (r=0.46) and February-April temperature (r=0.40). March-August temperature was positively related to radial pine growth (r=0.53), however, no relationship to precipitation was discerned. Spruce ring-width variability was most strongly correlated to previous July precipitation (r=0.48) and weakly related to February-September temperature of current year (r=0.28). The deciduous species correlated only with precipitation variables, where beech was related to May-July precipitation (r=0.47) and oak with previous year March precipitation (r=0.27).

Interestingly, moving correlations revealed highly dynamic climatic signals over the study interval, which may indicate a combined effect of recent climate change and industrial pollution emission since ~1950. For example, fir and spruce chronologies showed alternate temperature and precipitation signals, whereas pine growth was significantly related to temperature over a longer interval (24 years) punctuated by short episodes of growth related to precipitation, representing a finding that was not detected using stationary correlations. Both fir and pine radial growth showed a significant precipitation signal in the 1970s–80s, an interval of high pollution and broadly dry conditions. Beech growth was primarily controlled by precipitation with a short interval of temperature sensitivity.

At our study site, the radial growth of deciduous species is mainly limited by precipitation, and a combination of temperature and precipitation influences the growth of conifer species. Although the examined growth patterns are complex, climate remains an important factor explaining the variability in tree growth in southern Poland.

Higher climatic sensitivity of Scots pine (*Pinus sylvestris* L.) subjected to tourist pressure on a hiking trail in Brodnica Lakeland, NE Poland

Paweł Matulewski (1)*, Agata Buchwał (1), Mirosław Makohonienko (1)

(1) Adam Mickiewicz University in Poznań, Institute of Geoecology and Geoinformation, Poland
Correspondence: matul@amu.edu.pl

Climatic condtions are one of the main factors affecting the variation in annual tree-ring growth. However other exogenious processes, including geomorphic activity, can substantially modified the condition of trees growth. Up do day little is know on how human activity such as trampling influence tree growth along the hiking trails.

We analyzed the annual growth variation in 42 Scots pines (*Pinus sylvestris* L.) subjected to tourism pressure on heavily used hiking trail in the Brodnica Lakeland located in North-Eastern Poland (PRES site) and compared them with 45 trees growing under natural conditions (REF site). Specifically, we compared climate sensitivity of trees growing under trampling preassure with the reference site using climatic variables such as mean, minimum and maximum monthly temperature and monthly precipitation. Aditionally positive and negative pointer years for both sites have been designated using the Becker algorithm and compared.

Results revealed that Scot pines annual growth from both sites was highly correlated with winter (January, February) and spring (March) temperature. Aditionally significant correlation with February precipitation a was recognized for both sites. However, both response function and pointer years analyses revealed higher climatic sensitivity of trees subjected to trampling. Thermal and pluvial conditions play an important role for Scots pine growth from trampling site (PRES) especially in June and July when the cambium is the most active. At the same time, these are the months in which tourism activity is the most intense. Tree growth on a hiking trail wass positively correlated with the higher precipitation and the lower maximum temperature in June and July. This might indicate that pines subjected to trampling were threatened by a potential moisture limitation that occurres within and around the hiking trail due to an increase in soil compaction. Additionally the study revealed greater growth reduction in pine trees subjected to trampling preasure along the hiking trail than in the reference site. The growth reduction was observed in the mid 1980s, right at a time when a strong increase of tourist traffic at the Brodnica Lakeland was noted.

The study demonstrates that human impact associated with trampling on hiking trails significantlly modifies the growth of Scots pine and should be taken into account in future dendroecological studies.

Xylem and phloem growth of *Fagus sylvatica* after severe ice storm damage

Maks Merela (1)*, Katarina Čufar (1), Primož Habjan (1)

(1) Biotechnical Faculty, Department of Wood Science and Technology, University of Ljubljana, Slovenia
Correspondence: maks.merela@bf.uni-lj.si

After the severe ice damage (glaze) in February 2014 in Slovenia, many damaged trees were left in the forests. Approximately 9.3 million m3 of trees were damaged in only four days. The most affected tree species was the European beech (*Fagus sylvatica*) (32% of the entire wood stock) that prospers on a great variety of sites in Slovenia. After such catastrophe forest service needs to know which damaged trees should be removed from the forest and if removal should take place immediately or it can be postponed for a certain period. The service needs to know which trees have high chances to survive but also to retain productivity and adequate wood quality. This complex topic raises numerous questions on processes in variously damaged trees in the years after the damage.

