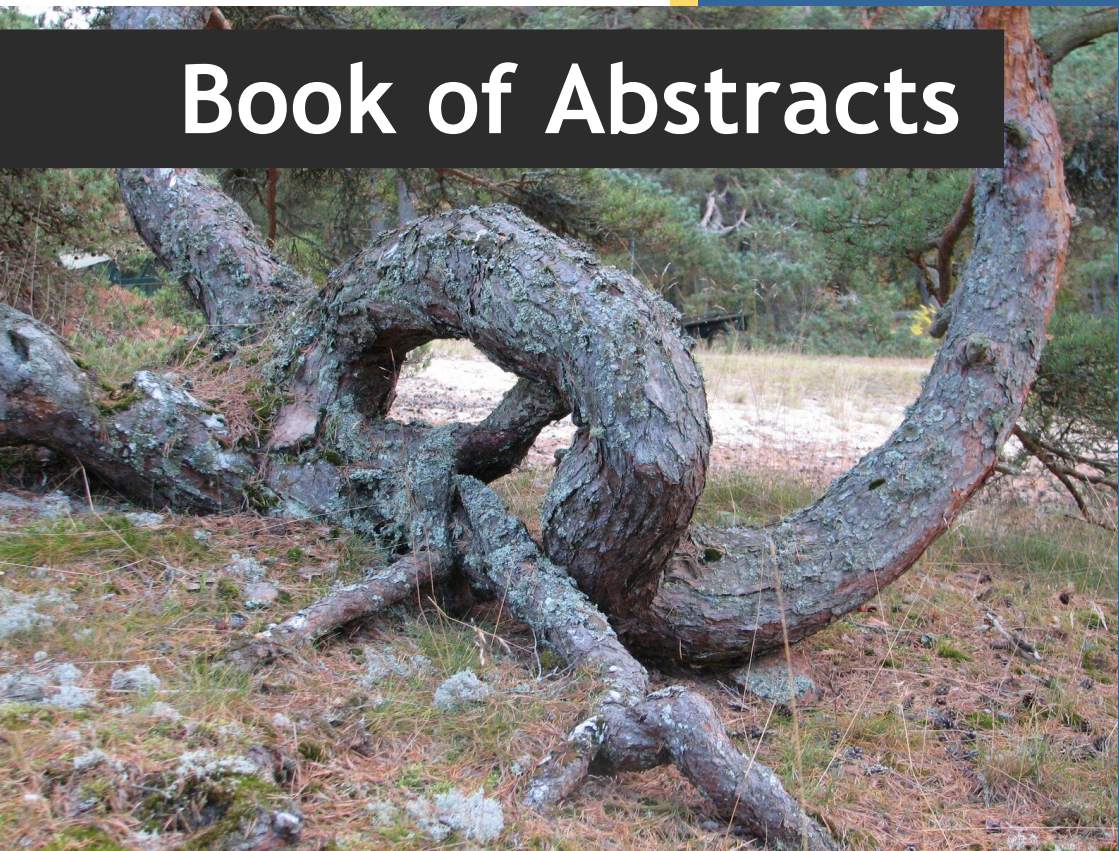




Book of Abstracts



EuroDendro

6–10 September 2017
Tartu, Estonia

EuroDendro Conference 2017
6–10 September, 2017, Tartu, Estonia

Book of Abstracts

Tartu 2017

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Foreword

Dear participants!

EuroDendro is a regular international conference on dendrochronology and a meeting point of the tree-ring scientific community. The conference provides an opportunity to present and discuss exciting advances that have been made currently in tree-ring research and related disciplines.

EuroDendro is traditionally not restricted to European scientists or research from the continent. Vice versa, people and research from outside European limits are warmly welcome as well.

EuroDendro 2017 conference is held in Tartu, Estonia on 6-10 September 2017.

We can state that the number of participants of EuroDendro 2017 exceeds one hundred. We warmly welcome here tree-ring researchers from 25 European countries as well as from some Asian and North and South American countries. Also we keep in mind these colleagues who could not come here for any reason. Herewith I have a pleasant duty to forward greetings from one of the founders of the EuroDendro tradition, Professor Dieter Eckstein.

By the sequence this EuroDendro 2017 held in Tartu is the 19th conference of its format.

We are happy to introduce you our university town Tartu and our small country, Estonia. Hopefully the conference will offer pleasant atmosphere both in social and meteorological sense. We wish you fruitful discussions that would result in continuing scientific collaboration and new international projects with involvement of Estonia. We hope to meet you again if not before then at the next EuroDendro.

Enjoy the conference!

On behalf of the organising team,

Alar Läänelaid

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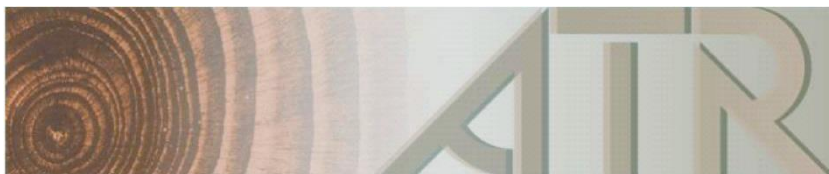
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EuroDendro 2017 Conference 6–10 September in Tartu, Estonia

Program

Wednesday, 06.09.2017	
Vanemuise St. 46, University of Tartu Natural History Museum	
17:00 – 20:00	Registration in Vanemuise St. 46 Hall (+ optional museum visit in Natural History Museum)
18:00 – 22:00	Ice-breaker

Thursday, 07.09.2017	
Riia St. 23B, Omicum (Room 105+Atrium)	
8:15 – 9:00	Registration & Hanging posters
9:00 – 9:30	Conference opening
Session 1: Dendrogeomorphology & Dendroecology	
Chairs: Jelena Lange and Allan Buras	
09:30	Radek Tichavský Dating of accelerated gully erosion in glacial deposits (Eastern Sudetes; Czech Republic) – dendrogeomorphic research based on exposed tree roots
09:45	Hana Přecechtělová Growth pattern of exposed tree roots as a tool for identifying of landslide velocities
10:00	Paweł Matulewski High resolution dating based on wood anatomical changes in Scots pine (<i>Pinus sylvestris</i> L.) roots in the Brodnica Lakeland, Poland NE
10:15	Isabella Aguilera Betti Climate variability and its effects on seed production and growth patterns of an old-growth forest in southern Chile
10:30	Mara Kitenberga Dendrochronological reconstruction of the forest fire regime in a <i>Pinus sylvestris</i> -dominated forest in the Slitere National Park, Latvia
10:45 – 11:15 Coffee break with posters	
Session 2: Dendroecology	
Chairs: Susanne Suvanto and Jan Altman	
11:15	Sybryn L. Maes Tree-ring measurements across European forest sites reveal effects of global-change drivers on tree growth dynamics

11:30	Melanie Saulnier Larch forest in the French Alps facing global change: a synthesis of both tree-ring growth–climate relationships and insect disturbances for the past 500 years
11:45	Jill Harvey The influence of grassland proximity on insect and fire activity in interior British Columbia, Canada
12:00	Maxim Yermokhin Transformation of pine bog forests in Belovezhskaya Pushcha – drainage or climate change?
12:15	Negar Rezaei Effect of late frost on the C dynamics in a Mediterranean beech forest
12:30 – 13:30 Lunch	
Session 3: Dendroarchaeology	
Chairs: Marta Domínguez-Delmás and Tomasz Ważny	
13:30	Niels Bleicher Tree rings as palaeoenvironmental proxy of cyclical prehistoric human impact on vegetation and landscapes. A case study from the late 4th millennium BC in Zurich (Switzerland)
13:45	Kurt Nicolussi Tree-ring analysis and dating of archaeological charcoals – examples from the Alps
14:00	Michael Grabner Wooden elements from the City of Vienna
14:15	Julia Weidemueller Wrong time, wrong place: wood supply in ancient Bavaria
14:30	Kristof Haneca Dendrochronology in <i>Flanders Fields</i> : timber supply during World War I
14:45	Alexander Janus 20 years of archaeological wood dating
15:00 – 15:30 Coffee break with posters	
Session 4: Dendroarchaeology	
Chairs: Julia Weidemueller and Alar Läänelaid	
15:30	Aoife Daly Timber for <i>Batavia</i>
15:45	Marta Domínguez-Delmás Is dendrochronology enough to establish the date and provenance of Iberian shipwreck timbers?
16:00	Tomasz Ważny The ForSEAdiscovery Project - How wood powered the Iberian World Exploration
16:15	Ünal Akkemik Dating and dendroprovenancing of the timber used in the Yenikapı Historical Jetty (İstanbul, Turkey)
16:30	Anne Crone Dendrochronological evidence for the early trade in timber between the British Isles and the American colonies
16:45	Andrea Seim The Jordaens Van Dyck Panel Paintings Project - first dendroarchaeological insights

17:00 – 19:00 Poster Session

Snacks & Drinks

Friday, 08.09.2017

Riia St. 23B, Omicum (Room 105+Atrium)

Session 5: Novel approaches & Technical advances

Chairs: Alma Piermattei and Ignacio García-González

- 09:00 **Flurin Babst** Towards spatiotemporal tree-ring width data for Europe
- 09:15 **Allan Buras** Tree-growth divergence – a global phenomenon?
- 09:30 **Samuli Helama** A new look at tree-ring standardization
- 09:45 **Ivan Tychkov** Process-based modeling of tree-climate relations in the Yenisey-Lena transect
- 10:00 **Urs Gut** Cross-validation of ring-width based dendro-provenancing
- 10:15 **Alexander Stine** Improved tree ring climate reconstructions using Liebig's Law of the Minimum

10:30 – 11:00 Coffee break with posters

Lunch package to take away

11:15 – 19:45 Excursion to southeastern Estonia

20:00 – 21:30 Dinner at Leigo

21:45 – 22:30 Bus to Tartu

Saturday, 09.09.2017

Riia St. 23B, Omicum (Room 105+Atrium)

Session 6: Dendroclimatology

Chairs: Melanie Saulnier and Samuli Helama

- 09:00 **Jan Altman** Reconstruction of tropical cyclones in Northeast Asia
- 09:15 **Tobias Scharnweber** How global change fakes medieval hydroclimate - a tree-ring based millennium long drought reconstruction for NE-Europe
- 09:30 **Max Torbenson** The relationship between seasonal moisture in central United States, 1685-2015
- 09:45 **Helene Svarva** Reconstruction of summer temperatures from tree-rings of Scots pine (*Pinus sylvestris* L.) in western Norway

10:00	Rayees Malik Growth responses of <i>Abies pindrow</i> to climate along elevational gradient in north-western Himalayas
10:15	Xiaochun Wang Inverse responses of Korean pine (<i>Pinus koraiensis</i>) and Mongolia oak (<i>Quercus mongolica</i>) growth to recent warming in northeast China
10:30 – 11:00 Coffee break with posters	
Session 7: Dendroclimatology	
Chairs: Sybryn L. Maes and Kurt Nicolussi	
11:00	Jelena Lange Micro-site conditions significantly affect growth performance and climate signals of Scots pine at its northern distribution limits
11:15	Susanne Suvanto Connecting conifer radial growth to potential frost damage events identified from meteorological records
11:30	Václav Tremľ Divergence of tree growth and summer temperature at treelines in the East-Central Europe
11:45	Valentina Vitali Effects of past and future seasonal trends on species growth in the Black Forest, Germany
12:00	Szymon Bijak Increment reaction of silver fir in central Poland to the extreme climate events
12:15	Anna Cedro Dendrochronology analysis of the wild service tree (<i>Sorbus torminalis</i> L.) in Poland
12:30 – 13:30 Lunch	
Session 8: Wood anatomy & Wood formation dynamics	
Chairs: Anna Cedro and Michael Grabner	
13:30	Katarina Čufar Wood formation and tree-ring variation in different species on different sites
13:45	Seyedehmasoumeh Saderi Measuring the adaptive potential of European larch to climatic changes using wood-formation monitoring
14:00	Marcin Koprowski Do the non-native pines follow the cambium dynamics of the native Scots pine (<i>Pinus sylvestris</i> L.)?
14:15	Britt Kniesel Vessel-based pointer-year analyses reveal different adaptation strategies of ring-porous and diffuse-porous species
14:30	Matthias Meyer Vessel lumen area, $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ in juvenile poplar plantations
14:45	Alma Piermattei Exploring the influence of kinship structure on tree growth performance of <i>Picea abies</i>
15:00 – 15:30 Coffee break with posters	

Session 9: Wood anatomy & Wood formation dynamics & Dendrochemistry

Chairs: Katarina Čufar and Paweł Matulewski

- 15:30 **Astrid Vannoppen** Climate driven trends in tree biomass growth show asynchronous dependence on ring width and wood density variation
- 15:45 **Manuel Souto-Herrero** Earlywood vessels explain the role of climate on wood formation of *Quercus pyrenaica* Willd. across the Atlantic-Mediterranean boundary in NW Iberia
- 16:00 **Klemen Novak** Growth characteristics of tree rings in *Pinus halepensis* in the Mediterranean
- 16:15 **Ignacio García-González** Facing 'Macaronesian dendrochronology': Can tree-ring analysis be applied to the Canarian laurel forests?
- 16:30 **Adomas Vitas** Sapwood rings estimation of Scots pine (*Pinus sylvestris* L.) in Lithuania
- 16:45 **Ariel Muñoz** Advances in dendrochemistry in Chile: Issues of cities, industries and volcanoes

Removing posters

Lossi St. 25 (Toome Hill), University of Tartu Museum White Hall

19:30 – 23:00 Farewell dinner & Closing words

Sunday, 10.09.2017

Departure

Dating of accelerated gully erosion in glacial deposits (Eastern Sudetes; Czech Republic) – dendrogeomorphic research based on exposed tree roots

Radek Tichavský^{1*}, Hana Přecechtělová¹, Olga Kluzová¹, Michal Břežný¹, Lenka Ondráčková², Petr Krpec¹, Radim Tolasz³, Karel Šilhán¹

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KEY WORDS: gully erosion, dendrogeomorphology, exposed roots, Eastern Sudetes

Recent acceleration of gully erosion caused by environmental factors as well as by human impacts leads to enhanced demand for applied research in risky areas worldwide. We investigated the dynamics of gullies threatening dwelling and railway in the NE part of the Czech Republic affected by Pleistocene continental glaciation. 22 gullies (mean length 49.6 m) have developed on a 1 km long escarpment (340–390 m a.s.l.; mean slope 25°) composed of various sized particles. Dendrogeomorphic techniques were applied on exposed roots (i) hanging above the gully bottom and slope failures, and (ii) creating the steps in the gully bottom. Fifty six samples from 23 roots of *Tilia cordata* Mill. were extracted. Micro sections were prepared using a GSL1 microtome and further analysed using WinCELL software to determine the year of exposure. Gullies have been presented at least since the 1950s; however, main events of accelerated gully erosion (up to 5 m incision and retreat of 140 m) occurred during the last 15 years (2002, 2007, 2010, and 2014). Sheet erosion has started since the 1990s and is currently enhanced by the undercutting due to the gully expansion. The approximate volume of material released during recent events is 1300 m³ of which more than 80% was transported down the railway and river floodplain. A combination of ameliorations, management of culverts and the presence of intense rainstorms (40 mm per 40 minutes in May, 2014) contributes to the recent acceleration of gully development.

Growth pattern of exposed tree roots as a tool for identifying of landslide velocities

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¹ Department of Physical Geography and Geoecology, Faculty of Science, University of Ostrava, Chittussiho 10, 710 00 Ostrava, Czech Republic

² Department of Biology, Faculty of Science, University of Hradec Králové, Rokitsanského 62, 500 03 Hradec Králové, Czech Republic

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KEY WORDS: landslide velocity, dendrogeomorphology, exposed root, Western Carpathians

The mechanism and velocity of landslide movements are important information for hazard assessment or protective measures. This contribution brings a new possibility of past landslide movement velocity reconstruction using dendrogeomorphic methods. The principle of this method is the analysis of exposed roots whose origin is directly associated with mass movement. The identification and dating of anatomical changes in root-ring series in various segments along a root (induced by gradual root exposure due to crack spreading) should discover the rate of root exposure and calculate the velocity of landslide movement. We analyzed anatomical reactions of 87 root-cross sections of *Tilia cordata* Mill., *Fagus sylvatica* L. and *Carpinus betulus* L. in tension cracks of active landslides located close the Vidče village (Western Carpathians). We noticed 17 years of exposure with the oldest exposure in 1997 and the youngest one in 2015. We calculated the partial velocities of the landslide movement expressed as the segment rate (between two neighbouring samples) of tension cracks spreading with an average of 11.8 cm.year⁻¹ and the total spreading rate of each tension crack (the mean spreading rate from all roots crossing one crack) with an average of 4.6 cm.year⁻¹. The most important advantage of this new approach is the possibility to reconstruct the velocity of past landslide movements without the need of long-term monitoring.

High resolution dating based on wood anatomical changes in Scots pine (*Pinus sylvestris* L.) roots in the Brodnica Lakeland, Poland NE

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KEY WORDS: dating of roots, cross-dating, wood anatomy, root exposure, *Pinus sylvestris* L., dendrogeomorphology

Hiking impact in forested areas is one of the main factors affecting the condition of root growth by exposure due to trampling activity. Trampling erosion, sometimes combined with natural geomorphic processes and the resulting exposure causes growth irregularities and wood anatomical changes in roots.

The goal of this study is to compare the changes in radial growth and wood anatomy of Scots pine (*Pinus sylvestris* L.) roots subjected to trampling on a heavily used hiking trail in the Brodnica Lakeland (NE Poland). Two adjacent roots from the same tree were collected for investigation. One root was completely buried and a second root had an exposed segment crossing a hiking trail. 12 cross-sections were analysed within each root and cross-dated with the corresponding stem and a respective site chronology. All ring analyses were conducted on micro-sections. Ring width measurements for all sections were done in 30 cm intervals. In addition, selected wood anatomical indicators were quantified for both roots, such as the occurrence of traumatic resin ducts (TRD), size of earlywood tracheids (EW), the percentage of latewood (LW) and the presence of compression wood.

Cross-dating between different parts of the roots revealed high discrepancies in the number and width of annual rings in different sections of the two analysed roots. The cross-sections sampled closest to the stem showed the highest coherency in growth pattern, which decreases with an increasing distance to the stem. The largest variations in ring width and wood anatomy was visible in the exposed roots subjected to an intense mechanical pressure due to trampling. Nevertheless, the highest correlation between root and stem growth was revealed for the exposed part of the root, which was characterized by the lowest amount of missing rings.

Matulewski Paweł is a scholarship holder of Adam Mickiewicz University Foundation scholarship programme for Ph.D students for academic year 2016/2017.

Climate variability and its effects on seed production and growth patterns of an old-growth forest in southern Chile

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KEY WORDS: precipitation reduction, resource allocation, long-term study, carbon isotopes, *Nothofagus obliqua*

Changes in forest dynamics due to climate change have been observed around the world in the last decades. However, the effect of such climate variability on the ecological performance of different tree species is still poorly studied. In a temperate rainforest in southern Chile (39°38'S, 73°07'W), we assessed the relationship between climate and seed production of five tree species during 27 years. The majority of the species shows a relation between seed production and precipitation. Also we analyzed seed production records (SPR), ringwidth (RW) and $\delta^{13}\text{C}$ chronologies of *Nothofagus obliqua*, the dominant species in the forest, to assess the effect of climate variability on growth, reproduction and carbon storage. Seed production was positively correlated with precipitation during the summer months of two years before the seeds fall to the forest floor. Tree growth was positively correlated with summer precipitation of the same year of the ring formation. $\delta^{13}\text{C}$ values in growth rings were negatively correlated with spring precipitation of the previous year. The negative correlation between ring width and seed production, in addition to the lagged responses of SPR, RW and $\delta^{13}\text{C}$ to precipitation, suggests a different resource allocation for reproduction and growth in this species. Our results suggest that the current reduction in precipitation and increased drought projected could have a strong impact on the ecology and dynamics of these forests.

Dendrochronological reconstruction of the forest fire regime in a *Pinus sylvestris*-dominated forest in the Slitere National Park, Latvia

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KEY WORDS: fire history, dendrochronology, *Pinus sylvestris*, disturbance regimes

The inter-dune peatland complex of the Slitere National Park is one of the best preserved natural areas of old natural *Pinus sylvestris* forest stands in Latvia. The aim of this study was to describe the historical forest fire regime and to assess its climatic-drivers. In total, 490 of deadwood samples were collected in a 2360 hectare large area where 72% were occupied by wetlands and 27% by sandy dunes. From 1558 to 2014, 27 fires were recorded with a mean point fire-return interval of 46.3 years. A spatial composite analysis showed a significant influence of the North Atlantic and the Baltic Sea surface temperature on fire activity. Our results show that fire is an important disturbance agent in the Slitere National Park, which is strongly influenced by large scale atmospheric circulations. To the best of our knowledge, this is the first reconstruction of the historical forest fire regime in Baltic countries.

Tree-ring measurements across European forest sites reveal effects of global-change drivers on tree growth dynamics

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KEY WORDS: tree growth, tree competition, global environmental change, dendroecology, multi-factor study, European scale

The last decades are characterized by an upsurge in the number of studies on global environmental change impacts on forests. In temperate forests, the most important global changes include land-use change (e.g. changes in forest management), climate change, and increased atmospheric deposition. Since the existing research has strongly focused on the effects of single factors on tree-growth dynamics, studies investigating the combined (and potentially interacting) effects of these changes are lacking. Multi-factor studies are urgently needed since interactions among drivers might cause responses to differ from those in single-factor studies. In this study, we will evaluate the interactive effects of past forest management, climatic changes, and increased deposition, on growth and competition dynamics of European tree layers. In a pan-European network of 192 plots, spread over 19 study sites, we cored a total of 370 dominant individuals of *Quercus robur/petraea*, *Fagus sylvatica*, and *Fraxinus excelsior*, the three most common broadleaved species in temperate European forests. Our sites covered a large gradient in climatic conditions and atmospheric deposition rates, while the different plots of each study site, encompassing similar site characteristics, covered distinct classes of past forest management. We demonstrate how this sampling design allows disentangling the effects of the three global-change drivers on tree-growth responses such as growth-release characteristics, tree-growth rates, and intraspecific competition rates. Our results should provide a more mechanistic understanding of how the three drivers of change interactively affect tree growth dynamics, so that forest managers and policy makers might make more informed decisions on sustainable resource extraction in European forests.

Larch forest in the French Alps facing global change: a synthesis of both tree-ring growth–climate relationships and insect disturbances for the past 500 years

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KEY WORDS: French Alps, global change, larch, tree-ring growth-climate relationships, larch forest disturbances

In the European Alps, tree species will be particularly threatened by the current global changes. Larch is one of the most emblematic species in high altitude forest ecosystems and is particularly suitable for a dendrochronological approach.

We used a dendroecological approach based on a wide network of sites and a very long climate data set for the French Alps to study the growth responses of larch to climate variability. To identify the main threats that larch will face in response to global changes, we studied the dynamics at different spatial-temporal scales of (1) the main parameter explaining most of the variation in larch radial growth and (2) the extreme events leading to an abrupt decrease in growth. Correlations, partial correlations, response functions (fixed and moving) and pointer years were also processed on the chronologies of 44 populations. The results evidence a strong response of larch to summer temperature that masks a lower but continuous response to summer precipitation. Response to precipitation decreases with altitude, lower altitude populations are the most sensitive to sufficient water supply.

We use these results coupled with the recent larch budmoth reconstruction in the French Alps (Saulnier *et al.* 2017), to propose a synthesis of the current context of growth for larch. This synthesis will yield an improved understanding of the dynamics of forest ecosystems composed of larch and the future threats that they may face in response to global change.

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The influence of grassland proximity on insect and fire activity in interior British Columbia, Canada

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KEY WORDS: western spruce budworm, fire, climate, Douglas-fir, outbreaks, ecotone, dendroecology, British Columbia, Canada

Wildfires and western spruce budworm (*Choristoneura occidentalis* Freeman) (WSB), a native conifer defoliator, are natural disturbances that affect the structure and function of montane forests in British Columbia, Canada. In these forests limited research exists describing the climate conditions associated with historical fire activity and outbreaks of WSB, and the interaction between fire and WSB outbreaks. The relation between fire years (AD 1600-1900), outbreaks of WSB (AD 1600-2009), reconstructed values of the Palmer Drought Severity Index and annual precipitation were examined with superposed epoch and bivariate event analyses at eight sites in the Cariboo Forest Region. We also evaluated the influence of grassland proximity on these relationships and the disturbance history characteristics. The findings show that fires affecting grassland proximal sites were historically more frequent than fires occurring in forests not near grasslands. Fire activity was related to both warm, dry and cool, wet conditions in the fire year and/or year(s) preceding the fire depending on proximity to grasslands, suggesting climate conditions associated with both fine fuel growth and drying are key determinants for fire activity. The initiation of outbreaks of WSB was significantly related to drought and this relationship was enhanced at sites next to grasslands. No associations were discerned between the initiation of WSB outbreaks and fire years. Considering the risk of dangerous fire activity in the future and potential timber losses associated with WSB defoliation, the findings provide important information to forest managers charged with promoting forest health and resilience in the dry conifer forests of interior British Columbia.

Transformation of pine bog forests in Belovezhskaya Pushcha – drainage or climate change?

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KEY WORDS: pine bog forests, drainage, climate, transformation

The goal of our research was to reveal the main causes of pine bog forests transformation on the territory of the National Park “Belovezhskaya pushcha” (Belarus). Studies were carried out on 4 permanent plots (dynamic of stand structure is estimated since 1970) and 55 temporary plots from different parts of the National park. The work on each plot includes a geobotanical description and dendrochronological investigation. Totally, the increment of 330 pine trees of 40-260 years of age was analyzed.

It was found that the transformation of the natural pine bog forests towards drier forest types started 10-20 years before large-scale drainages. It is linked to a steady decline (about 20%) of annual precipitation in the southern regions of Belarus since the beginning of the 1940s. Drainage from 1950-1970s intensified the process of natural drainage and caused over-draining of the Belovezhskaya Pushcha territory. This entailed not an increase, but a sharp decline in the growth and death of pine trees in the 1970s and 1980s.

Currently, there is a close positive correlation of tree-ring width with precipitation in winter and spring, which is not typical for natural bogs. In addition, the dynamic of tree growth in transformed phytocenoses is synchronous with the growth of trees on dry soils, but has a larger amplitude of oscillations.

Under the current hydrological and climatic conditions in the territory of the Belovezhskaya Pushcha, phytocenoses of pine bog forests will continue to transform into dry forest types.

Effect of late frost on the C dynamics in a Mediterranean beech forest

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KEY WORDS: late frost, cambium phenology, stem respiration, carbon reserves, *Fagus sylvatica* L.

Temperature increase has been inducing advances in leaf unfolding and thus exposing trees to late frost damages. Common beech is very sensitive to spring frost damage because of an earlier onset of leaf unfolding. Frost below -4°C can kill the developing new shoots and reduce growth (Dittmar *et al.* 2006), thus affecting the C dynamics inside the tree.

In a Mediterranean beech forest (Apennine, Italy), since 2015, cambium phenology, wood formation, carbon reserves and CO_2 stem fluxes have been monitored. In 2016, after a warm early spring, on 25th April, temperature reached -6°C causing the frost of all leaves. In this context, the objective of the study was to assess the effect of the late frost event on the carbon dynamics in beech stems. We want to evaluate the combined effect of extreme low temperature and the leaf unfolding period on cambium phenology, wood formation dynamics, carbon reserves and stem respiration.

The results showed a modification of the cambium phenology and wood formation dynamics, a strong reduction of radial growth and stem CO_2 fluxes. At the end of the growing season, the values of carbon reserves were similar to the values at the beginning of the growing season.

The findings suggest the presence of efficient internal regulation mechanisms in Mediterranean beech trees, ensuring a favourable physiological status to survive to extreme events, such as late spring frosts. Our results highlight the role of reserves for plant survival and for resilience processes to extreme events.

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Tree rings as palaeoenvironmental proxy of cyclical prehistoric human impact on vegetation and landscapes. A case study from the late 4th millennium BC in Zurich (Switzerland)

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KEY WORDS: dendroecology, dendrotypology, dendroarchaeology, vegetation history

Due to waterlogged conditions in the lake sediments many settlement remains from the fourth millennium BC have been organically preserved along the shore of Lake Zurich. Among the remains are thousands of piles and pieces of timber. Zurich has a high density of such UNESCO World Heritage rated sites.

A detailed dendroecological study of several thousand dendrosamples revealed an organized woodland management involving both coppicing and pollarding/shredding in the late Neolithic. However, timber sources changed over time, indicating a local degradation of the oak stands, resulting ultimately in the abandonment of the area after about 250 years. Settlers returned after further 250 years, initiating a second, similar course of events. Pollen data support these interpretation and botanical macroremains add further details to the reconstructions.

We present evidence that series of such events led to local centennial scale cycles both of settlement and vegetation history in many places in central Europe.

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Tree-ring analysis and dating of archaeological charcoals – examples from the Alps

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KEY WORDS: dendrochronology, archaeology, charcoals, firewood, mining, Alps

Charcoals are frequently found during archaeological excavations. They are often small, and usually just few tree rings are visible. However, larger pieces and charcoals from slowly grown trees can also contain dozens of tree rings and are therewith potentially datable by means of dendrochronology. Moreover, the analysis of larger assemblages of charcoals can reveal that many charcoals originate from relatively few trees. This allows the combination of the tree-ring series of many pieces to a potentially longer series and improves thereby the chance of tree-ring dating. However, wane edges are rarely determinable due to the features of this sample type as well as preservation conditions. This limits the accurate dating of events. Even if no dendro-dates can be provided by tree-ring analyses, the established tree-ring series can be used in combination with radiocarbon dating to improve the dating precision by applying the wiggle matching approach.

The paper presents some examples for the analysis of charcoals collected during archaeological excavations. These charcoals are remains of firewood either from fireplaces at high-elevated sites or from prehistoric copper mines in the eastern Alps. The established dendro-dates spread from the 5th to the 1st millennium BC.

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Wooden elements from the City of Vienna

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KEY WORDS: dendrochronology, dendroprovenancing, wood, wood utilization

The BOKU Tree-ring laboratory sampled wooden elements from 179 buildings in the city of Vienna within the last 20 years. Out of 3437 samples, 2171 were successfully dated (63%). Norway spruce shows the highest number of dated samples (60.7%) followed by Silver fir (35.6%), oak (2.3%), pine (0.9%) and larch (0.5%).

The building-historical dates (without archaeological findings) vary between 1142 AD and the 20th century.

Within a project under the guidance of the Austrian Monuments Authority in 2016 almost half of these samples were taken and analysed. Next to the dating itself, first steps of dendroprovenancing were undertaken. As the wood demand of the city of Vienna was higher than the stock in the surrounding forests the material was likely being supplied over the river Danube. Within this project at each roof construction floating marks were documented - the presence and types of wedges and/or withies. In most of the cases, a mixture of the types of floating marks was found (e.g. flat wedges as well as withies fixed with round wedges inserted in a pre-bored hole on the same beam).

A first set of regional chronologies were built: the Weinviertel- and Waldviertel-region (representing the eastern part of Austria), Steyer, northern alpine foothills (representing the north-central part of Austria with rivers running to the Danube) and the city of Salzburg (representing the western part of Austria as well as partially the region of southern Germany).

It was possible to refer some of the samples to the different regions. Cooperations with other laboratories (holding chronologies for further upstream regions) will bring more insight into the timber supply of Vienna.

Wrong time, wrong place: wood supply in ancient Bavaria

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KEY WORDS: dendroprovenancing, elevation modeling, dendroarchaeology, transport of timber, rafting

Ancient timber transport is always associated with the growth of towns. An increase of settlements would not have taken place without wood as crucial commodity. The great empires used timber imports by sea to provide their cities with essential building materials. The demand for wood in the southern parts of Germany during the Roman period was similar. Not surprisingly, rafts were used for timber transport. The academic discourse assumes that commercial timber transport ceased completely and people utilized local wood after the decline of the Roman Empire. In the ninth century, harvesting increased exponentially in the Upper Isar Valley. After a few decades, old forests vanished. Preserved wood samples include fast grown oak as well as other species like beech, elm, and spruce, which are partly allochthonous.

The question is: Where did this wood come from?

To determine whether transportation of timber has taken place, all archaeological wood samples found in the Upper Isar Valley were investigated. First, the samples were provenanced. To specify the results, a non-linear regression model was applied (Eißing and Dittmar 2011). This enabled us to estimate the elevation of the growing site and separate imported timber.

The results show that the used conifers originated most likely from higher elevation sites. For the Upper Isar area, this could be the Bavarian Forest, the Tertiary Hills, or the Bavarian Upper Moraine and Molasse Foreland. Thus, the examination of tree-ring data rewrites the hitherto existing history of rafting and timber transport in southern Germany.

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Dendrochronology in *Flanders Fields*: timber supply during World War I

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KEY WORDS: WWI, archaeology, wood anatomy, dendro-provenancing

During the First World War, the landscape along the European Western front was mutilated by warfare and military operations. In Flanders, a front line along the Yser river was held by Belgian forces. Along low ridges around the town of Ypres, Allied and German troops entrenched themselves for about four years.

The military operations fuelled a constant demand for timber: for constructing and maintaining trenches, deep-dugouts and footpaths. Soon local woodlands were depleted and forests in France and England became of strategic importance in order to maintain a continuous supply of timber to the battlefield.

Today, infrastructural works in the former front zone often unearth WWI structures and finds (Robertshaw 2008). During subsequent archaeological field campaigns wood is by far the most prominent finds category, in terms of its volume.

Ca. 350 timbers of structures and deposits from WWI were examined. Thin sections were made for wood species identification. Simultaneously, it was assessed whether these timbers were suited for tree-ring analysis, in order to determine the provenance of the wood.

For the first time the spectrum of wood species encountered in WWI trenches was determined, showing a dominance of European softwoods. However, also some North American species were identified (Haneca 2016, Van Acker *et al.* 2017). Only few timbers were suited for tree-ring analysis, but these examples already provide more insight in the procurement and transport of timber to the battlefront.

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20 years of archaeological wood dating

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KEY WORDS: dendroarchaeology, collecting, measuring, dating - an overview of the last 20 years

In 1968, the dendrochronological department was invented at the former Academy East in the GDR. Since 1988, the department is working under the head of the laboratory, Karl-Uwe Heußner. In the first years one of the main problems was to get enough samples to compare and build up long chronologies. It started with 60 samples of one excavation. It lasted over a year to work on them and finally being able to date them. Today a 2-person team is working with five- to six thousand samples a year. As a result, it was possible to build up more than nine main chronologies of common tree species for the last 1000 years and longer. Overall the laboratory is working with more than 15 tree species and has measured approximately more than 15 million rings for the last 20 years. All this data give a great chance for more detailed analysis of climate and growing. That is why the laboratory is working in close cooperation with different other institutes to use the mass of information and to build up new scientific views for the last several centuries. Let us have a look back on all what was happening and let us see what all could be possible.