The objective of the present study was to investigate variously damaged beech trees on a representative lowland site in central Slovenia to relate the impact of crown damage on cambial productivity in the sense of wood and phloem formation in the growing season immediately after the extensive ice damage in 2014. For this purpose, we selected 14 beech trees with variously damaged crowns, which were ranked in four categories of crown damage: intact, control (Class K), up to 50% (Class A), between 50 and 75% (Class B), and more than 75% (Class C) as proposed by Smith and Shortle (Smith and Shortle, 2003, Shortle and Smith, 2014). Through the entire growing season we collected micro-cores and processed them for microscopy to analyse cambial zone, wood and phloem. We followed wood and phloem formation of the season immediately after the ice damage. The results were correlated with the degree of crown damage. The wood increment was compared with the one in the year before damage. The xylem rings formed in 2014 were narrower in all classes of damaged trees compared to those of undamaged trees. The reduction of tree-ring widths in moderately damaged trees was on average 20% in Class A, 88% in Class B and 95% in Class C, compared to that of undamaged trees (Class K). We noticed that the width of the phloem rings decreased with increasing crown damage. The differences in width of early phloem were small between the classes, whereas the width of the late phloem decreased with increasing damage.

Relationship between the width of the phloem and xylem rings (Ph/Xy ratio) was comparable in Classes K and A (1: 18.68 and 1: 16.79), but much lower in Classes B (1: 3.79) and C (1: 1.65). Classes K and A produced much more xylem than phloem, but the ratio changed in damaged beech (Classes B and C). This is in agreement with other studies (Gričar et al., 2014; Martinez del Castillo et al., 2016), which showed that trees growing under stress must produce adequate amount of phloem, as a crucial tissue for their survival.

Reduced wood production affects wood quality as well. Growth ring width is related to density which is correlated to mechanical properties. As beech wood is not resistant to various biological pests, we can expect wood deterioration and severe loss of wood quality in a short time after the exposure. The presented new knowledge contributes to a better prognosis of survival and productivity of trees and wood quality.

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Effects of Climate and Extreme Weather Events on Growth of European Beech (*Fagus sylvatica* L.) towards the Cold and Dry Distribution Margins

Lena Muffler (1)*, Marcin Klisz (2), Juergen Kreyling (1), Ernst van der Maaten (1, 3), Robert Weigel (1), Martin Wilmking (1), Marieke van der Maaten-Theunissen (1, 3)

(1) Institute of Botany and Landscape Ecology, University of Greifswald, Germany, (2) Department of Silviculture and Genetics of Forest Trees, Forest Research Institute, Poland, (3) Chair of Forest Growth and Woody Biomass Production, TU Dresden, Germany.
Correspondence: lena.muffler@uni-greifswald.de

Climate limits species distribution. At range margins, growth of individual trees is thought to be more often limited by extreme events compared to trees in the distribution centre. The widespread European beech (*Fagus sylvatica* L.), the dominant natural forest tree in Central Europe, is said to be limited by drought at the southern and by frost at the northeastern distribution margin. We stress this theory and we asked (1) Is growth in *F. sylvatica* really more limited by climatic drivers and more synchronized at the dry (drought stress) and the cold (cold stress) distribution margin compared to the centre of the distribution range? (2) Does the probability of negative growth anomalies increase towards the distribution margins? (3) What are the differences between the dry and the cold distribution margins?

Our study sites were nine sites along a European gradient from the warm-dry distribution margin (Spain) to the cold-wet (Sweden) and cold-dry distribution margins (Poland). We analysed and compared climate-growth relationships, growth synchronicity between trees per site, average wood increment, and stand-wide negative growth anomalies (pointer years).