Timber for *Batavia*

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KEY WORDS: shipwreck, timber trade, Dutch East India Company, *Batavia*

Batavia set sail from Amsterdam in 1628 with over 300 people on board, bound for the Dutch East Indies. It became wrecked on the Houtman Abrolhos islands off the west coast of Australia before reaching its destination, and those islands were the scene of mutiny and murder before the survivors were eventually rescued. The remains of the ship were located in the 1960s and excavated in the 1970s, and are now displayed at the Western Australian Museum in Fremantle.

Over the last couple of years these timbers have been the subject of dendrochronological analysis by us, to understand how shipbuilders selected the trees and organised the supply of timber in terms of procurement areas and timber products. We know that timber in the early 17th century was shipped to Amsterdam in great numbers, and the study of the surviving timbers from *Batavia* would give us a snapshot of this timber trade for shipbuilding.

These results of the dendrochronological investigation of *Batavia* will be presented here, and compared to the timber trade evidence dendrochronology is providing through analysis of other Northern European shipwrecks from the same time.

Is dendrochronology enough to establish the date and provenance of Iberian shipwreck timbers?

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KEY WORDS: chronology building, deforestation, historical timbers, timber trade

With the aim to establish the date and provenance of wood from Iberian shipwrecks, a network of oak and pine chronologies has been developed in key areas of the Iberian Peninsula that supplied timber for shipbuilding activities from the 16th to the 18th centuries.

The dataset comprises i) 619 oak samples from 15 sites in the north of Spain, including four species: *Quercus robur*, *Q. petraea*, *Q. faginea* and *Q. pyrenaica*, the latter two being endemic and almost restricted to the Iberian Peninsula; ii) 702 pine samples from 10 sites in central and southern Spain, including two species: *Pinus sylvestris* and *P. nigra*; and iii) 214 oak and 157 pine timbers from historic buildings located in the vicinity of the selected forests.

The chronologies from living oak trees reach back to the 16th century, and have been extended to the 14th century with the historic material. Most of the pine chronologies span more than 400 years, with two of them covering the 14th century almost entirely. The pine historic material has extended the chronologies back to the 13th century.

These chronologies were tested with 150 oak and pine timbers retrieved from 10 shipwrecks suspected to have been built in Iberian shipyards. Results show a very low dating success. The potential reasons for this will be presented and discussed in the light of the forest history of the research areas, the historical timber trade, and the inter- and intra-correlations between oak and pine species, respectively.

The ForSEAdiscovery Project – How wood powered the Iberian World Exploration

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KEY WORDS: dating, dendroprovenancing, shipwrecks, Iberian Peninsula

The period from 16th to 18th centuries is known in the world history as the Age of Discovery. Technological development in shipbuilding and navigation advances enabled the exploration of the New World and connected continents. Ships were built until mid 19th c. exclusively of wood. As Urteaga (1987) wrote: "wood was the first and most important natural resource for building navies for expansion and conquest of the new territories, as well as for subsequent merchant operations". Timber resources were limited and Albion (1923) compared the timber problem to the present oil problem. The importance of timber supplies was usually underestimated, and we decided to join forces of historians and wood scientists to get these relationships and their evidence out from the darkness of the past.

Oak and pine were the main sought-after wood species for construction of ocean-going ships. Therefore we focused our tree-ring study on Andalusia as the main region supplying shipyards in pine, and Cantabrian area as the "kingdom of oak". Still existing spots of old forests helped understand problems of forest exploitation for shipbuilding. Shipwrecks and contemporary historic buildings gave a direct glimpse of material building the foundations for the expansion of empires. Ten selected buildings yielded oak chronologies going back to AD1326. Historic buildings in Andalusia extended the *Pinus nigra* chronologies back to AD1219. The presented set of chronologies look satisfactory from the point of view of temporal coverage, but a quick glance at the map of Iberia will immediately show that we just made "a good start". Proportion of dated and undated Iberian shipwrecks delivers the best confirmation.

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Dating and dendroprovenancing of the timber used in the Yenikapı Historical Jetty (İstanbul, Turkey)

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KEY WORDS: Yenikapı, dating, dendroprovenancing, dendroarchaeology, historical jetty

The purpose of this paper is to present the results for identification, dating and provenancing of the wood used in a historical jetty in İstanbul-Yenikapı. A total of 435 samples were collected for wood identifications, and 140 samples for dating.

354 of the timbers were identified as *Quercus* sp.-Group *Quercus*, 57 *Quercus* sp.-Group *Cerris*, 15 *Abies* sp, 4 *Pinus nigra* Arnold, 4 *Fagus* sp, and 1 *Acer* sp. We conclude that oaks were the main wood in the construction.

The best statistical values - GLK 74%***, and t-value 11.4*** - for oak the samples were obtained against the Vezneciler oak chronology. The dating result is 1762-1763 and this result was confirmed by archaeological documents. Tree-ring patterns at both sites indicate that the southern part of the Balkans (northern Greece and Kosova) was the main region supplying İstanbul with oak timbers for construction in that time. For the dating of the fir samples, three chronologies (from Bolu, Karabük, and Kastamonu) were used and the cutting date was determined as 1906. The best results were obtained with the Kastamonu chronology (GLK 75%***, and t-value 9.29***). The origin of these fir samples may be the Kastamonu-Küre forests, only some 15 km apart from the Black Sea port of İnebolu. Fir might have been transported from İnebolu via the Black Sea to Yenikapı, an easy two or three days' sail along the Marmara Coast.

Finally, we can conclude that in Ottoman times construction in and near Yenikapı, next to the Theodosian Harbor, was continuous, just as it was in Byzantine times.

Dendrochronological evidence for the early trade in timber between the British Isles and the American colonies

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KEY WORDS: American oak, 18th century, 19th century, timber trade

Dendrochronology is beginning to identify small amounts of imported American white oak (*Quercus alba*) in 18th and early 19th century contexts in the British Isles. The oak has been found in a variety of contexts; in buildings in Scotland and England, in boatwrecks in Dublin and the Western Isles of Scotland. American oak in 19th century contexts is not unexpected; the Napoleonic Wars and the blockade of Baltic trade routes forced the British government to look elsewhere for their timber supplies and America, with its vast forests, was the obvious source. However, some of the oak found in Scottish and Irish contexts is much earlier, predating the American War of Independence. Dendroprovenancing suggests that a major early source was the Boston area in eastern Massachusetts, but later timber was also coming from further south, from New York and Pennsylvania.

One of the reasons for the establishment of the American colonies was they would be able to furnish Britain with the timber that was increasingly in short supply at home. However, the focus of this early trade was the provision of masts for the British Navy and while this has been extensively researched (Albion 1926) very little is known about the early trade in non-naval, ie domestic timber products between America and Britain. The growing tree-ring dataset therefore has the potential to provide information on the nature of this trade, the type of timber being imported and its final destinations.

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The Jordaens Van Dyck Panel Paintings Project – first dendroarchaeological insights

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KEY WORDS: dendroarchaeology, *Quercus* sp., Flemish artists, Van Dyck, Jordaens, 17th century, dendroprovenancing

For the first time, dendrochronology is being applied to a comprehensive and multidisciplinary study of 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.

In this presentation, we explain the uniqueness of this project, and its importance, from a dendrochronological perspective. We reveal preliminary results of non/micro-invasive dendrochronological analyses and the dating of 180 oak planks of ca. 90 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.

Towards spatiotemporal tree-ring width data for Europe

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KEY WORDS: radial tree growth, gridded data, Earth system science, random forest regression, climate anomalies

Tree-ring data are an underexploited resource in Earth system science, partly because their representation of global forests is discontinuous and overlaps insufficiently with modern Earth observations. Improving this representation is of broad research interest and we need to seek ways of estimating radial tree growth where measurements are missing.

We report on efforts to produce gridded tree-ring width (TRW) products for the most abundant tree genera in Europe (*Abies*, *Fagus*, *Larix*, *Picea*, *Pinus*, and *Quercus*). We used ten monthly-resolved climate variables from the CRU TS3.22 dataset (1901-2013) as predictors in random forest regressions to estimate TRW anomalies at each site. These models explained 30-40% of the variance in the site chronologies, with slightly lower values obtained for *Larix* and *Pinus*. Adding monthly gross primary productivity from global vegetation models as predictors did not improve the performance and neither did a dimension reduction using principal component analysis.

With these random forest regression models, we can predict spatialized and yearly resolved TRW anomalies across the distribution range of each genus. Ongoing efforts aim at improved model performance by i) reducing the autocorrelation in the predictions, ii) excluding disturbance years (e.g. larch bud moth), and iii) adding further training datasets. The resulting gridded products are expected to considerably increase the utility of tree-ring data for interdisciplinary research agendas.

Tree-growth divergence – a global phenomenon?

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KEY WORDS: individualistic growth response, growth divergence, multivariate statistics, transfer functions, climate reconstruction

Tree-ring data are considered an essential cornerstone of paleoclimatology and a valuable tool for predicting climate change impacts on forest ecosystems. However, a growing body of literature indicates, that the standard dendrochronological approach to evaluate tree-ring data may too rigorously neglect individualistic tree-growth: Trees of the same species sampled at one site may express different long-term growth patterns and therefore differing climate-growth relationships. This phenomenon is commonly termed growth divergence (GD) and might weaken our ability to correctly estimate past climatic extremes and variability, project future forest growth, and benchmark mechanistic models. Yet, there we lack detailed information on the frequency, magnitude and severity of GD occurrence. Here, we present results from a global GD assessment covering 135 data-sets from 50 tree species distributed over 116 sites across 22 countries. We found clear signs of GD in 85 percent of all data-sets. When accounting for GD, explained variance and stability of climate transfer functions increased remarkably. A multiple linear regression based on sample size, latitude, and climatic water balance significantly was able to explain 37 percent of global GD variations. These results advocate for an incorporation of GD assessments into dendrochronology to increase the precision of climate reconstructions as well as the prediction of forest ecosystem responses to global change.

A new look at tree-ring standardization

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KEY WORDS: tree-ring index, tree-ring standardization, regional curve standardization, missing ring, dendroisotopic data

Tree-ring series of individual trees are standardized (detrended) before the mean chronology is calculated. To do so, the millimetre data of tree-ring widths is transformed into series of dimensionless indices. In order to surmount the loss of the original growth measurements, a new method was previously proposed (Helama 2015). Simply, the tree-ring growth is obtained through ranked transformation of the tree-ring values within the user-defined reference age class (RAC) and all remaining cambial age classes. The RAC chronology is presented on the scale of growth measurements of the specific tree's age, instead of dimensionless tree-ring indices. Moreover, the RAC method performs equally to the regional curve standardization (Briffa and Melvin 2011) in retaining low-frequency variability in resulting tree-ring chronology (Helama 2015). Recently, it was suggested to combine the RAC method with conventional tree-ring standardization methods to unite the benefits of both methods, for further removing the non-climatic bias from the data (Helama *et al.* 2017).

The RAC method is applied here to delve into the classical conjectures of dendrochronology and its use is expanded to detrending issues of dendroisotopic data. The method is used to assess a hypothetical temperature/drought threshold(s) for a missing ring and to standardize the tree-ring carbon-13 data with lifelong biological trends (Helama *et al.* 2015). Dendrochronologists no longer need to rely on dimensionless tree-ring data.

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Process-based modeling of tree–climate relations in the Yenisey-Lena transect

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KEY WORDS: VS-oscilloscope, Central Siberia, tree-ring width, tree-ring growth, climate signal, process-based modeling

The response of forest ecosystems to possible climate changes is one of the most principal problems of modern forest ecology. What are the mechanisms of such affection? How climate changes in past affected growth of woody plants and what affect will be in present and future?

This study is aimed at analyzing the internal and external reactions of woody plants of the Northern Hemisphere under conditions of a changing external environment, using the visual parameterization of Vaganov-Shashkin process-based model algorithm, called VS-Oscilloscope, on the existing and new large-scale experimental material (Vaganov *et al.* 2006, Shishov *et al.* 2016). VS-Oscilloscope requires as inputs only study site latitude, daily mean temperature, and daily accumulated precipitation. Thus choice of input data helps to negate the affect of nonclimatic influences, including tree biology, size, age-dependending effects and the effects of localized forest dynamics (fire disturbances, insect outbreaks etc.) (Shishov *et al.* 2016).

The model was successfully applied to simulate tree-ring growth over different regions of Siberia, Central Asia and Mediterranean (Shishov *et al.* 2016, He *et al.* 2017). However, the study areas retained common features throughout their whole length (high temperatures and arid territories, or study areas located in mountains). For this reason, this work is carried out on the territory of the Yenisey-Lena transect, containing on its territory regions with different climatic conditions.

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Cross-validation of ring-width based dendro-provenancing

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KEY WORDS: dendro-provenancing, cross-validation, dendroecology, Alps

According to the main principles of dendrochronology, it is assumed that similar site conditions and micro-climate lead to the formation of similar ring-width-patterns. Thus, dendro-provenancing uses pairwise statistical comparison of ring-width curves for the analysis of growth-similarity. Surprisingly, there have been few attempts to validate this method. Hence, this conference presentation proposes a new cross-validation approach to test the reliability of dendro-provenancing.

This approach is carried out on a dataset of 400 ring-width series from 15 sites located in the foothills and mountains of the north-eastern Swiss Alps. The statistical procedure presented here is a modified k-Nearest-Neighbor search. In this new method, the classification of an anonymized ring-width series is determined by examining varying amounts of Nearest Neighbors. In addition, a plot called 'scissor-plot' is developed. This plot allows for the visualization of a leave-one-out cross-validation, which is used to test the stability of the classification.

The results show a high provenancing performance for the t-value (Hollstein 1980). This t-value has a stable and low misclassification rate ranging between 15% and 20%. The t-value according to Baillie and Pilcher (1973), the fraktionierte Gegenläufigkeit (Jazewitsch 1948) and Gleichläufigkeit (Huber 1943) have a mean misclassification rate above 25%, which is too high for reliable dendro-provenancing of samples from the area under investigation.

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Improved tree ring climate reconstructions using Liebig's Law of the Minimum

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KEY WORDS: climate reconstruction, temperature reconstruction, law of limiting factors

A basic principle of ecology, known as Liebig's Law of the Minimum, is that plant growth reflects the strongest limiting environmental factor (Liebig 1840). This principle implies that a limiting environmental factor can be inferred from historical growth patterns (Fritts 1976), and in dendrochronology such reconstruction is generally achieved by averaging collections of standardized tree-ring records. Averaging is optimal if growth records are composed of a signal of interest plus unrelated noise (Cook 1985), but if variable growth across trees reflects the operation of the Law of the Minimum, averaging is no longer optimal because certain variations reflect a local, more-limiting factor. We use a large collection of Arctic tree-ring density records to show that growth patterns reflect operation of Liebig's Law. Recognition that the Law of the Minimum operates at the level of individual trees can be leveraged to improve the skill of dendroclimatological reconstructions. Improvements in reconstruction skill occur across all frequencies, with the greatest increase at the lowest frequencies. More comprehensive statistical models of tree-growth may offer still greater improvement in reconstructive skill.

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Reconstruction of tropical cyclones in Northeast Asia

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KEY WORDS: typhoon, forest disturbance, climate change, tree rings, stable isotopes, growth release

Typhoons have significantly increased in intensity over the recent decades in Northeast Asia. We aim to provide new insights into the long-term typhoon variations by using a novel combination of tree-ring width data (i.e. release detection) and oxygen isotope composition of tree-ring cellulose. These high-resolution records will allow us to determine long-term and large-scale changes in frequency and intensity of typhoons and improve our knowledge of the specific climate factors forcing typhoon activity. Our preliminary results show the high potential of both growth release detection and $\delta^{18}\text{O}$ of tree-ring cellulose as proxies for typhoon reconstruction. We found that the most intensive typhoons are followed by a high proportion of trees showing a major release along the latitudinal gradient in South Korea (Altman et al., 2013) and in Hokkaido (Altman et al. 2016). Our long-term reconstructions of past disturbances based on 220 cores from *Quercus mongolica* South Korea revealed an increasing typhoon intensity over the recent decades (Altman et al. 2013). This was confirmed here by further extensive analyses of >900 cores from several tree species. Our preliminary comparison of latewood $\delta^{18}\text{O}$ residuals (deviations from the mean of 4 individual tree-ring series) with instrumental records of past typhoons showed that negative deviations of tree-ring $\delta^{18}\text{O}$ correspond with the occurrence of typhoons in the same year.

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How global change fakes medieval hydroclimate – a tree-ring based millennium long drought reconstruction for NE-Europe

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KEY WORDS: drought reconstruction, growth increase, tree-rings, fertilization

Over the last century, fertilization effects (N and CO₂) have markedly influenced growth rates of trees (Pretzsch *et al.* 2014). Therefore, using long-term trends of recent tree growth to reconstruct climatic trends may lead to strongly biased results. For robust estimates it becomes important to either remove the relative influence of these non-climatically induced trends or to assure that their effect was stable over time.

In our study we used a millennium long TRW-dataset from beech wood originating from living trees and historical construction wood from NE-Germany to reconstruct regional summer drought. To enable a direct comparison of the modern period with medieval times, we developed a data adaptive method to identify and detrend the recent non-climatically induced growth trends. This allowed us to use one common RCS for standardizing both wood sources (living and historical) and in turn facilitated a direct comparison of today's summer hydroclimate with the conditions of 1000 years ago. Our results revealed considerably drier conditions during the medieval climate anomaly (MCA) compared with standard reconstruction methods and other existing reconstructions. Although being most pronounced in highly industrialized and/or agricultural regions of Central-Europe, the effect of growth stimulation by atmospheric depositions might also be apparent in more remote boreal regions and potentially impact TRW-based temperature reconstructions from this area.

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The relationship between seasonal moisture in central United States, 1685-2015

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KEY WORDS: dendroclimatology, seasonal reconstructions, climate prediction

Land-surface feedbacks impart a significant degree of persistence between cool and warm season moisture availability in the central United States. However, the degree of correlation between these two variables is subject to major changes that appear to occur on decadal time scales, even in the relatively short 120-year instrumental record. We present two separate 331-year long seasonal moisture reconstructions for the central United States, based on subannual and annual tree-ring chronologies that have sensitive and discrete seasonal moisture signals, and provide an estimate of May soil moisture balance and a second estimate of June to August atmospheric moisture. The predictors used in each seasonal reconstruction are not significantly correlated with the alternate season target. Both reconstructions capture over 70% of the interannual variance in the instrumental data for the calibration period and also share significant decadal and multidecadal variability with the instrumental record in both the calibration and validation periods. The instrumental and reconstructed moisture levels are both positively correlated between spring and summer, likely due to land-surface feedbacks, and strongly enough to have potential value in seasonal prediction. However, the relationship between spring and summer moisture exhibits major decadal changes in strength and even sign that appear to be related to large scale ocean-atmosphere dynamics in general and the Atlantic Multidecadal Oscillation in particular.

Reconstruction of summer temperatures from tree rings of Scots pine (*Pinus sylvestris* L.) in western Norway

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KEY WORDS: temperature reconstruction, tree-ring width, maximum density, dendroclimatology

A tree-ring chronology spanning from 1237-2008 AD has been made from Scots pine trees growing in Sogndal, western Norway. The climate in this area is greatly influenced by air-masses originating in the Atlantic, and is moist with warm winters, producing a climate signal centred on July temperature for the ring-width chronology.

A subset of the samples, which were cored with a 10 mm increment corer, were used to make a densitometric chronology using an ITRAX Multiscanner from Cox Analytical Systems (<http://www.coxsys.se/>). This chronology was detrended with the signal-free approach of Melvin and Briffa (2008), producing a reconstruction of July-August temperatures reaching back to ca. 1500 AD.

The two reconstructions, i.e. ring width and maximum density, reflect summer season temperatures in the south-western parts of Norway, and show many common characteristics with reconstructions from Jämtland in the Central Scandinavian Mountains (e.g. Gunnarson *et al.* 2011). For the density reconstruction, there is also a certain overlap with temperatures in the northern parts of Scotland, although they are weaker than correlations with those in southern Scandinavia. No persistent relationship was found with the NAO, which probably reflects its periodic influence on the climate in western Norway.

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Growth responses of *Abies pindrow* to climate along elevational gradient in north-western Himalayas

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KEY WORDS: dendroclimatology, *Abies pindrow*, tree-ring width

The relationship between regional climate and tree growth is not well understood in the case of Himalayan conifers. Previous studies have shown a huge dendroclimatic potential of Himalayan conifers (Hughes 2001). In order to understand the response of trees to regional climate along an elevational gradient, increment cores were extracted from *Abies pindrow* at three elevational sites. Total ring width was measured and crossdated. The raw series were standardised and site chronologies were built. Static and moving bootstrapped correlations and response functions were computed between the site chronologies and monthly climatic variables. Low and mid elevation trees showed significant negative relationships with the growing season May and June temperatures, and positive with May precipitation, while the high elevation trees showed a significant positive relationship with January temperatures and overall positive relationships with growing-season temperatures, and did not show any significant response to precipitation. Also, moving correlations showed that response of radial growth to growing season temperatures weakened in the second half of last century. Similar results were shown by a recent study of growth-climate relationship in Himalayan conifers (Sohar *et al.* 2017). Warm temperatures in early spring could induce earlier snowmelt thereby lengthening the growing season in high elevation trees, and could enhance evapotranspiration and decrease the amount of available soil water in lower elevation trees.

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Inverse responses of Korean pine (*Pinus koraiensis*) and Mongolia oak (*Quercus mongolica*) growth to recent warming in northeast China

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KEY WORDS: divergent response, tree rings, global warming, relative humidity, standard precipitation/evapotranspiration index

Different tree species growing in the same area may have different, or even opposite growth responses to climate change. Korean pine and Mongolia oak are two crucial species of the temperate forest ecosystem in northeast China. Three chronologies for Korean pine and Mongolia oak were developed by using the zero-signal method to explore growth response of the two species to recent warming. Results showed that Korean pine growth was mainly limited by monthly minimum temperature. With the latitude decreasing, the precipitation-growth relationship of Korean pine changed from negative to positive correlation, and the positive correlation with monthly temperature was gradually weakened. In contrary, Mongolia oak growth in the three sampling sites was significantly positively correlated with precipitation in growing season and the negative correlation with monthly temperature decreased with the latitude decreasing. The radial growth of Korean pine at different sites showed clearly discrepant responses to the recent warming since 1980. Korean pine growth in the north site increased with the temperature increase, decreased in the Midwest site, and almost unchanged in the southeast site. Conversely, Mongolia oak growth was little or not affected by the recent warming. Our finding suggested that tree species trait and sites are both key factors that affect the response of tree growth to climate change. The distribution area of Korean pine may move northward in the future.

Micro-site conditions significantly affect growth performance and climate signals of Scots pine at its northern distribution limits

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KEY WORDS: *Pinus sylvestris*, tree-ring width, wood density, micro-site, treeline, individualistic growth response, growth divergence

At its northern distribution limits, growth of Scots pine is generally driven by summer temperature. However, some studies found a decoupling of tree growth and summer temperature in certain parts of boreal Eurasia and propose reduced water availability as a possible explanation (e.g. Wilmking *et al.* 2005). Moreover, Duthorn *et al.* (e.g. 2016) demonstrated that differing micro-site conditions influence Scots pine growth in Fennoscandia.

To investigate the effect of differing micro-site conditions on a broader spatial scale, we analyzed tree-ring width (TRW) and maximum latewood density (MXD) over six sites, spanning three latitudinal gradients in Eurasia (Finland, Western and Central Russia), and included dry and wet micro-site conditions at each site. Per site and proxy we performed a Principal Component Gradient Analysis (PCGA) to explore the existence of sub-populations with different growth patterns. For each identified sub-population proxy, climate-growth relationships were calculated.

At five out of six sites, PCGA showed a clear distinction between dry and wet micro-sites. Corresponding climate correlations were stronger on dry than on wet sites with more pronounced effects for TRW in comparison to MXD. Concluding, our preliminary results corroborate the assumption that Scots pine growth might be affected by micro-site conditions, which certainly has implications for dendroecological and -climatological studies.

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Connecting conifer radial growth to potential frost damage events identified from meteorological records

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KEY WORDS: frost damage, frost hardiness, tree growth, snow cover

The aim of this study was to examine if temperature conditions potentially causing frost damage are associated with radial growth declines in Norway spruce and Scots pine. We hypothesized that frost damage reduces radial growth due to 1) extreme cold winter temperatures, 2) insufficient level of frost hardiness, and 3) lack of insulating snow cover during freezing temperatures, resulting in low soil temperatures.

Meteorological records were used to define variables describing the conditions of each hypothesis and a frost hardiness model was used to find events of insufficient hardiness levels. As frost damage is likely to occur only under exceptional conditions, we used generalized extreme value distributions (GEV) in the analysis.

Our results did not show strong connections between radial growth and frost damage events. However, growth reductions were found at some Norway spruce sites after events of insufficient frost hardiness levels and, alternatively, after winters with high frost sum of snowless days. In Scots pine, growth reductions were not found to be related to any of the studied variables. Thus, radial growth in Norway spruce may be more sensitive to future changes in winter conditions. Our results demonstrate that considering only temperature is unlikely to be sufficient in studying winter temperature effects on tree growth. Instead, understanding the effects of changing temperature and snow conditions in relation to tree physiology and phenology is needed.

Divergence of tree growth and summer temperature at treelines in East-Central Europe

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KEY WORDS: dendroclimatology, treeline, Sudetes, Carpathians, climatic change, pollution

There is growing evidence of recent decoupling of tree growth from temperature across cold regions such as northern or mountain treelines. Increasing or diminishing regional coherency in tree growth has been observed as well. Pollution has been frequently discussed as possible cause of divergent or convergent growth patterns. At treelines in Czechia, Poland and Slovakia (50° N, 15-20° E), we compiled climatic records and robust tree-ring chronologies of *Picea abies* from four regions differing in acid pollution load. The divergence of radial growth and Jun-Jul temperature was compared with temperature and pollution trends. We determined a period of low intra-regional growth coherency in 1950s reflecting warm conditions and abrupt land-use change. Highly coherent growth in the 1930s, 1970s and 1980s was related to a strong environmental growth-limiting signal of short growing seasons and acid pollution load. We identified periods with higher (1940-1960s) and lower (1970-1980s) growth than expected according to temperature. In the high-frequency domain, the effect of pollution on growth departure from temperature was limited and visible exclusively in regions with the highest pollution load. In the low-frequency domain, the departures of growth from temperature were caused by combined effects of changing the seasonal window of tree growth sensitivity to climate and pollution load. Our study highlights the need for the recognition of non-stationary noise in relation to temperature and tree growth.

Effects of past and future seasonal trends on species growth in the Black Forest, Germany

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KEY WORDS: Central Europe, climate change, climate–growth relationships, dendroecology, Douglas fir (*Pseudotsuga menziesii*), Norway spruce (*Picea abies*), Silver fir (*Abies alba*)

Forest management in Europe is heavily relying on the drought sensitive Norway spruce (*Picea abies*) for timber production. Presently, mixed forests are suggested as an adaptive strategy to mitigate the effects of climate change and maintain important ecosystem services. The more drought resistant Silver fir and Douglas fir are considered as potential substitute species in the Black Forest. Here, we assessed the effect of seasonality on tree-ring growth for the last 60 years, and made a projection for the future decades under the RPC4.5-8.5 climate scenarios. The positive correlation to winter and spring temperatures of the growth of firs suggests their ability to take advantage of milder conditions, which was not true for spruce. This early activity could play a main role in the capacity of firs compensating for harsher summer conditions. Droughts play a major part as disturbances to growth, and should be accounted for combined with the overall effects of climatic trends. The species reactions to past drought events, highlighted how spruce is vulnerable to summer droughts, while firs were more resistant and resilient. Growth projections confirm that future climate could lead to an increase of firs growth rates, which in addition to their higher drought resistance, makes them valuable complementary or substitutes species. Adaptive measures should be implemented in the near future as spruce's growth projections indicate a continuous decline, and increasing drought vulnerability.

Increment reaction of silver fir in central Poland to the extreme climate events

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KEY WORDS: *Abies alba*, increment response, disturbance, age dependence

We studied the radial growth of silver fir (*Abies alba* Mill.) from 30 pure and uneven-aged silver fir stands in the Świętokrzyskie Mountains (central Poland). The focus was laid on the response of these stands to increment disturbances by adverse climatic factors. We assessed the incremental response of the stands to situations of reduced growth using indicators of resistance, recovery and resilience (Lloret *et al.* 2011). We also studied the influence of the stand age and the forest habitat type on the disturbances.

The shortest chronology consisted of 94 and the longest of 137 tree rings. Older fir stands were characterised by significantly narrower tree rings. Neither the location, nor the forest habitat type are factors for the rhythm of the radial growth of the firs. Extreme climatic conditions, responsible for the majority of short-term (one-year-long) incremental depressions are the factor of regional importance, which affects the growth of the trees. Older stands characterized by better possibilities of increment recovery after a disturbance than younger stands, which may be a result of the formation of secondary crowns. No consistent differences in the indices of resistance and resilience were found among the analysed stands.

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Dendrochronological analysis of the wild service tree (*Sorbus torminalis* L.) in Poland

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KEY WORDS: tree-ring width, dendroclimatology, wild service tree, Poland

The study was aimed at investigating effects of climatic conditions on annual growth of the wild service tree in Poland. A total of 612 trees (984 samples) at 31 sites were sampled. The wild service tree can be regarded as a slow-growing species: its mean annual growth increment amounts to 1.44 mm. A total of 31 local chronologies, extending over 74 (1940-2013) to 238 years (1776-2013) were developed, each consisting of 3 to 16 individual growth curves. Cluster analysis allowed distinguishing two service tree dendrochronological regions in Poland and a single site characterised by different habitat properties and water regime. The local and regional chronologies formed a basis for dendroclimatology analyses: analysis of signature years as well as correlation analysis and response functions. The correlation analysis and the response functions indicated insolation as the dominant factor shaping the service tree cambial activity: a low number of hours with sun in the preceding year (particularly in September) and in the current year (June-July) favours the development of wide growth rings. Similar relationships are observed for the air temperature. Precipitation showed only positive values of correlation and regression: high precipitation sums in the preceding and current growth season resulted in the development of wide rings. The growth-climate relationships point to a substantial role of meteorological conditions in the preceding growing season on the magnitude of growth in the current year.

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Wood formation and tree-ring variation in different species on different sites

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KEY WORDS: wood formation, dendrochronology, *Fagus sylvatica*, *Picea abies*, *Pinus halepensis*, *Pinus sylvestris*

Combined studies of inter-annual tree-ring variation and intra-annual wood formation on a cellular level help to better understand the environmental signals registered by a tree during growth and to understand/predict the climate-growth relationships. Such studies have been conducted in Slovenia and Spain in temperate, Alpine and Mediterranean environments. European beech (*Fagus sylvatica*), Norway spruce (*Picea abies*), Aleppo pine (*Pinus halepensis*) and Scots pine (*Pinus sylvestris*) have been investigated (Prislan et al. 2013, Gričar et al. 2015, Novak et al. 2016).

The results show that intra-annual wood-formation patterns are site- and species-specific and vary in accordance with altitude, latitude and the climatic zone. Tree-ring variation reflects the site- and species-specific response to climate in most cases, also when different species grow on the same site. Wood formation monitoring helped us to record the development of wood anatomical traits like intra-annual density fluctuations (IADF). We also recorded the processes leading to the occurrence of missing rings or dark rings. The collected data have been also included in global data sets and studies which help to predict how climatic changes affect tree productivity and survival. As *Picea abies* is an important wood species for making musical instruments, our studies also help to explain some problems related to dendrochronological dating of violins.

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Measuring the adaptive potential of European larch to climatic changes using wood-formation monitoring

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KEY WORDS: wood formation, larch, cambial activity, French-Alps

Long-term emission of greenhouse gases will result in lots of long-lasting changes in all components of the climate systems. Monitoring wood formation is a way to see how tree species are affected by these changes. Temperature is among those ecological factors showing an altitudinal trend. Therefore, trees growing in mountain forests can provide very unique data about how trees are responding to the recent environmental changes. In this study *Larix decidua* Mill. trees growing along an altitudinal gradient were selected for wood-formation monitoring. After the preparation of anatomical slides, the number of cells in the cambium and in each phase of differentiation were counted. The results showed an earlier resumption of cambial activity on the bottom sites, the cambial activity started by one month earlier than on the top site. A linear trend was observed for the onset of cambial activity from the bottom site toward higher elevations ($bE=0.024Alt+107$) that can be translated into 3 days/100 m altitude. At lower elevation, with an earlier resumption of cambium, a longer duration of cambial activity was expected but in contrary it was limited. The shortening of the growing season at the bottom site can be related to water availability limitation and the anisohydric characteristics of this species in water limited areas. The shortest period of cambial activity at the top site can be explained by temperature limitation making the middle altitude as the optimum site for the wood formation.

Do the non-native pines follow the cambium dynamics of the native Scots pine (*Pinus sylvestris* L.)?

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KEY WORDS: cambium phenology, wood formation, Scots pine, black pine (*P.nigra*), pitch pine (*P.rigida*), eastern white pine (*P.strobus*)

In Polish national forests, about 30 non-native tree species grow, which is about 75% of the local tree species (Gazda and Augustynowicz 2012). Scots pine is the most common tree in different forest types and covers more than 70% of the forested area in Poland (Białobok *et al.* 1993). In terms of observed climate change the importance of non-native species in forest communities may grow, because of their possibility to be more competitive and may replace the native trees, which may be more sensitive to changing environmental conditions (Battipaglia *et al.* 2009). The aim of this study is to examine climatic sensitivity and radial growth patterns of *Pinus nigra*, *P. rigida* and *P. strobus* in comparison with native pine. To this purpose, three study sites near Torun where selected and at each one non-native pine and Scots pine co-exist. From March to October 2016, samples of the cambial region and developing xylem were taken by means of a Pressler borer at 5-14-day intervals. In total, 384 samples (i.e. 24 samples from each tree) were taken from 3-5 trees. The highest similarity between xylem-widths of Scots pine and non-native trees was observed with pitch pine (t-value 9.0) and the lowest with eastern white pine (t-value 3.5). The differences were observed for example during the process of lignification which starts earlier in the native pines and in *Pinus strobus* (observed on 9th of May) than in *P. rigida* and *P. nigra* (observed on 6th of June).

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Vessel-based pointer-year analyses reveal different adaptation strategies of ring-porous and diffuse-porous species

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KEY WORDS: wood anatomy, *Fagus sylvatica*, *Quercus petraea*, ROXAS

Investigating tree responses to extreme events can help to better understand adaptation strategies to climate/environmental variability. While analysing tree-ring width over time gives insights into annual growth responses, cell-anatomical analyses provide intra-seasonal insights with a link to water transport. It is still unknown whether co-occurring diffuse- and ring-porous species show the same responses to environmental drivers.