Summer drought events hampered growth at the centre and eastern distribution margin, but not at the southern margin. The average wood increment decreased from the wet to the dry distribution margin and was not highest at the centre of the distribution range. Warmer winter temperatures in February favoured growth at the site in Switzerland (more central site), but not at the cold distribution margins of beech in Poland or Sweden. Further, growth synchronicity increased from the southern to the eastern and northern distribution margin. The probability of negative growth anomalies increased from the distribution margins to the centre and from the dry margin to the wet margin. At four (Poland, Germany, Switzerland) of the nine sites negative growth anomalies were related to drought indicators.

Our results suggest that southern beech populations are adapted to grow in dry conditions through local adaptation or phenotypic plasticity. Missing synchronicity at the dry sites could hint towards microscale differences in water availability. In contrast, frost events might affect whole populations at the local scale, leading to more growth synchronicity at the cold sites.

Tree reaction to drought in a montane rainforest in southern Ecuador

Volker Raffelsbauer (1)*, Achim Bräuning (1)

(1) Institute of Geography, Friedrich-Alexander-University of Erlangen-Nuremberg
Correspondence: volker.raffelsbauer@fau.de

The eastern declivity of the Cordillera Real in southern Ecuador is covered by a highly diverse mountain rainforest. Local climate is humid with around 2200 mm of annual rainfall, and dry spells are rather rare but nevertheless a regular event during the "Veranillo del Niño" (VdN) periods in October or November (Volland-Voigt et al. 2011). However, different tree species might respond diverse to occasional drought stress, raising the question if some species might be better adapted to a higher frequency of dry periods that may occur under future climate conditions. We monitored 43 individuals of eight different families with high-resolution electronic dendrometers and analyzed tree responses during dry intervals with a minimum length of four consecutive days without rainfall during July 2007 to November 2010, and additionally during March 2015 to March 2017. We calculated the averaged stem shrinkage rates during these periods, and compared the specific recovery times in consideration of plant families and plant functional types. Our results showed that the two deciduous broadleaved species Cedrela montana and Tabebuia chrysantha showed the biggest loss of increment during dry spells, with up to 2 mm stem shrinkage after 10 days of drought. However, the two species differ strongly regarding growth rate and averaged daily increment change with +0.046mm and +0.016mm respectively. Looking at the recovery time, Vismia tomentosa and Tapirira guianensis moved into focus. While Vismia recovered to the pre-drought circumference after only five days, Tapirira needed 52 days on average to restore its circumference. If such dry spells change in duration and frequency, this may result in an alteration of the forest composition.

Blue Intensity shows more stable dendroclimatic signal than tree-ring width at a Himalayan treeline

Niels Schwab (1)*, Karolina Janecka (2), Ryszard J. Kaczka (3), Jürgen Böhner (1), Ram P. Chaudhary (4), Thomas Scholten (5), Udo Schickhoff (1)

(1) Physical Geography, Center for Earth System Research and Sustainability (CEN), University of Hamburg, Germany, (2) Institute of Botany and Landscape Ecology, University of Greifswald, Germany, (3) Faculty of Earth Sciences, University of Silesia in Katowice, Poland, (4) Centre for Applied Science and Technology (ReCAST), Tribhuvan University, Nepal, (5) Department of Geosciences, Chair of Soil Science and Geomorphology, University of Tübingen, Germany.
Correspondence: niels.schwab@uni-hamburg.de

Himalayan treelines are exposed to above average climate change impact, resulting in complex tree growth-climate relationships for Himalayan Silver Fir (*Abies spectabilis*) at central Himalayan treelines. Here we present a first application of Blue Intensity (BI) proxies (early wood BI, late wood BI, delta BI) in the Himalaya, derived from *Abies spectabilis* tree-rings, in order to determine BI-climate relationships and their stability as compared to tree-ring width (TRW) - climate relationships. Analyses were conducted using more than one century long gridded temperature and precipitation data. The results showed significantly unstable dendroclimatic signals over time. However, early wood BI exhibited a stable positive correlation with spring temperature over the whole analysed period from 1902 to 2012, in line with findings of Sano et al. (2005) for early wood minimum density. Correlations of all BI parameters with climate variables resulted in longer significant evolutionary interval correlations in comparison to TRW. In general, we found significant static correlations of BI parameters to a larger extent, with climate variables showing higher correlation coefficients. Contrary to early wood BI, TRW correlated weakly with climate in early and mid-20th century. These results suggest *Abies spectabilis* BI to be a suitable surrogate for wood density parameters and a promising climate proxy for the Himalaya.