Vessel-based parameters of *Fagus sylvatica* L. and *Quercus petraea* (MATT.) LIEBL. were collected for negative and positive pointer years since 1900. Two sites with different moisture conditions in Thuringia (central Germany) were sampled. 9 parameters (incl. mean vessel area, vessel density, theoretic hydraulic conductivity) were collected for 29 pointer years, including especially dry and moist years according to scPDSI.

Preliminary results show that the number of vessels in oak was nearly constant in favourable and unfavourable years, whereas in beech it significantly decreased during unfavourable conditions. In negative pointer years, oak trees at the dry site decreased tree-ring width, total vessel area and maximum vessel area, whereas at the wet site only the tree-ring width decreased. The inverse response occurred under favourable conditions: at the dry site tree-ring width, total vessel area and maximum vessel area increased, whereas at the wet site only tree-ring width increased - exhibiting a higher sensitivity of oaks at the dry site.

Vessel lumen area, $\delta^{13}\text{C}$ and $\delta^{18}\text{O}$ in juvenile poplar plantations

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KEY WORDS: *Populus*, water deficit, juvenile trend, phenotyping, delta 13C

The simplicity of poplar cropping (*Populus* spp.) in fast growing tree plantations, the ease of vegetative propagation, and their excellent growth and biomass yield have resulted in a growing interest in poplars for Europe's bio-economy. Poplar breeding has been carried out for ca. 150 years. Species were introduced to produce hybrids that grow faster than the native species.

However, poplar breeding is different from common plant breeding. It takes multiple years until phenotyping / selection can be carried out. In practice, this period takes minimum 3 years for poplars in dendro-biomass crops. It is complicated to compare clone performance by measuring physiological and growth traits over several years; this requires breeding collectives (tall trees, several trial plots). Even weighing single-tree biomass is more complicated than, for instance, weighing maize plants. Alternatively, the tree-ring archive provides an excellent opportunity to support phenotyping for poplar breeding.

The presentation will illustrate how tree performance can be read retrospectively with dendrochronological methods. The juvenile development of isotope signatures ($\delta^{13}\text{C}$, $\delta^{18}\text{O}$) and of vessel lumen area (A_v) will be presented. As the fast growth of poplars requires relatively large amounts of water, clone-specific differences will be evaluated in terms of water relations and drought resistance. An outlook will be given on other traits that were tested for practical relevance in tree improvement.

Exploring the influence of kinship structure on tree growth performance of *Picea abies*

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KEY WORDS: individual growth pattern, growth–climate correlations, genetic relatedness, microsatellites, multidisciplinary approach

Tree cambial growth is a complex phenotypic trait resulting from the interaction of several determinants such as age, climate, and genetics. However, only few studies have tried to assess the genetic influence on tree growth performance in natural populations.

Here, we studied the relationship between kinship structure and dendrochronological responses in five *Picea abies* stands along two altitudinal transects located one in the Northern Apennines (Italy) and one in the Bavarian Forest (Germany). We collected increment cores from 313 (Italy) and 172 (Germany) adult trees and we genotyped them with 11 nuclear microsatellites.

We aimed at *i*) assessing the variability of annual radial growth and growth-climate relationships at the individual tree, forest stand and transect level, and *ii*) testing whether genetically related trees show similar growth performances using Mantel and permutation-based tests, and mixed-model regression analysis.

We found a high variability of growth and growth-climate correlations at individual and stand level. In some stands genetically related trees show a slightly higher growth synchronicity.

With this work we intended to foster further research for linking dendrochronological and genetic data to explain inter-individual growth variability and understand its relevance in adaptive processes.

Climate driven trends in tree biomass growth show asynchronous dependence on ring width and wood density variation

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KEY WORDS: BAI, X-ray CT scan, radial growth, mixed-effects models

Tree growth plays an important role in the global carbon cycle, and is therefore considered as a climate change mitigation strategy. But climate change may also influence the carbon sequestration capacity of trees by influencing their growth. Tree cores provide a retrospective view on tree growth, but the usual reporting of tree-ring width trends does not consider potential co-variation of wood density. We therefore propose the correction of the annual basal area growth with the average wood density of the corresponding tree ring as a better proxy for biomass increment, and thus for sequestered carbon. The goal of this study was to evaluate the effect of long-term changes in tree growth and wood density on the aboveground biomass. Using a mixed modeling technique long-term changes in tree growth, wood density and aboveground biomass can be determined. In combination with climate data the drivers of changes in tree growth and wood density could be detected. This is done for common beech (*Fagus sylvatica*) and sessile oak (*Quercus petraea*) from the Belgian Ardennes. The models indicate that aboveground biomass changes through time are mostly driven by changes in tree growth rather than changes in wood density. Though, the assumption that wood density is constant in most carbon sequestration studies is not correct. For beech, ignoring wood density results in an underestimation of long-term change in aboveground biomass. For oak, the absolute value of the long-term change in aboveground biomass is overestimated when wood density is not considered. Besides, different climate variables are influencing tree growth and wood density, tree growth is mostly driven by climate variables of the current year wood density is more driven by the climate variable of the previous year. Climate change might thus affect tree growth and wood density differently.

Earlywood vessels explain the role of climate on wood formation of *Quercus pyrenaica* Willd. across the Atlantic-Mediterranean boundary in NW Iberia

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KEY WORDS: dendrochronology, oak, quantitative wood anatomy, climate–growth relationships

Quercus pyrenaica is a very widespread species in Iberian Mediterranean mountains, and dominates forests along the boundary to the Atlantic region in northern Spain, a transitional area that is very sensitive to potential environmental changes.

In order to understand the role of climate on radial growth, we sampled five stands in NW Iberia, following a transect of increasing elevation in the Atlantic-Mediterranean transition. We obtained tree-ring chronologies of earlywood vessels, which were expressed as hydraulically-weighted diameter, and radial increment expressed as latewood width. Chronologies were compared to monthly meteorological records, and to the North Atlantic Oscillation index (NAO).

Although latewood is controlled by water availability during late spring-early summer all throughout the study area, differences among sites were mainly dependent on the disturbance regime. In contrast, earlywood responses, optimized by considering only the initial row, were more influenced by the topographic position. Thus, the three low-elevation sites, located at windward of a central mountain range, were related to conditions during quiescence, whereas the two other stands responded in early spring. The association between NAO and vessel size was strong, and could be explained by the altitudinal gradient.

The intense micro-, meso-, and macroclimatic responses found highlight the value of *Q. pyrenaica* to understand the behavior of tree species in transitional areas.

Growth characteristics of tree rings in *Pinus halepensis* in the Mediterranean

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KEY WORDS: *Pinus halepensis*, growth dynamics, intra-annual density fluctuations, missing rings

Future climate predictions include global warming, increased temperatures, prolonged droughts, global decrease of precipitation and increased frequency of extreme events. The climate factors strongly influence the growth dynamics of *Pinus halepensis*, a widespread tree species in the Mediterranean Basin. The principal anatomical characteristics of its growth rings are the appearance of missing rings (MR) and intra-annual density fluctuations (IADFs). The methods of dendrochronology, microscopy of the cambial zone and quantitative wood anatomy allowed analysing their occurrence, and the global analysis of the dendrochronological network allowed exploring their biological trends. Contrarily to their consideration as growth anomalies of trees in the negative sense of meaning, they can be interpreted as the variability of growth responses to different environmental conditions. The formation of IADFs is the reflection of the variability of climatic conditions during the growing season and can be used as a proxy for the reconstructions of past environmental conditions with an intra-annual resolution. The occurrence of MR is related to the extreme environmental conditions and can be used as markers for the occurrence of extreme events. The presence of MR and IADFs shows a high plasticity of adaptation of *Pinus halepensis* to the variability and severity of environmental conditions that frequently occur in Mediterranean areas.

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Facing ‘Macaronesian dendrochronology’: Can tree-ring analysis be applied to the Canarian laurel forests?

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KEY WORDS: *Lauraceae*, Canary Islands, subtropical, trade winds

Laurel forests constitute a peculiar ecosystem of the Macaronesian archipelagos of Canaries, Madeira, and Azores. They occur at a certain elevation on windward slopes, as trade winds reach their dew point, causing a persistent fog layer all throughout the year. Humidity is very high, but temperature is not limiting, resulting in forests dominated by species with ‘laurel-type’ leaves (thermophile evergreen trees with no adaptation to xeric conditions). These subtropical ecosystems are considered relict formations of Tertiary European vegetation, and constitute priority habitats for conservation.

Species in Canarian laurel forests have often been referenced as having no distinct rings, but to our knowledge, no dendrochronological research has been attempted up to date. In order to fill this gap, we preliminarily evaluated their dendrochronological potential. For this, we selected two stands in the Garajonay National Park (La Gomera Island), and sampled a representative number of trees of *Laurus novocanariensis* and *Persea indica* (*Lauraceae*), two of the most dominant species in mature, humid forests. Using classical dendrochronological methods of crossdating, chronology computation, and quality assessment, we succeeded at developing site chronologies for both species, and relating them to each other and to climatic data. In view of the results obtained, we discuss the main potentials and limitations of tree-ring research when applied to the Macaronesian laurel forests.

Sapwood rings estimation of Scots pine (*Pinus sylvestris* L.) in Lithuania

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KEY WORDS: Scots pine, tree rings, sapwood, dating, Lithuania

The estimation of sapwood rings of Scots pine was not investigated in Lithuania up to now. We have counted the sapwood rings of 1009 living Scots pine trees from 102 research plots in Lithuania. The age of investigated pines in Lithuania ranges from 34 to 278 years. Our results prove out that the borderline between pine sapwood and heartwood sometimes may cross many tree rings, therefore it causes difficulties in the estimation of the relationship between sapwood and heartwood rings even in the same tree. The results indicate a much higher variation in sapwood rings between sites than in the same site, i.e. the number of sapwood rings of pine is site-specific. Therefore, a high sample depth (replication) is necessary in each age group to obtain a sufficient accuracy. Such an accuracy of the sapwood rings is obtained when at least 20-30 trees are included in the respective age group. The relationship between the average number of sapwood rings and the age of the tree is well approximated ($R^2 = 0.98$) using a polynomial regression model: $y = -0.0008x^2 + 0.4702x + 13.682$. Using this regression model it is easy to calculate that a 50-year old pine in Lithuania will have 35, a 100-year old pine will have 53, and a 200-year old pine will have 76 sapwood rings, on average. The relationship between the average number of sapwood rings and heartwood rings also conforms ($R^2 = 0.93$) to a polynomial regression model: $y = -0.0023x^2 + 0.6456x + 27.326$. A pine containing 50 heartwood rings will have 54 sapwood rings, a pine with 100 heartwood rings will have 69 sapwood rings, and a pine with 150 heartwood rings will have 72 sapwood rings, on average. According to the model, the number of sapwood rings of trees older than 150 years is stable and will not increase significantly with age.

Advances in dendrochemistry in Chile: Issues of cities, industries and volcanoes

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KEY WORDS: Santiago city, Antofagasta city, Ventanas Industrial Park, Villarrica Volcano

In South America, there are short records of chemical variability in the territory, including rural and urban areas. This information is a mayor issue for the territory planning and to assess the impact of anthropogenic and natural sources over the ecosystems and the human communities. Here we present four study cases of environmental changes from different sources in Chile. The most studied case is the pollution of Santiago, where the dendrochemical records showed high correlations with air-quality records demonstrating the capacity of this technique to capture chemical changes when environmental policies were implemented. In Antofagasta city, dendrochemistry showed coherent temporal patterns with the dynamics of the mining activities in the region. The decadal analysis used in this study did not permit corroborate the dendrochemical record using instrumental data. On the other hand, volcanic eruptions showed pulses of specific heavy metals in tree rings, thus opening a new opportunity to extend eruption chronologies and study its effects in Chile. Finally, in a comparison of trees grown in industrial and non-industrial areas of the same region of Chile, dendrochemical records showed a higher concentration of heavy metals in industrial areas than in non-industrial areas. Here the annual analysis also demonstrated a coherence of instrumental and tree-ring records.

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Dendroarchaeology on Svalbard – Material from shipwrecks and other objects

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KEY WORDS: Svalbard, Svalbard Museum, dendroarchaeology, shipwrecks

Svalbard is a Norwegian archipelago in the Arctic Ocean. Situated north of mainland Europe, it is about midway between continental Norway and the North Pole. According to tradition, Svalbard was discovered by the Dutchman Barentsz in 1596. This means that the history of Svalbard is young. In the following centuries people from all over Europe came here for hunting and whaling.

Svalbard has a rich cultural heritage, and visitors will find traces of human activity everywhere. There is little soil, so even the oldest traces are exposed. Cultural remains are found in coastal areas all around the archipelago. The Svalbard Environmental Protection Act states that all traces of human activity dating from 1945 or earlier are protected elements of the cultural heritage. This applies both to permanent cultural monuments such as sites, graves, buildings and facilities of any kind, as well as to unattached artifacts. The artifacts in Svalbard are vulnerable treasures preserved well in the dry and cold climate. However, they are exposed to the ignorance of passers-by. Every year the Governor of Svalbard systematically records artifacts in Svalbard. This work has been going on since 1976 and provides the basis for a Svalbard artifact database.

Finds are stored at Svalbard Museum (see also: <https://digitaltmuseum.no>). In the present project we decided to start our research by doing ‘fieldwork’ in the magazines of Svalbard Museum. 16 objects were chosen for dendrochronological analysis: Objects of oak (*Quercus* sp.), pine (*Pinus sylvestris*) and spruce (*Picea* sp.). The samples were taken as cores or discs. So far we have been able to date five items – 4 ship parts and one ladder – one piece of oak and four of pine. The oldest object dates to ca. 1730 AD, and the youngest to 1956 AD.

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What drives the regression of beech in the Kłodzko Region (SW Poland)?

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KEY WORDS: *Fagus sylvatica*, growth response, extreme conditions, age dependence

Significant decrease in radial growth of European beech (*Fagus sylvatica* L.) can be observed for the Kłodzko Region (SW Poland) since 1960s. In our study we searched for the factors that might have caused limitation in growth of this species, especially with regard to the age of the analysed stands and environmental conditions they grow in.

We sampled 150 beeches in 18 stands on three locations. The age of the stands that grew on various elevations and in diverse site conditions ranged from 70 to 200 years, while the site index varied from 23.7 to 33.5 m. We developed standard chronologies with the RSC method for both individual locations as well as two age groups (> or < 100 years old). The resulting sequences were correlated against climate variables from CRU TS database. The pointer years were determined and analysed in terms of causes of the extraordinary radial growth. Additionally, we investigated the impact of health status of the trees described with defoliation and vitality on the formation of the extremely narrow tree ring in 2012.

Tree species successions predicted from age structure of broadleaved tree stands in the hemi-boreal forest zone

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KEY WORDS: *Quercus*, succession, nemoral, *Tilia*

The Eastern Baltic Region of northern Europe is at the northern distribution limit of noble broadleaved tree species like *Quercus robur*, *Tilia cordata*, *Ulmus glabra*, *U. laevis*, *Acer platanoides*, *Fraxinus excelsior*, and *Carpinus betulus*. In Latvia, woodland with these species was historically more common on rich soils, but has dwindled now to less than 2% of the forest area, due to past logging and deforestation for agriculture. Broadleaved tree stands have a great value for conservation of biological diversity as they are habitat for many protected epiphytes and invertebrates. It is considered that the establishment of *Quercus robur*, the most common broadleaved tree species, is tightly associated with human activity. However, very little is known of temporal changes in canopy composition. The aim of the work was to reconstruct the past development of stands based on present age structure, to predict future changes. In 50 randomly selected broadleaved tree stands, all trees >10 cm DBH in 20 m*50 m plots were cored. Tree age was determined by standard dendroecological methods. Smaller trees were counted in height classes. *Quercus robur* was not regenerating. In some plots it was replaced by other broadleaved tree species, particularly *Tilia cordata* and *Ulmus glabra*. However, *Picea abies* was frequently establishing in all canopy layers, threatening the conservation value of the stands. *Fraxinus excelsior* was generally lost.

Decay rate of coarse woody debris of *Picea abies*

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KEY WORDS: dead wood, logs, decay, density

Coarse woody debris is an important structure that highly contributes to the value of the forest for biological diversity. Successions of organisms utilize coarse woody debris as a substrate, depending on the decay stage. Coarse woody debris also significantly contributes to the total carbon pool, while being less than for soil. Wood decay leads to carbon emissions, which is often estimated using known coefficients or measurement of respiration. The aim of the present study was to determine mass loss of *Picea abies* logs in Latvia, located in the hemi-boreal zone. Discs were cut by chainsaw at about 1.3 m from the tree base from 50 logs in different stages of decay (scale 1-4). Logs were sampled from 2 areas. Cores were taken from 3-5 living *Picea abies* in the vicinity of the sampled logs. Standard cross-dating methods were used to estimate the time since the mortality of the sampled logs. Volume of discs was estimated based on cross-section area (image analysis of perimeter) and thickness. The decay rate of logs estimated by percentage decrease in density (g/cm³) was 7.7% over 10 years, with extremely high variability. Density decreased from 0.44-0.34 g/cm³ between decay stages 1 to 4.

Disentangling the effect of management on climate–growth relationships, a retrospective analysis of beech and oak stands in a coastal forest in northeastern Germany

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KEY WORDS: *Fagus sylvatica*, *Quercus robur*, tree-ring width, dendroecology, forest management

Understanding how climate change is affecting forest growth is a central concern to be addressed given the important role that forest ecosystems play in the carbon cycle. Adapting forest management strategies to changing environmental conditions is only possible if we disentangle the effects of climate and management. In this study, we do so for typical central European lowland forests while using a retrospective tree-ring based approach. We collected increment cores in *Fagus sylvatica* L. and *Quercus robur* L. stands with similar age structures but different management schemes (managed vs. unmanaged). The tree-ring widths are related to temperature, precipitation, and a drought index (SPEI) to elucidate the climatic forcing of tree growth. Forest management was found to have only minor influence, with unmanaged stands showing slightly higher climate sensitivity. This is probably related to the lower stand density in managed stands, with less inter- and intra-species competition, making managed stands less prone to growth declines under unfavourable conditions (e.g. drought) as climate's influence on growth is smaller. No consistent differences between the two studied species were found. Further studies with added tree species, as well as monitoring efforts are taking place in our sites. Recognizing the compound effect of climate and management will be vital to adapt forestry practices and meet sustainability goals, regarding climate and biodiversity protection.