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Dynamics of the radial increment of Scots pine (*Pinus sylvestris* L.) and Austrian pine (*Pinus nigra* Arn.) in Balkan Mountain range, Bulgaria, depending on climate change and stand origin

Nikolay Zafirov (1)*, Dimitar P. Dimitrov (2), Stefan Mirtchev (1)

(1) Department of Plant Pathology and Chemistry, University of Forestry, Sofia, Bulgaria, (2) Forest Research Institute under the Bulgarian Academy of Sciences, Sofia, Bulgaria
Correspondence: niki.zafirov@gmail.com

Over the last decades, after prolonged drought periods and heat waves, forest decline has occurred in many countries. Studies show that usually it is a result of unfavorable climate conditions that are often combined with biotic stress factors (mostly fungal diseases and insect pests).

The purpose of this study is to analyze the dynamics of the health condition of Scots and Austrian pine stands in Balkan Mountain range, Bulgaria, and to assess the impact of climate conditions on it.

The performed dendrochronological analysis is based on observations of a representative sample plots, collected samples and laboratory analyses. Samples are taken from two hundred years old natural Austrian pine stand and pine plantations of different age classes, growing at diverse ecological conditions in the study area. Climate data from several hydro-meteorological stations in this region are used.

The last stress period in the analyzed Scots pine plantations continued until the end of their growth period. Multifactorial regression analysis has revealed that the impact of precipitation is stronger than that of air temperatures on the dynamics of the condition of low-altitude plantations. At high altitudes, however, the temperature regime prevails over the dynamics of the radial increment.

The natural Austrian pine stand is in poor health condition at the beginning of the current 21st century, while the plantation from this tree species is in relatively good condition. A greater role for the dynamics of their radial increment has the precipitation compared to the air temperatures in both stands.

The statistical analyzes carried out on the influence of the temperature-precipitation regime on the dynamics of the radial increment of the studied tree species prove the significance of these factors as predisposing factors for the changes in their health condition. The analysis outlines a tendency for rise of the air temperatures over the last 100 years in the study region. This requires a more in-depth analysis of the likely future climate change and its impact on forest ecosystems.

List of participants

Name	Institution	Country	Email address
Linar Akhmetzyanov	Wageningen University and Research	The Netherlands	linar.akhmetzyanov@wur.nl
Alba Anadon-Rosell	University of Greifswald	Germany	alba.anad@gmail.com
Anjy Nandrianina Andrianantenaina	UMR SILVA, INRA Grand Est Centre de Nancy	FRANCE	anjy-nandrianina. andrianantenaina@inra.fr
Mohsen Arsalani	University of Tehran	Iran	arsalan_mohsen@yahoo.com
Matyas Arvai	Institute for Soil Sciences and Agricultural Chemistry, MTA ATK	Hungary	arvai.matyas@agrar.mta.hu
Angela Balzano	Biotechnical Faculty, University of Ljubljana	Slovenia	Angela.Balzano@bf.uni-lj.si
Marie-Therese Barrett	Queen's University Belfast	Northern Ireland	mbarrett08@qub.ac.uk
Giovanna Battipaglia	Department of Environmental, Biological and Pharmaceutical Sciences and Technologies University of Campania "L. Vanvitelli"	Italy	giovanna.battipaglia@ unicampania.it
Andreas Bauerochse	Lower Saxony State Service for Cultural Heritage	Germany	andreas.bauerochse@ nld.niedersachsen.de
Jenny Berg	University of Victoria	Canada	vedaworks@gmail.com
Alen Berta	Oikon ltd. Institute of Applied Ecology	Croatia	aberta@oikon.hr
Stella Bogino	State University of San Luis	Argentina	stellabogino@gmail.com
Achim Bräuning	Institute of Geography, University Erlangen-Nürnberg	Germany	achim.braeuning@fau.de
Manuel Broich	University of Cologne, Institut für Ur- und Frühgeschichte, RTG 1878 "Archaeology of Pre-Modern Economies"	Germany	Manuel.Broich@gmx.de
David Brown	Queens University Belfast	United Kingdom	d.brown@qub.ac.uk
Agata Buchwal	Adam Mickiewicz University Poznan	Poland	kamzik@amu.edu.pl
Allan Buras	Wageningen University and Research	Netherlands	allan@buras.eu
Christin Carl	Technische Universität München	Germany	christin.carl@tum.de
Marco Carrer	Università di Padova	Italy	marco.carrer@unipd.it
Anna Cedro	Univerisity of Szczecin	Poland	anna.cedro@usz.edu.pl

Feng Chen	Institute of Desert Meteorology, China Meteorological Administration	China	feng653@163.com
En-Bi Choi	Chungbun National University	Republic of Korea	chenbi0715@gmail.com
Alan Crivellaro	Dept. TESAF, University of Padova	Italy	alan.crivellaro@unipd.it
Roberto Cruz Garcia	University of Greifswald	Germany	rcruzgarcia84@gmail.com
Aoife Daly	University of Copenhagen	Denmark	aoife.daly@hum.ku.dk
Darren Davies	Swansea University	Wales	darren.davies@swan.ac.uk
Barbara Diethelm	University of Cologne, Institute of Prehistoric Archaeology, Laboratory of Dendroarchaeology	Germany	b.diethelm@gmx.de
Johannes Edvardsson	Department of Geology, Lund University	Sweden	johannes.edvardsson@ geol.lu.se
Olafur Eggertsson	Icelandic Forest service	Iceland	olie@skogur.is
Thomas Eißing	Otto-Friedrich-Universität Bamberg	Germany	thomas.eissing@uni-bamberg.de
Ouya Fang	Institute of Botany, CAS	China	oyfang@ibcas.ac.cn
Macarena Férriz	National Institute for Agronomic Research (INIA)	Spain	ferriz.macarena@inia.es
Giulia Fontana	Swiss Federal Research Institute WSL	Switzerland	giulia.fontana@wsl.ch
Thomas Frank	University of Innsbruck	Austria	Thomas.Frank@ student.uibk.ac.at
Thomas Frank	University of Cologne, Institute of Prehistoric Archaeology, Laboratory of Dendroarchaeology	Germany	tfrank@uni-koeln.de
Mary Gagen	Swansea University	United Kingdom	m.h.gagen@swansea.ac.uk
Arina Galimova	Institute of Plant and Animal Ecology UB RAS	Russian Federation	arina_galimova93@mail.ru
Holger Gärtner	Swiss Federal Research Institute WSL	Switzerland	holger.gaertner@wsl.ch
Aster Gebrekirstos	World Agroforestry Centre	Kenya	A.gebrekirstos@cgiar.org
Jussi Grießinger	University of Erlangen, Institute of Geography	Germany	jussi.griessinger@fau.de
Björn Günther	Technische Universität Dresden	Germany	bjoern.guenther@tu-dresden.de
Marina Gurskaya	Institute of Plant and Animal Ecology	Russia	marina_gurskaya@mail.ru
Andrew Hacket-Pain	University of Liverpool	UK	andrew.hacket-pain@ liverpool.ac.uk