Determination of treefall gap age by using growth release method in *Picea koraiensis*- *Abies nephrolepis* mixed forest in NE China

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KEY WORDS: *Picea koraiensis*, *Abies nephrolepis*, uprooted tree, treefall gap, growth release, gap age

The degree of decay of uprooted dead trees (UDT) by which a treefall gap (TFG) was formed was classified according to the classification system of Moghimian. In this study, the TFG was only referred to the gap formed by a UDT with a decay grade of II and III. The starting time of growth release of gap-edge trees (GETs) is considered as gap-formed time, i.e., gap age. Boundary-line release criteria were established by the relationship between percent-growth change and prior growth to judged growth release of GETs of *Picea koraiensis* (PK) and *Abies nephrolepis* (AN) in gaps and non-gaps to decide on the gap age. In total, 219 cores were extracted from 31 PK and 35 AP GETs in 14 treefall gaps and 50 PK trees and 25 AN trees in their non-gaps in PK-AP mixed forest in low-lying land in scientifically experimental area of Liangshui' national natural reserve of Lesser Khingan Mountains, NE China, September, 2015. Growth releases in the tree-ring series using boundary-line release criteria were identified to infer the gap-formed age. The results indicated that a total of 182 release events lasting for ≥ 5 years from PK, including 65 major releases and 117 mediate releases, 134 release events lasting for ≥ 5 years from AP, including 55 major releases and 79 mediate releases were identified from 141 GETs. Major releases from both of two tree species were mainly present during 1970-1990 and 2000-2010. The number of treefall gaps at the age of 5, 7-9, 10, 11, and 12 year-old were 2, 3, 2, 1, and 2.

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An efficient protocol for measuring earlywood vessels in ring-porous trees

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KEY WORDS: quantitative wood anatomy, image analysis, wood surface preparation, oak, tree rings

The measurement of earlywood vessels across sequences of tree rings has proved to be a powerful technique to understand the effects of climate on tree growth, especially in areas where ‘classical’ dendrochronology fails to identify reliable relationships. However, this analysis of wood surfaces is still rather time-consuming due to the requirements for both an optimal sample preparation and the multiple steps for image processing.

During the last years, we tested different techniques, and implemented a set of methodologies, devices, and software packages, which let us propose an efficient protocol to obtain dendrochronological series of earlywood vessels. This methodology includes: i) optimal preparation for the visualization of conduits, involving surface cutting by sliding microtome, removal of tyloses with pressurized water, and staining for maximum contrast; ii) sequential image acquisition by means of a self-constructed device that implements a moving platform attached to a digital camera, which is controlled by our own software, and followed by the stitching of all single images; and iii) development of image analysis tools, including the VesselJ plugin to measure earlywood vessels within the free program ImageJ, as well as an application to assign each vessel to the corresponding tree ring.

This protocol allows a fast analysis of a high number of samples, and the automation of some processes avoids many mistakes usually made when measuring earlywood vessels.

TreeRingJ: A plugin to obtain and edit tree-ring measurements in ImageJ

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KEY WORDS: *ImageJ*, image analysis, tree-ring measuring

Recent computer improvements allowed a fast use of high-resolution images. In dendrochronology, the measurement of tree rings is usually carried out manually using a tree-ring measuring device, but very high-quality images can be used with no additional limitation for ring identification. One of the main advantages of measuring tree rings on surface images is also that the exact point that has been measured can be recognized, and therefore crossdating and the correction of errors can be more efficient. Therefore, several software packages allow the measurement of distances (tree rings) across images, or even pattern analysis that can be used to identify ring boundaries.

ImageJ is a free image analysis software that is widely extended in many scientific areas. It is very powerful, and has been written in Java, so that it can be run as multiplatform. In addition, one of its main advantages is that it can be easily extended by writing and redistributing plugins for specific applications.

We present *TreeRingJ*, a user-friendly plugin for ImageJ, which is specifically aimed at obtaining and editing tree-ring measurements from images of the wood surface. By means of this plugin, the user can easily trace the tree rings, calculate the corresponding measurements, and correct them afterwards; it can also be extended by automatically recognize ring boundaries in some cases. We believe that its simplicity will make this plugin very useful not only for research, but also for teaching purposes.

Dendrochronological study of a long-term persistence forest during the Holocene in central Iberia

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KEY WORDS: *Pinus sylvestris*, macroremains, dendrochronology, Spain

Compared with northern latitudes of Europe, the Iberian Peninsula is not a territory suitable for the preservation of tree macroremains. Consequently, only a few sites with subfossil macroremains have been studied, the Iberian Central Range being the most remarkable of these, due to the large number of remains located and analyzed. The Gredos mountain range, in the west, was studied in detail a few years ago; more recently two new sites have been sampled in the Ayllon mountain range, in the east. Of the 52 recovered remains in these two sites, 34 samples have been analyzed by dendrochronological methods and 26 of them were radiocarbon dated. The remains have been ascribed to the genus *Pinus* and most of them have been determined as *Pinus* gr. *sylvestris*. Extraordinarily, given that both sites are very close, they present consecutive chronologies that do not overlap: Valdojos in the first half of the Holocene (8198-5453 yr cal BP) and Sandria in the second half of the Holocene (4349-225 yr cal BP). For the first time in the south of Europe, this set of data allows to elaborate floating tree-ring chronologies with certain continuity throughout the Holocene in a small area. In addition, these data could help to explain the evolution of the paleoecological conditions and the *Pinus sylvestris* forest dynamics in Central Spain over the Holocene.

Evaluating the dendroecological potential of *Pinus pinaster* in the center of the Iberian Peninsula

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KEY WORDS: dendroecology, *Pinus pinaster*, resin tapping, Spain

Pinus pinaster Ait. (Maritime pine) is the pine species which currently occupies the larger extension in the Iberian Peninsula due to its wide ecological range and anthropic management. However, its intensive use for the extraction of resin and wood, makes it very hard to find stands older than 100 years.

Four stands in central Spain, in which some trees exceed 150 years of age, were analysed with dendrochronological techniques, in order to identify and evaluate the dendroecological information contained in these longer-lived trees. Venero claro (Navaluenga, Ávila) and Almenara (Robledo de Chavela, Madrid) sites are at lower altitude (900-1200 m), whereas Hornuez (Moral de Hornuez, Segovia) and La Jarosa (Guadarrama, Madrid) sites are between 1100-1350 m. Our main aim is to compare growth and climate-growth relationships of *P. pinaster* in different ecological conditions and between resin-tapped and non-tapped trees. Moreover, we extend the inventory of local and regional chronologies in Spain, which will allow to contrast the dendrochronological data for different species from a multi-territorial point of view (intra and interregional).

Flood dendrogeomorphological evidence: the best palaeoflood record of a small mountain catchment

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KEY WORDS: flood dendrogeomorphological evidence, historical events

A multidisciplinary palaeoflood study, carried out in the lower stretch of the ungauged Portainé stream (Eastern Pyrenees, Iberian Peninsula), combines and cross-checks Flood Dendrogeomorphological Evidence (FDE) with historical data. In the riparian forest of the study area, 67 damaged trees from 10 species were sampled and analysed. FDE allowed to date with a reliability 10 floods since the middle of the 20th century. Historical data about rainfalls and floods were collected from different sources (county archive, administration catalogue, newspapers, witnesses, etc.). The results show an interesting correlation between FDE-based dated events and documentary data, as the local documented events coincide with the ones evidenced by FDEs. Some regional documented events did not affect the Portainé basin, others cannot be certainly related and some of them can be clearly correlated. Also, there is one example where a recent, well-documented regional flood did not affect the Portainé basin, whereas a very local storm in the same year produced a torrential, damaging flood. The main conclusion is that FDE is paramount for the palaeoflood reconstruction of mountain catchments and reflects very well the local flood history and the dynamics of this small basin, which can behave differently in response to regional rainfall.

This study has been supported by MINECO (CHARMA project, CGL2013-40828-R), and by the University of Barcelona.

Implementing new dendrogeomorphological evidence in Flood Frequency Analysis

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KEY WORDS: flood dendrogeomorphological evidence, decapitation, flood frequency

When a dendrogeomorphological study is carried out in a territory of limited extent, it is essential to use all the available evidence in order to obtain the most reliable and long event record. In a study of changes of torrential floods frequency due to anthropic activities (Portainé stream, Central Pyrenees, Spain), several types of Flood Dendrogeomorphological Evidence (FDE) were analysed.

The studied reach (400 m long) corresponds to an elongated alluvial debris cone (0.5 ha). In this little cone a deciduous broadleaf forest with a great diversity of tree species has recently developed. During field surveys, all the trees showing external damages were sampled using dendrogeomorphological methods and 166 samples of 67 trees from 10 species were collected. Due to the limited number of external scars, other FDE were also studied, dated and related among them; including decapitations, never used before to infer dendrogeomorphological events. In order to estimate the date of the past flood event that decapitated those trees, the date of the inner ring of the replacement branch was related to other dated evidence. Their geomorphological position and decapitation height were also contrasted to the rest of the data. Working with the integration of data and convergence of evidence significantly increased the knowledge on the stream behaviour and on the potential of FDE for flood frequency analysis.

This study has been supported by MINEICO (CHARMA project, CGL2013-40828-R), and by the University of Barcelona.

A new case study of the application of dendrogeomorphology to hydraulic modelling: using tree scars for palaeoflood magnitude reconstruction

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KEY WORDS: dendrochronology, fluvial geomorphology, hydraulic modelling, scar

The application of dendrogeomorphology to the study of geological hazards (e.g. snow avalanches, landslides, rockfalls and floods) is well known since 1960s. Regarding fluvio-torrential processes, the analysis of Flood Dendrogeomorphological Evidence (FDE) allows reconstructing the magnitude of past events.

A multidisciplinary palaeohydrological approach was carried out in an ungauged mountain catchment (the Portainé stream, Eastern Pyrenees, Spain), which combined dendrochronology, fluvial geomorphology and flow hydrodynamics. Among the 12 dated events, the 2008 and 2010 ones were reconstructed by means of hydraulic modelling, using respectively 18 and 6 scars as palaeostage indicators. The obtained peak discharges were $316 \text{ m}^3\text{s}^{-1}$ and $314 \text{ m}^3\text{s}^{-1}$. Hydraulic parameters (water depth, velocity and unit stream power) were also determined for each analysed tree. In order to integrate all the information, flow hydraulics was related to the geomorphic position of the damaged trees.

The present work shows the high potential of the combination of techniques for flood assessment in problematic contexts, such as basins without gauging stations, densely forested areas with poor topographic data, and rivers with few disturbed trees of several species for detailed dendrogeomorphological studies.

This study has been supported by MINEICO (CHARMA project, CGL2013-40828-R), and by the University of Barcelona.

The biggest driftwood sites in Hungary

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KEY WORDS: driftwood, Hungary

The biggest driftwood site of Hungary and probably of the Carpathian Basin as a whole is in the north-eastern part of the country, in the region of the small Sajó River. However, its predecessor, the Old Sajó built a huge alluvial fan on the edge of the Great Hungarian Plain. The finding of nearly hundred pieces of driftwood was discovered in its southern part, around Nyékládháza and Ónod in the mid-1990s. The dendrochronological analysis of the pieces happened shortly after.

In 2010 the region suffered from major flood water after which large-scale riverbed arrangement and flood control works began. During the construction of new dams and canals a considerable quantity of driftwood came to light on the northern edge of the alluvial fan. This finding allowed us to compare the material of the two sites being about 25 kilometres from each other.

The historical and archaeological significance of the research is that small finds dated to the Neolithic were found together with the driftwood discovered in the 1990s, proving that the hydrological circumstances of the region were considerably different from the present situation.

Dendrodated buildings in Transylvania

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KEY WORDS: buildings, medieval churches, historical roof, Transylvania

During the project we managed to analyse about 800 samples coming from 65 objects, and the only missing region remains Mezőség. Based on these, the dendro-regions for oak, spruce and pine started to get contours. The oak chronology goes down till 1172 and a new spruce chronology has been made (1201-1940). For pine, there are more dated series between 1498-1940.

We learned and successfully applied non-destructing measuring methods on art objects. Even first dendro-provenance conclusions could be drawn.

29 roofs were researched, so by now, 60 dendro-dated structures are known from the 14th century till the present day. Typologically these belong to those formed on “Germanic” territories, but some new forms also appear and several types survive long periods. Till the 17th century only oaks and spruce were used for roof structures, but during the century mixed species can be identified and pine appears also, which becomes dominant, even monopolist from the middle of the 18th century.

Publishing and result-sharing was a main focus so along conferences we participated also on university and post-university educational courses. Near site-reports thematic articles were written (see on academia.edu). The Transylvanian laboratory started its own web page (dendrolab.ro) where all sites and results can be read in three languages (Hu, Ro, En).

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Wooden supports for 17th century Flemish panel paintings of the El Prado Museum collection – characterization and dendrochronological study

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KEY WORDS: panel paintings, Flemish art, Prado Museum

The collection of Flemish paintings in the Museo del Prado includes a large number of paintings on wooden supports, several of which are panels by Flemish painters active in Antwerp in the first half of the 17th century.

The project presented here includes a comprehensive study of the supports of a group of 100 works painted by Antwerp artists, including various aspects related to their physical characteristics and manufacturing process. Specifically, information about the species of wood used, the quality, the panel structure (board width and orientation of the wood cut) and their sizes and formats were registered. At the same time, dendrochronological analysis of the oak wood panels was carried out aimed to set its fabrication date and the geographical area of origin of the wood (182 individual planks). Finally, a complete record of all brands present on the surface of the wood on the back, both related to the manufacture of the support was compiled.

Regarding the dendrochronological dating, the results confirm the suitability of this technique for panel painting study, obtaining an acceptable result for 91% of cases: only in the case of very small fragments of wood a valid result was not obtained. Departing from a group of signed panels in which a date appears written on the surface of the painting, it has been possible to estimate the degree of agreement between the result of dendrochronological analysis and the actual historical moment.

The dendrochronological analysis has also revealed the origin of the wood. The Baltic area was the major source over the whole period considered. Nevertheless, around the turn of the century, several examples of local origin are detected, and towards the middle of the 17th century, in a few cases the wood was imported from Germany. These variations in the supply sources are probably related to the economic and political situation in the region.

Relation between English oak tree-ring chronologies from different growth conditions

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KEY WORDS: English oak, forest types, climate

The main goal of our research was to find relations between English oak tree-ring chronologies from different forest types in the National Park “Belovezhskaya pushcha” (Belarus). In total, more than 100 wood samples were taken in stands with oak trees from four forest types - *Quercetum oxalidosum*, *Quercetum aegopodiosum*, *Quercetum urticosum*, *Quercetum pteridiosum*. Master tree-ring chronologies which include trees from different parts of the National park were built for each forest type.

Studies have shown that in almost all investigated stands forest felling was carried out in different years throughout the XIX-XX centuries. In some of them, the influence of drainage melioration is clearly visible, and some of them are even-aged stands, which indicate their artificial origin. This reduces synchronicity between chronologies, despite the rather close location of the stands to each other.

It was found that for oak trees in *Quercetum aegopodiosum*, *Quercetum oxalidosum* and *Quercetum pteridiosum* forest types the main limiting factor is precipitation during June, July and August (positive correlation). In the *Quercetum oxalidosum* and *Quercetum pteridiosum* forest types the additional limiting factor is temperature of June (negative correlation).

Synchronicity between chronologies is reduced by the gradient of soil moisture, while differences in the gradient of soil fertilization are not established.

Tree-ring dating of two historical wooden mosques in Samsun (Turkey)

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KEY WORDS: dendrochronology, oak, wooden buildings

Samsun, located in the central part of the Black Sea Region, has numerous wooden buildings. It is still possible to see good examples of civil and religious wooden buildings in rural areas, while most of them are destroyed in city centers. Samsun Regional Council of Conservation recorded some of the wooden mosques as immovable cultural heritage. However, construction dates of these historical mosques are mostly unclear, while three of these mosques were dated by Peter I. Kuniholm and his team in 1990s. Moreover, these mosques are facing conservation problems caused by biotic and abiotic factors. In this research we have worked on two mosques, one of which has been registered as a cultural heritage (Dere Mosque) and the other one is unregistered (Karlı Mosque). We aimed to find out construction and/or restoration dates of these mosques and determine the conservation problems. For tree-ring dating, we took 11 cross sections from the Karlı Mosque and 7 from the Dere Mosque. We identified tree taxa of all samples as *Quercus* sp. based on their macroscopic features. Then, we measured and dated these samples using standard dendrochronological methods. Our results showed that the floating chronology of the samples obtained from the wall of the Dere Mosque is dated to 1606+, and the chronology of the samples from the base is dated to 1835. These two different dates support the rumor that the mosque has moved from its original location. The floating chronology of the samples from the Karlı Mosque is dated to 1870. Dendrochronological results indicate that this mosque was built in this Circassian village in the same period as the Circassians settled. Our team is still working on the determination of conservation problems caused by users and investigation of damages in wood.