Jill Harvey	University of Greifswald	Germany	harveyj@uni-greifswald.de
Martin Häusser	FAU Erlangen-Nuremberg	Germany	martin.haeusser@fau.de
Minhui He	Northwest Institute of Eco-Environment and Resources, Chinese Academy of Sciences	China	minhuihe16@gmail.com
Karl-Uwe Heußner	German Archaeological Institute	Germany / Berlin	dendro@dainst.de
Andrea Hevia	Fundacion CETEMAS, Universidad de Huelva	Spain	ahevia@cetemas.es
Philipp Hochreuther	Institute of Geography, FAU Erlangen-Nürnberg	Germany	philipp.hochreuther@fau.de
Mahmuda Islam	Institute of Geography, University of Erlangen-Nuremberg	Germany	mahmuda.islam@fau.de
Karolina Janecka	University of Greifswald	Germany	karolinaejanecka@gmail.com
Alexander Janus	German Archaeological Institute	Germany / Berlin	alexander.janus@dainst.de
Gottfried Jetschke	Institute of Ecology, University of Jena	Germany	bgj@uni-jena.de
Jernej Jevšenak	Slovenian Forestry Institute	Slovenia	jernej.jevsenak@gozdis.si
Marek Ježík	Institute of Forest Ecology, Slovak Academy of Sciences	Slovak Republic	jezik@savzv.sk
Ryszard Kaczka	University of Silesia	Poland	ryszard.kaczka@us.edu.pl
Akira Kagawa	Wood Anatomy and Quality Laboratory, Forestry and Forest Products Research Institute	Japan	akagawa@ffpri.affrc.go.jp
Elena Kasatkina	Kola Science Centre RAS, Polar Geophysical Institute	Russia	oleg@aprec.ru
Jakub Kašpar	The Silva Tarouca Research Institute	Czech republic	jakub.kaspar@vukoz.cz
Marko Kazimirovic	University of Belgrade, Faculty of Forestry	Serbia	marko.kazimirovic@sfb.bg.ac.rs
Zoltan Kern	Research centre for Astronomy and Earth Sciences, MTA	Hungary	zoltan.kern@gmail.com
Andreas J Kirchhefer	Dendroøkologen	Norway	andreas.kirchhefer@dendro.no
Lara Klippel	Johannes Gutenberg University Mainz	Germany	laklippe@uni-mainz.de
Marcin Klisz	Forest Research Institute	Poland	m.klisz@ibles.waw.pl
Britt Kniesel	Technische Universität Dresden	Germany	britt.kniesel@ forst.tu-dresden.de
Natalia Knysh	Institute of Experimental Botany of National Academy of Science of Belarus	Belarus	Knyshnv@gmail.com

Michael Körner	Public Enterprise Sachsenforst	Germany	michael.koerner@ smul.sachsen.de
Stefan Kruse	Alfred-Wegener-Insitut Helmholtz-Zentrum für Polar- und Meeresforschung	Germany	stefan.kruse@awi.de
Jelena Lange	University of Greifswald	Germany	jelena.lange@uni-greifswald.de
Martina Lavri	Slovenian Forestry Institute	Slovenia	martina.lavric@gozdis.si
Jaqueline Lekscha	Potsdam Institute for Climate Impact Research	Germany	jaqueline.lekscha@pik-potsdam.de
Tom Levani	Slovenian Forestry Institute	Slovenia	tom.levanic@gozdis.si
Neil Loader	Swansea University	UK	n.j.loader@swansea.ac.uk
Katarzyna Łuszczy ska	University of Silesia, Faculty of Earth Sciences, Department of Reconstructing Environmental Change	Poland	katarzyna_luszczynska@o2.pl
Lixin Lyu	Institute of Botany, Chinese Academy of Sciences	China	lixinlv@ibcas.ac.cn
Ireneusz Malik	University of Silesia, Faculty of Earth Sciences, Department of Reconstructing Environmental Change	Poland	irekgeo@wp.pl
Paweł Matulewski	Adam Mickiewicz University in Pozna	Poland	matul@amu.edu.pl
Wolfgang Jens-Henrik Meier	Institute of Geographie, University of Erlangen/Nürnberg (FAU)	Germany	wolfgang.jh.meier@fau.de
Edina Merdan	Freie Universität Berlin	Germany	e.merdan@mailbox.org
Maks Merela	University of Ljubljana, Biotechnical Faculty, Department of Wood Science and Technology	Slovenia	maks.merela@bf.uni-lj.si
Stjepan Mikac	Faculty of Forestry, University of Zagreb	Croatia	smikac@sumfak.hr
Frits Mohren	Wageningen	The Netherlands	frits.mohren@wur.nl
Lena Muffler	University of Greifswald	Germany	lena.muffler@uni-greifswald.de
Andrei Mursa	Stefan cel Mare University of Suceava	Romania	m.andreimursa@gmail.com
Viorica Nagavciuc	Stefan cel Mare University of Suceava	Romania	nagavciuc.viorica@gmail.com
Constantin Nechita	National Research and Development Institute for Silviculture "Marin Dracea" (INCDS)	Romania	nechitadendro@gmail.com

Burkhard Neuwirth	DeLaWi TreeRing Analyses	Germany	b.neuwirth@online.de
Kurt Nicolussi	University of Innsbruck, Institute of Geography	Austria	kurt.nicolussi@uibk.ac.at
Jörg Niederberger	Univesy of Freiburg, Chair of Silviculture	Germany	joerg.niederberger@ waldbau.uni-freiburg.de
Nikolaus Obojes	Eurac Research	Italy	nikolaus.obojes@eurac.edu
Timo Pampuch	University of Greifswald	Germany	Pampuchs_Timo@gmx.de
Jun-Hui Park	Chungbuk National University	Republic of Korea	wnsgml9547@cbnu.ac.kr
Pavel Peresunko	Siberian Federal University	Russia	peres94@yandex.ru
Dawid Pi tek	Institute of Geography and Spatial Management, Jagiellonian University	Poland	dawidpt23@gmail.com
Alma Piermattei	Department of Geography, University of Cambridge	Regno Unito	alma.piermattei@ geog.cam.ac.uk
Ionel Popa	National Research and Development Institute for Silviculture Marin Dracea	Romania	popaicas@gmail.com
Margarita Popkova	Siberian federal university	Russia	popkova.marg@gmail.com
Angela Luisa Prendin	Università degli Studi di Padova	Italy	angelaluisa.prendin@ gmail.com
Inken Rabbel	Department of Geography, University of Bonn	Germany	irabbel@uni-bonn.de
Volker Raffelsbauer	Institute for Geography FAU Erlangen-Nuremberg	Germany	v.raffelsbauer@gmx.de
Mizanur Rahman	Institute of Geography, Friedrich-Alexander-University Erlangen-Nuremberg	Germany	mizanur.rahman@fau.de
Elisabeth Robert	CREAF	Spain	e.robert@creaf.uab.cat
Andreas Rzepecki	Rheinisches Landesmuseum Trier	Germany	andreas.rzepecki@gdke.rlp.de
Raul Sanchez-Salguero	IPE-CSIC, Universidad Pablo de Olavide	Spain	rsanchez@upo.es
Tanja Sanders	Thuenen Institute of Forest Ecosystems	Germany	tanja.sanders@thuenen.de
Ute Sass-Klaassen	Wageningen University	The Netherlands	ute.sassklaassen@wur.nl
Matthias Saurer	Swiss Federal Institute for Forest, Snow and Landscape Research WSL	Switzerland	matthias.saurer@wsl.ch
Tobias Scharnweber	University of Greifswald	Germany	tobias.scharnweber@ uni-greifswald.de
Henriette Schmidt	Eberswalde University for Sustainable Development	Germany	henriette.schmidt@hnee.de
Burghart Schmidt	Dendro-Labor, Univ. Köln (retired)	Germany	dendro-schmidt@t-online.de