The radial growth of European ash in forest-steppe zone of the West Ukraine

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KEY WORDS: the radial growth, European Ash, climate, groundwater level

European ash (*Fraxinus excelsior* L.) has occupied 1.4% of the area of forest government fund of Ukraine. In forests of the West Ukraine drying of ash trees was revealed in pure and mixed stands. Reasons of these events could be worsening the state of forests connected with changes of climate and groundwater level, the simplification in structure and species composition of forests, infected ash trees by the fungus *Hymenosyphus pseudoalbidus* etc. (Davydenko 2014, Karpavicius and Vitas 2006).

The aim of our research was detecting reasons for the drying ash trees in the forest-steppe zone in the Zhytomyr region by dendrochronological methods.

The object of research was a middle-aged stand growing in moist conditions on gray forest soils. In 2010-2014 mass drying ash trees were detected. This event was expedited for the last two years.

From 1986-2014, the sensitivity of ash radial growth to climatic factors in was higher than from 1956-1985 what indicated a decrease of resistance of stands caused by climatic changes. Depressions of the ash radial growth and increase of root decays are the result of increasing droughts in July and September, increase of winter and early spring temperature that has provoked an increase of the groundwater level. Unsatisfactory state of secondary melioration channels aggravated the state of ash stands.

What it needs to do with ash stands that are losing their resistance and are drying out? Mass cutting of trees will be the reason for swamping in a big area. The best way in this situation is natural regeneration of other species and/or possibly artificial regeneration, more commonly known as tree planting.

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Radiocarbon dated late-glacial Scots pine (*Pinus sylvestris* L.) chronology from Kwiatków (Kolska Basin, Central Poland)

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KEY WORDS: subfossil pine, dendrochronology, Late Glacial, Central Poland

Dendrochronologically dated wood of subfossil trunks of trees presents the basic material for the construction of a calibration curve (Kaiser *et al.* 2012).

In the last years, Koźmin (Dzieduszycka *et al.* 2014) and Kwiatków (Kolska Basin, Central Poland) proved to be very perspective sites, where wood from the end of Allerød and Younger Dryas was recognized. In 2014 the excavations of buried trees were undertaken at the Kwiatków site within three large trenches of approximately 100 square metres each. Altogether over 600 fragments of fallen trunks and also several stumps were collected, mostly of pine (*Pinus sylvestris* L.).

Dendrochronological analysis was made for 407 selected samples of wood coming from these subfossil trunks and branches. Amongst the pine trees examined, young specimens prevailed. The trees older than 150 years appeared only occasionally.

The samples analysed dendrochronologically mostly represented pine trunks. The construction of a local chronology was based on the samples displaying sufficiently long patterns (at least 50-60 growth rings) and only minor anatomical perturbations. The average curve, produced from the tree-ring sequences best correlating mutually, spans 265 years. The approximate age of the pine chronology was determined on the basis of the AMS radiocarbon dating of samples representing single annual growth rings. The results of wiggle matching indicate that the subfossil pine chronology represents the period 11763-11498 (± 45) cal BC.

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Climate impact on radial increment of Scots pine growing on raised bogs

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KEY WORDS: Scots pine, raised bogs, climate

The aim of our study is the detection of factors determining the dynamics of radial growth of Scots pine on raised bogs in Northern Belarus. Two objects of research are located near the villages of Malyja Liocy and Ševina in the Vicebsk region. Wood cores were collected in pine forests, 140-180 years old (*Pinetum ledosum* forest type). For the analysis, we used the standard and residual chronologies, as well as monthly air temperature and precipitation from the Vicebsk station from 1945-2015.

As part of the study, a cyclicity of air temperature and precipitation was revealed which is consistent with the cycles described in climatology and geography. There was no significant relationship between temperatures and radial increments. Significant correlations were found between the standard chronologies and the sum of annual precipitation ($r = 0.39$), the sum of precipitation during the vegetation period ($r = 0.39$), the sum of precipitation for the hydrological year ($r = 0.43$), the sum of precipitation for the two hydrological years ($r = 0.53$), three hydrological years ($r = 0.52$), and four hydrological years ($r = 0.45$).

This makes possible to use the chronologies from raised bogs to reconstruct the humidification of the territory. Studies also have shown that in order to identify the significant influence of climatic factors on the growth of trees it is necessary to use regional master chronologies. Research in this direction will be continued.

Reconstructions of streamflow and PDSI using tree-ring data in the Volga region

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KEY WORDS: dendroclimatology, tree rings, streamflow, PDSI

The length of hydrological and meteorological instrumental observations in the Volga region (53-56N, 46-52E) is 120 years at maximum, and for streamflow is even shorter and goes up to only 70 years.

The aim of our study is to determine a climatic signal in tree-ring width (TRW) of nine pine chronologies (*Pinus sylvestris*) and to examine the relationships between tree growth and streamflow of the Volga river's inflowing streams and Palmer Drought Severity Index (PDSI).

Most of the pine chronologies demonstrate a response to the streamflow during the low-water season from May to September but do not show any correlation during the flooding season from April to May.

Based on TRW data of the site Y01S, we built a simple linear regression model and reconstructed streamflow of the Iletriver for current July-September (JS) from 1827 to 2013. Correlation coefficient between TRW and the river streamflow is 0.55 ($p < 0.05$). Therefore, the model explains 27% of JS streamflow variability ($r^2 = 0.27$).

The strongest significant relationship between TRW and PDSI is shown in the regional master chronology MasterTY with correlation coefficient of 0.6 ($p < 0.05$) from July to September. Based on that finding, we reconstructed the PDSI from 1828 to 2013.

The statistical characteristics of the model for the PDSI reconstruction are more significant than for the streamflow reconstruction with an explained variability of the streamflow data in the reconstruction of 34%.

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Radial increment of spruce (*Picea abies* Karst.) in fertile stands in relation to rotation length

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KEY WORDS: Norway spruce, radial increment, BAI, rotation

Radial growth of trees takes place at different time scales: circadian, annual (seasonal), age-specific (centennial), and millenarian (succession of trees). Direct human impact on growth can be imposed beforehand at the age-specific scale, carrying over to succession of multiple tree generations. During the age of trees, a forester can improve growth conditions by forest melioration, fertilizing, and sanitary cutting. Regulating the length of rotation affects realization of those measures. In case of varied rotation lengths, the total millenarian growth of tree generations (or increment per year) adds up different. Radial increment of trees (per year) is highest in case of a certain rotation length, decreasing gradually at higher rotations.

The Forest Act of Estonia and the Forest Managing Regulation establish a renewal cutting (clear cutting) rotation of spruce forest sites by either 1) a rotation age threshold of 80 years or 2) diameter at breast height threshold 26 cm, whatever reaches first.

Based on a case of a dozen spruce stands at fertile site types in Estonia we show that the rotation age threshold arrives either at the highest level of maximum diameter increment or after it. As a rule, the log size of spruce reaches before the rotation threshold.

Although basal area increment (BAI) is not established as a rotation criterion in the Forest Act, BAI is continuously increasing with rotation length. Nevertheless, the increase slows down at higher rotations.

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Radial growth model for European beech in Latvia

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KEY WORDS: base-age-invariant model, tree-ring width, productivity, adaptation

Radial growth of European beech (*Fagus sylvatica* L.) at its northeasternmost stands (experimental plantations) in Europe (in Latvia) was modelled. The diameter at breast height of the trees was reconstructed based on tree-ring width measurements from cores collected from opposite sides of stems. Two cores per tree were taken; in total, 165 trees were sampled. Non-linear models rewritten in the generalized algebraic difference form were used to link age and growth of the trees. Such models are independent of the base age and diameter, expanding their predictive ability over a variety of site types. Autocorrelation for stands and generations were taken into account. Several equations were fitted to empirical data and their performance was compared. Among the tested models, Hossfeld's and Korf's equations showed the best predictive ability. Differences in growth of beech of the first and second generation were observed.

Effect of generation and diameter class on climate–growth relationships of European beech in the northeasternmost stands in Europe

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KEY WORDS: assisted migration, high-frequency growth variation, dendroclimatology, adaptation

Age, genetics and social status of trees affect their sensitivity to environmental factors, hence growth potential. Climatic sensitivity of tree-ring width of European beech (*Fagus sylvatica* L.) of different generations and social status was studied. As expected, sensitivity of radial growth to climatic factors was modulated by the generation and social status of trees. The first generation trees, originating from northern Germany, were sensitive to a spectrum of climatic factors. Dominant trees were sensitive to June precipitation, indicating an effect of water deficit; suppressed trees were mainly sensitive to temperature in the dormant period. The second generation trees were mainly affected by water deficit in summer, yet site factors, modulated the mechanisms of response. In one stand, a direct influence of weather conditions on xylogenesis was observed. In another stand, tree-ring width was coupled with the weather conditions in the preceding year, suggesting an influence via carbohydrate reserves. The effect of social status in the second generation stands was considerably weaker, likely due to natural and anthropogenic selection of the best adapted genotypes. The effect of climatic factors on radial growth has shifted during the 20th century. The effect of autumn temperature has weakened; the effect of factors related to water deficit in summer has intensified. The observed climate-growth relationships suggested that conditions in winter have become suitable for beech, yet careful selection of sites/regions with appropriate hydrological conditions appear the main issue for the productivity of future beech stands.

Climatic sensitivity of radial growth of silver birch in Latvia

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KEY WORDS: *Betula pendula*, dendroclimatology, tree-ring width

Silver birch (*Betula pendula* Roth.) is a common and widespread tree species in Europe; however, its climate-growth relationships have been poorly studied, likely due to laborious measurements of tree-ring widths. In this study, samples were collected in 10 mature birch stands distributed across the territory of Latvia. In each stand, 10-15 dominant trees were sampled; two increment cores per tree were taken at breast height. In the laboratory, samples were fixed and progressively grinded until their surface was polished (grit of the finest sandpaper was 800 grains per inch). The measured time series of tree-ring width were crossdated (graphically and COFECHA) and detrended (negative exponential curve and flexible cubic spline) producing residual chronologies for each stand. The relationships between climatic factors (monthly mean temperature, precipitation sums and drought index) and high frequency variation of tree-ring width were assessed by a bootstrapped Pearson correlation analysis. Overall, tree-ring width of birch showed weak relationships to climatic factors, and the sets of significant factors were site-specific. Most commonly observed correlations suggested that growth of birch was affected by water deficit in summer, while conditions during the rest of the year had a minimal effect on increment. Hence, birch appeared quite tolerant to weather conditions, as expected for trees growing in the mid-part of their distribution area.

Exploring the atmospheric and streamflow drought signals of chronologies from two neighbouring regions in eastern Austria

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KEY WORDS: dendroclimatology, dendrohydrology, streamflow, low flow, drought, *Pinus spp.*

Water resource planning strongly depends on instrumental streamflow data or records of meteorological measures such as precipitation. However, instrumental records are generally too short to provide insight on long-term trends and to detect drought events of the past centuries. Tree-ring chronologies are suitable and widely used proxies for the reconstruction of past climate and were also successfully used to augment hydrological measures, but there are relatively few studies focusing on streamflow drought.

In our study, we investigated the links of multi-century pine (*Pinus sylvestris* and *Pinus nigra*) chronologies of two neighbouring regions in eastern Austria to precipitation, temperature and streamflow measures. Spearman correlation analysis showed significant differences regarding climatic response. While the latewood chronology of the region “Weinviertel” is strongly associated with precipitation during the vegetation period ($r=0.59$) and anti-correlated with winter temperature, the latewood chronology at “Waldviertel” relates less to summer precipitation, but is also influenced by temperature during the vegetation period. The correlation with low flow discharge Q80 [$\Pr(Q>Q80) = 0.8$] in surrounding gauges is partially higher than for precipitation and reaches up to $r=0.73$ for some gauges. These findings indicate the chronologies’ high potential for reconstruction purposes as well as for identification of low flow events.

Growth response of Norway spruce advance regeneration to release based on tree-ring analysis

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KEY WORDS: age, clear-cut, growth release, tree-rings, *Picea abies*, understorey

An understanding of response of advance regeneration to release after overstorey removal is fundamental to predict successional forest dynamics and forest regeneration in managed stands. In this study we investigated the response of Norway spruce (*Picea abies* Karst.) advance regeneration after clear-cut. The sample trees that were growing in a permanent sample area in southeast Estonia, were measured annually at the end of each growing season. Basal cross-sections were collected from trees having fifteen years growth under full light conditions. We examined the growth response of Norway spruce by using tree-ring analysis. We hypothesize that i) tree growth response to release is not determined by tree size, ii) tree growth response is age-dependent, and iii) trees with lower competition show greater relative growth change compared to trees with higher competition.

Hydro-climatic changes during the last centuries inferred from streamflow reconstructions in Chile

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KEY WORDS: streamflow reconstruction, drought recurrence, South America, Southern Annular Mode

The current deficit in water availability in south-central Chile (37-45S) has increased the necessity to understand the natural hydro-climate variability in long-term perspectives. This knowledge is a key to assess the current climate patterns with respect to the last centuries to provide a long-term perspective to the water management. Two of the principal questions to be solved with long-term data of water availability are: Is the current drought pattern unusual in the long-term perspective? Is the current water availability reduction part of a climatic cycle? Using tree-ring records from various species we developed seven streamflow reconstructions for the rivers Maule, Biobío (low and high elevation), Cautín, Imperial, Fuy and Puelo. In this work we present a comparison of the return intervals of extreme low flows and the long-term cycles in these rivers. The results showed a common pattern of increase in annual and biannual low flow extreme events, infrequent in the last four hundred years. The Southern Annular Mode (SAM) and El Niño Southern Oscillation (ENSO) climate forcing anomalies are associated to the occurrence of these events. Important cycles of around 80 and 30 years were found in some streamflow reconstructions, related with SAM, Pacific decadal Oscillation (PDO) and orbital forcings. Low flows during the last decades seem to be part of these cycles.

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Reconstruction of the dynamics of multispecies old-aged stands of Belovezhskaya Pushcha

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KEY WORDS: broadleaved forests, dynamics, disturbances, climate change

The goal of our research was a reconstruction of multispecies old-aged stands dynamics and an estimation of a climate impact on the increment of different species at the territory of the National park “Belovezhskaya pushcha”.

Our research was carried out in 2016 on four permanent plots established from 1980-2000: 1) *Tilietum oxalidosum*, 2) *Aceretum aegopodiosum*, 3) *Tremuletum oxalidosum*, and *Abieto-albetum oxalidosum* forest types. In total, samples were collected from 241 trees and 14 tree-ring chronologies were developed: *Tilia cordata* (3 chronologies), *Acer platanoides* (2), *Quercus robur* (1), *Picea abies* (3), *Carpinus betulus* (3), *Populus tremula* (1), *Abies alba* (1).

It was determined that the causes of all examined stands formation were one-time (within 1-3 years) breakdowns of the previous stands canopy at different periods of the XIX - XX centuries. The maple stand is only one where the breakdown of the canopy was gradual (in the 1940s).

In each stand, we found trees which remained from the previous forest. The oldest trees are Norway spruce (210 years old), Norway maple (190), and hornbeam (190). All stands are even-aged with only few older trees. An exception is the multilayers uneven stand from seven tree species with domination of Silver fir.

The current and the predicted climatic conditions are/will be favourable for tree species: 1) which growth increases in the warm previous autumn and winter; 2) which growth is not strictly limited by summer draughts. The first of them are Silver fir, Norway maple and hornbeam, the second are English oak, Norway maple and aspen.

A dendrochronological approach of wooden cultural heritage history in Northern Romania

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KEY WORDS: oak, Maramures, monasteries, tree-rings, crossdating

Archaeological wood is of high value, since it is a finite resource that helps us to construct long tree-ring chronologies used for absolute dating and interpretation of past environmental events. In Romania, several attempts have been made to date cultural heritage items but few have been published so far. The propose of this study was to investigate the potential of using wood samples extracted from old wooden houses and monasteries, (AD 1200-1800) for dendrochronological dating. A total of 473 samples have been collected and analysed from historical constructions, the aim was to: (a) crossdate the samples, (b) establish a tree-ring chronology for NW Romania (c) investigate tree-species selections, beam size, procurement and modification techniques and the use of wood from other buildings (d) establish a strategy for future dendroarchaeological research in the region. We succeeded to crossdate 136 tree-ring sequences from a total of 426, meaning oak samples. Using the wood anatomical method, a number of 45 samples of fir and two of elm have been identified. Our results show that only 32 % of the oak cores analysed gave absolute dating, even if only 25 samples contained less than 50 rings. Somme Samples with around 300 tree rings could not be crossdated, most likely they belonging to a period older than available reference series for the region. These new dates provide a more distinct understanding of the cultural resources in the NW Romania, and more accurate information can be given to the public about age of different historical constructions.

Glacier advances and summer temperature variability at the onset of the Little Ice Age in the Alps

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KEY WORDS: Little Ice Age, glacier advance, dendrochronology, summer temperature variability

The term “Little Ice Age” (LIA) is generally used for the period of repeated and far reaching glacier advances during the last millennium. Moreover, this term is also utilized for the period of relatively low temperatures following the Medieval Climate Anomaly (MCA) and preceding the modern warming. The end of the LIA is in general set to the mid- or late 19th century CE, however, the published dates for the onset of the LIA vary from the late 13th to late 16th century. In the European Alps, the late or main phase of the LIA, i.e. the late 16th to mid-19th century CE, is relatively well known from historical descriptions and pictures, but the timing of the onset is less clear. Here we present new advance dates of glaciers in the Alps based on tree-ring analyses and dating of buried tree remains. A major advance traceable at different glaciers happened in the late 13th century and culminated in the mid-to late 14th century. Trees with lifespans of several hundred years were buried at various glaciers during this general advance phase. A dendroclimatic reconstruction of summer temperatures indicates relatively cool conditions in the late 13th and 14th century, which coincides with the glacier record. The glacier as well as the summer temperature record suggests a subdivision of the LIA (approx. 1270 to 1860 CE) in the Alps into an early phase (late 13th to late 14th century), an intermediate period and a main phase (late 16th to mid-19th century).