Markus Schmidt	Eberswalde University for Sustainable Development, Botanical Garden	Germany	markus.schmidt@hnee.de
Sebastian Schneider	Geography Department, Humboldt-Universität zu Berlin/Climate Geography	Germany	sebastian.schneider.8@ geo.hu-berlin.de
Jens Schröder	Thünen-Institute for Forest Ecology	Germany	jens.j.schroeder@thuenen.de
Niels Schwab	Physical Geography, Center for Earth System Research and Sustainability (CEN), Universität Hamburg	Germany	niels.schwab@uni-hamburg.de
Róbert Sedmák	Technical University in Zvolen	Slovak Republic	sedmak@tuzvo.sk
Jeong-Wook Seo	Chungbuk National University	Republic of Korea	jwseo@chungbuk.ac.kr
Xavier Serra-Maluquer	Pyrenean Institute of Ecology (CSIC)	Spain	xaviserra92@gmail.com
Rohan Shetti	University of Greifswald	Germany	rohanshetti@gmail.com
Lisa Shindo	associated researcher to Centre Camille Jullian (CNRS, Aix-en-Provence)	France	shindo@mmsh.univ-aix.fr
Velislava Shishkova	University of Forestry, Sofia	Bulgaria	ivelvell@gmail.com
Vladimir Shishov	Siberian Federal University	Russia	vlad.shishov@gmail.com
Oleg Shumilov	Kola Science Centre RAS, Polar Geophysical Institute	Russia	oleg@aprec.ru
Maya Sidorova	Siberian federal university	Russia	mayasidorova12@gmail.com
Georgios Skiadaresis	Chair of Silviculture, Freiburg University	Germany	georgios.skiadaresis@ gmail.com
Susanne Spannl	University of Bayreuth	Germany	Susanne.Spannl@uni-bayreuth.de
Scott St. George	University of Minnesota	USA	stgeorge@umn.edu
Branko Staji	Univerity of Belgrade-Faculty of Forestry	Serbia	branko.stajic@sfb.bg.ac.rs
Norbert Szyma ski	University of Agriculture in Krakow	Poland	szymanski.norbert@wp.pl
Sonja Szymczak	FAU Erlangen-Nürnberg	Germany	sonja.szymczak@fau.de
Andrew Trant	University of Waterloo	Canada	atrant@uwaterloo.ca
Vaclav Treml	Charles University, Faculty of Science	Czech Republic	treml@natur.cuni.cz
Kerstin Treydte	Swiss Federal Research Institute WSL	Switzerland	treydte@wsl.ch
Domagoj Trlin	Faculty of Forestry, University of Zagreb	Croatia	dtrlin@sumfak.hr

Mario Trouillier	University of Greifswald	Germany	mario.trouillier@uni-greifswald.de
Jan Tumajer	Department of Physical Geography and Geoecology, Faculty of Science, Charles University, Prague	Czech Republic	tumajer1@email.cz
Ivan Tychkov	Siberian Federal University	Russia	ivan.tychkov@gmail.com
Ernst van der Maaten	TU Dresden	Germany	ernst.vandermaaten@gmail.com
Marieke van der Maaten-Theunissen	TU Dresden	Germany	marieketheunissen@gmail.com
Carla Vázquez-González	Consejo Superior de Investigaciones Científicas (MBG-CSIC)	Spain	cvazquez@mbg.csic.es
Javier Vázquez-Piqué	University of Huelva	Spain	jpique@uhu.es
Monika Vejpustková	Forestry and Game Management Research Institute	Czech Republic	vejpustkova@vulhm.cz
Danielle Verdon-Kidd	University of Newcastle	Australia	danielle.verdon@newcastle.edu.au
Xiaochun Wang	Northeast Forestry University	China	wangx@nefu.edu.cn
Robert Weigel	University of Greifswald	Germany	robert.weigel@uni-greifswald.de
Jakob Wernicke	ThüringenForst (FFK Gotha)	Germany	jakob.wernicke@gmail.com
Thorsten Westphal	Curt-Engelhorn-Zentrum Archäometrie Mannheim	Germany	thorsten.westphal@cez-archaeometrie.de
Ellen Wilderink	Wageningen University & Research	Netherlands	ellen.wilderink@wur.nl
Martin Wilmking	University of Greifswald	Germany	wilmking@uni-greifswald.de
Rob Wilson	University of St Andrews	United Kingdom	rjsw@st-andrews.ac.uk
Dominika Wro ska-Wałach	Institute of Geography and Spatial Management	Poland	d.wronska@gmail.com
Piotr Wrzesi ski	Forest Research Institute	Poland	p.wrzesinski@ibles.waw.pl
Giles Young	Swansea University	UK	g.h.f.young@swansea.ac.uk
Max Zacharias	University of Bonn, Department of Geography	Germany	max.zacharias@uni-bonn.de
Nikolay Zafirov	University of Forestry, Sofia	Bulgaria	niki.zafirov@gmail.com
Hui Zhang	Institute of Tibetan Plateau Research, Chinese Academy of Sciences	China	zhanghui@itpcas.ac.cn
Yesi Zhao	Nanjing University; University of Erlangen Nuremberg	China	DG1527046@smail.nju.edu.cn

Fan Zhao	Xishuangbanna Tropical Botanical Garden, Chinese Academy of Sciences	China	zhaofan@xtbg.ac.cn
Anja Žmega	Faculty of Forestry, University of Zagreb	Croatia	azmegac@sumfak.hr