Growth-climate relations of a high subalpine forest in an inner-alpine dry valley

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KEY WORDS: *Larix decidua*, *Pinus cembra*, sap flow, dendrometer, tree ring width

European larch (*Larix decidua* Mill.) and Swiss stone pine (*Pinus cembra* L.) are the dominant tree species in the high subalpine belt and at the forest line in large parts of the Alps. Increasing temperatures due to climate change in the last decades led to increasing growth rates in high elevation forests across the Alps (Carrer *et al.* 1998; Rolland *et al.* 1998). To investigate the effects of topography and management on this general trend, we measured tree-ring widths and calculated climate-growth relations of six sites in the LTSE platform Matsch/Mazia in South Tyrol /Italy at elevations from 1990 to 2430 m asl, south-east and north-west aspect, and non to quite intensive pasturing. To add higher time resolution data and create a link to tree-water relations we additionally installed dendrometers and sap-flow sensors at three sites. We found a generally larger sensitivity and increase of radial growth of larch than of Swiss stone pine in the last decades; it was stronger at the forest line than around 2000 m asl. Growth was positively correlated with previous summer and autumn and current summer temperatures at most sites especially at higher elevation. At similar elevation, growth rates and sap flow was higher at south- than north-exposed sites. Overall, larch appears to benefit more from currently increasing temperatures than Swiss stone pine. Therefore, larch will probably extend its range especially at high elevation. Considering the shadow intolerance of larch, *P. cembra* will still play its role when forests mature though.

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Relating drought effect on growth and wood anatomical traits of Scots pine in Transylvania, Romania

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KEY WORDS: drought-induced mortality, *Pinus sylvestris*, wood anatomical features

Through their long lifespan, the trees are sensitive to climate change and particularly to abrupt variations in climate conditions, which could alter their growth. In 2012 an extended tree-mortality phenomenon was observed in the temperate-continental climate region of Transylvania, near the Brasov region. Especially coniferous tree species such as Scots pine planted outside their natural range were most affected. Using tree cores sampled in 4 stands (3 affected by mortality and one without mortality) within a paired sampling design (living vs. dead trees), we compared the growth patterns of the living and dead and analysed tree-growth response to past climatic variations. For one stand we measured also several anatomical features (radial lumen diameter, cell-wall thickness, cell area). Scots pine exhibited a predominant summer response, especially to precipitation in June and less to temperature. Comparing the growth patterns (basal area increment) of the living and dead trees, an important reduction of growth rate prior to death was recorded in two stands over the last decades. Although radial lumen diameter and cell-wall thickness were more reduced in dead than in the living trees in the year prior to death, no statistically significant differences were found between living and dead trees neither at the whole ring level nor separately for earlywood and latewood. But wood anatomical measurements are needed to be extended to the other two stands to verify these preliminary results.

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Wood supply at the edge of the world: a Norse Greenland case study

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KEY WORDS: archaeobotany, Norse Greenland, wood identification, wood provenance

Wood used in construction and boat building, in domestic productions or as a fuel resource was a key material for medieval North European societies. For people living in Medieval Scandinavia, trees and timber were common in both landscapes and mythology and therefore essential cultural items. Several studies have been conducted on the use of wood in Scandinavia, the British Isles and the North Atlantic islands, and have demonstrated a wide variety of objects that can be unearthed when preservation conditions are good (e.g. Malmros 1994, Mooney 2016, Pinta 2015).

The aim of this poster is to present the current research on the identification of wood species (both local and imported) used by European settlers in Greenland. An analysis of wood will help us to understand and retrace the origin and circulation of wood resources in the Norse settlements. What was the nature of woodworking strategies and management in the Norse Greenland society? Is this process best understood in terms of cultural dynamics or adaptive strategies when compared to other case studies in the Norse world?

The methodology goes beyond the traditional approach of classifying artefacts using typo-technology by also applying methods of wood anatomy and dendrology. Together, these approaches provide a better understanding of the wood artefact production sequence employed by Norse craftsmen, as well as the relationship between Greenland and the other North Atlantic islands.

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Dendrochronology in Republic of Moldova

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KEY WORDS: tree-ring network, oak, Moldova, drought

Climatic change scenarios indicate an increase of temperature and frequency and intensity of drought in the Republic of Moldova. Drought is the main climatic risk factor in this region with consequences on the economic and ecologic level. Spatial variability of the climate response of oak tree-ring chronologies offers information on the sensitivity of this main forest species to climate change. The responses were quantified using both monthly temperature and precipitation amount and the SPEI index at different time scales. In the analysis also beech chronologies were included, in this region is the eastern border of this species distribution in Europe. The dendrochronological network comprises over 10 chronologies of oak and beech, distributed throughout Moldova. Results of climate-growth correlations indicate a high sensitivity of beech to drought as compared with oaks. Maximum correlation for beech is observed at 18-20 month SPEI scale and for oak at time scales of 12-18 months, but lower. In the case of oak, precipitation is the main growth driving factor, but the intensity of correlation and significant year periods differ from north to south of the country. This first tree-ring chronologies in Moldova (a white spot in European dendrochronological studies) is the foundation for development of tree-ring science in this part of Europe, both for dendroclimatological and dendroarcheological studies.

Simulated cell-growth rate and timing of tracheid production for conifer species in Siberia

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KEY WORDS: South Siberia, Vaganov-Shashkin model, tracheidograms, cambial activity, cell size, timing

The cells within the wood play an important role in the formation of tree rings. Seasonal tree-ring growth is a complex of interconnected processes of cell division and morphological differentiation in the cambium zone (Vaganov *et al.* 2006). Due to the specificity of these procedures and complexity of labor-intensive experimental methods mathematical modeling can be considered as one of possible approaches to simulate cell production by cambium, which requires developing adequate mathematical methods and corresponded software components.

A new block of the Vaganov-Shashkin model was proposed to estimate a cell production in tree rings and transfer it into time scale based on the simulated integral growth rates of the model. The VS-modeling is an extremely important step because the simulated daily tree-ring growth rate is a basis to evaluate intra-seasonal variation of cambial production. The comparative analysis of the growth rates with one of the main tree-ring anatomical characteristics of conifers - radial cell size was carried out to provide a new procedure of timing cambium cell production during the season. In the study, we demonstrate the approach which allows detecting the precise time moment to form each cell in the cell profile based on VS-simulation. The results of such research can be a methodological basis of process-based tree-ring simulations and dendroclimatic reconstructions.

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Growth trends of forest stands on drained peatlands according to tree-ring and remote sensing data: a case study in East Estonia

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KEY WORDS: forest drainage, peatland, growth rate, fAPAR

Forest management on peatlands is often possible only if the natural hydrological regime is altered by constructing a drainage system and soil conditions are improved. However, due to deterioration of drainage ditches, soils can become waterlogged again. Hence, ditch network maintenance (DNM) must be carried out in order to sustain an increased quality of forest growth conditions.

The aim of the current study is to assess effects of drainage operations on tree and stand growth. A sample of stands in artificially drained sites and a set of reference stands located in East Estonia were selected for this case study. Radial increment of Scots pine trees was measured and interpreted using dendrochronological techniques. Time-series of yearly means of satellite-derived fAPAR (Fraction of Absorbed Photosynthetic Active Radiation) values from 2000-2012 were used. Agreement of tree-ring chronologies and fAPAR series was described using Gleichläufigkeit (Glk) score. Also correlation coefficient and pointer years were calculated.

Preliminary results indicate that fAPAR series are more correlated to residual than to raw tree-ring chronologies, suggesting a possibility of using fAPAR values to describe growth response of forest stands to hydroclimatic factors, but not to DNM. Glk values were up to 75% and correlation coefficient - up to 0.5 (depending on the stand and time interval used). The year 2003 was identified as a negative pointer year both in fAPAR and in tree-ring series.

A first chronology for the subtropical climate of Northern Uruguay

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KEY WORDS: *Sebastiania commersoniana*, dendrochronology, tree-ring growth, water availability

Climate change has influenced tree growth of native species in the last century. We studied the presence of annual growth rings via terminal fiber bands in *Sebastiania commersoniana* in northern Uruguay, a sub-tropical region. Standard dendrochronological methods were applied to understand the effects of local climate on annual ring width. We developed a chronology from 1967 to 2007 using 23 series from 17 trees. Results showed average radial growth of $1.922 \pm 0.425 \text{ mm y}^{-1}$ (SD). The average chronological sensibility was 0.43; EPS ranged between 0.63 and 0.87; and the interseries correlation was $r = 0.455$. The *S. commersoniana* chronology had a positive correlation with accumulated rainfall in early spring to mid-summer (Aug-Jan; $r=0.52$) and accumulated streamflow from early spring to late summer (Aug-Mar; $r=0.559$) during the previous year of growth. There was a negative correlation with maximum monthly temperature ($r=-0.55$) in summer (Jan-Dec) and with accumulated temperature in spring (Sept-Nov; $r=-0.43$) in the current year. Results suggest that radial growth is affected by site-specific water availability during the current and former year of growth, as indicated by the hindering effects of high temperatures at the end of spring and early summer as well as the acceleration of radial growth with heavy spring rainfall in the preceding year. Nowadays the chronology is increasing in 57 trees, collected by site water availability.

Climate change vulnerability of floodplain oak forests in the city of Kyiv

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KEY WORDS: chronology, climate, sensitivity, oak

The vulnerability of forest ecosystems to climate change and to human impact is known to be largely determined by climate sensitivity and the adaptive capacity of key species that ecologically dominate these systems (Capon *et al.* 2013). In riparian forests, rivers and streams act as factors not only of significant disturbances such as flood events, but also of specific microclimates which differ from physical and chemical conditions of adjacent territories (Agafonov and Gurskaya 2013).

We show that the river regulation causes for slowdown in a flooded ecosystem ability to mitigate warming process. By analyzing a pedunculate oak tree-ring chronology from a flooded old growth wood in Kyiv, we found that under rising regional temperature driven by global warming, coupled with seasonal soil-water shortage due to human use, this species' enhances sensitivity to early spring precipitation, temperature in the end of the previous growing season and in the current January-March, and to severe and extreme drought events. A considerable change in an oak growth-to-climate relationship pattern manifests itself in a weakened correlation between the ring-width series and May temperature, i.e. thermic conditions in the period of earlywood formation.

Given the significant role of pedunculate oak in structure and function of ecosystems that it dominates, we have concluded that a planned adaptation is needed to allow oak trees and the overall forest to overcome an impact of climate change in the future.

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Effects of drought on leaf phenology and cambial activity in Sessile oak (*Quercus petraea*) and European beech (*Fagus sylvatica*) at the north-east margin of their range in Poland

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KEY WORDS: wood anatomy, water deficiency, xylogenesis, extreme weather events

The native distribution of European beech and Sessile oak is limited by the influence of continental climate. In result of its influence beech has its eastern boundary in north-central Poland where Sessile oak has low frequency (Zajac and Zajac 2001). In recent decades in Poland, the frequency of summer droughts were observed (Lorenc *et al.* 2006). This factor is considered as one of most limiting for establishment of subatlantic species in this region. The aim of our study was to determine the effect of subsequent droughts on cambial activity and radial growth of these two species. To detect the impact of climate change on tree-ring widths we sampled 5 trees per species. Tree-ring chronology was built using standard dendrochronological procedures. To assess intra-annual weather-growth relations, cambium and developing xylem was sampled with a Pressler borer and leaf phenology was observed at 7-14-day intervals from March to October in 2015. The chronology of trees was generally similar, t-value was 5.8, however the mean ring width revealed differences, for oak it was 1.82 mm and for beech 2.26 mm. Leaf flushing was observed several days earlier in beech than in oak. In contrast, onset of tree-ring formation was detected several weeks earlier in oak than in beech, indicating that the timing of leaf and growth phenologies is species-specific. The radial growth of beech seemed to be more sensitive to the summer drought in 2015, because it negatively affected cambial cell production. The number of cambial cells during the summer drought was comparable to the number in dormant stage.

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Dating the Palace Garden infrastructure

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KEY WORDS: garden history, Vilnius Lower Castle, medieval wattle, wooden well, pond reinforcement

A garden was an indispensable part of medieval castles, monasteries, and renaissance palaces. But a garden, as distinct from buildings, is not a long-lasting and rather alternating element of a terrain. Therefore, locating traces of historic gardens is usually much more challenging than investigating a building history.

Earliest notes on royal gardens at the Vilnius Lower Castle are from the 1530s. Long-lasting archaeological excavations of the site did not help to locate these gardens. Nevertheless, remnants of wooden constructions were found in the cultural layer which could be interpreted as garden elements. Dendrochronological dating of the constructions supports this interpretation, placing the infrastructure elements in time suited to garden installation.

Two pieces of wattle were found during the archaeological investigations. Dendrochronological dating of nearby timbers has dated the wattles to the late 14 - early 15 c., thus suggesting the wattles as elements of a medieval garden. Wooden reinforcement of a pond was dated to 1510, thus supporting the interpretation of the pond as a landscape element in front of the new Renaissance palace built in that time. Two wooden wells have been found to be contemporary and were dated to 1561-1562, the time of florescence of Renaissance gardens. The location of the dated infrastructure objects hints at the likely situation of the gardens.

Dendroarchaeological studies of an early Neolithic water well from Uničov (Czech Republic)

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KEY WORDS: archaeology, oak, Neolithic, well

The discovery of an early Neolithic well in Uničov, Czech Republic, is one of the most significant archaeological discoveries in the country within recent years. Thanks to the excellent conservation of the timber elements, we could describe the well structure in detail and date it by dendrochronological methods. The well consists of four corner posts, each of them with two longitudinal grooves with inserted horizontal planks. The planks formed the wall of the well lining and ensured its cross reinforcement at the same time. This type of construction is known only from the Roman times and the Middle Ages. The quality of woodworking manifests high accuracy and skills of the early Neolithic craftsmen. The dendrochronological analysis shows that the trees used for the well lining were felled between 5093–5085 BC. Wells in the period mentioned usually consisted of a chest-like construction of split wooden planks with jointed corners (e.g. Tegel *et al.* 2012). Until now the construction with planks inserted in grooves of corner posts is unique in Europe for the Neolithic period. Currently, it is the oldest archaeological discovery of wooden artefacts that have been dated by dendrochronology in the territory of the Czech Republic.

Acknowledgments: The study was prepared by means of funding from the Czech Republic Grant Agency through the grant numbered 17-117115 and 13-042915.

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Climate sensitivity of rare native tree species in NE-Germany – a dendroecological and ecophysiological approach

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KEY WORDS: rare tree species, extreme summer drought, deciduous trees, pointer- year analysis

The aim of our study is to identify tree species suitable for increasing biodiversity in northeastern German forests under changing climate. The climate projections for this region predict higher temperatures and less precipitation during the growing season and generally more extreme events (Lasch *et al.* 2002; Lindner *et al.* 1997). In particular we assess the sensitivity of rare native tree species to extreme/prolonged summer droughts. These rare and less studied species include *Taxus baccata*, *Betula pendula*, *Carpinus betulus*, *Prunus avium*, *Acer campestre*, *Malus sylvestris*, *Pyrus pyrastrer* and *Sorbus torminalis*.

In a pot experiment, leaf gas exchange, turgor and biomass are assessed on watered and non-watered 3-year old seedlings during the main growing season. In forest plots we collect stand data and extract increment cores for dendrochronology and isotope analysis of distinct pointer years.

Concerning the focus of dendrochronology, we tested different approaches to visualise tree-ring boundaries. Some species have diffuse porous, bright wood where rings are difficult to discern. For the analysis of pointer years, the R-Package PointRes (van der Maaten-Theunissen *et al.* 2015) is used to rank the vulnerability and the potential for recovery of the different species.

The results of this study can be used to shape silvicultural decisions for making tree-species richness and biodiversity increase in a changing climate.

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Climate signals in tree rings from Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* Karst.) in southern Norway

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KEY WORDS: tree rings, climate response, temperature sensitivity, southern Norway

Although an abundance of dendroclimatological temperature reconstructions originate from the northern parts of Fennoscandia, fewer have been made from trees growing in the southern parts of this region. This is mainly due to weakening of the climate signal at these more southern latitudes, along with the increasing influence of precipitation. In southern Norway, the climate is less influenced by polar air masses than the sites in northern Fennoscandia, and due to the prominent influence of Atlantic originated air-masses, the Scandinavian mountains form a boundary for climate and vegetation in these areas (Moen 1998).

Here we present tree-ring chronologies from central, western and eastern Norway, and discuss the differences and similarities in the climate signals from these sites. As altitude has a great impact on the potential temperature sensitivity, one might think that the Scandinavian mountains in southern Norway would be a suitable site for a temperature-sensitive chronology for the southernmost parts of Fennoscandia. We compare the chronology characteristics, and compare the climate signal in spruce and pine. The latter only applies to the central and eastern region, as spruce does not grow naturally at most sites in western Norway. The influence of factors such as altitude and latitude are discussed, along with the differences between coastal and inland sites.

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Climate and hydrology relations of pine (*Pinus sylvestris* L.) growing in some drained Central Estonian mires

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KEY WORDS: dendrochronology, drainage, dendroecology, *Pinus sylvestris*, disturbance, dendroclimatology, mires

Although the overall share of ecologically intact peatlands in Estonia is considered to be rather high compared to the rest of Europe, the overall decrease of mire area over the past decades has been significant. Estonia among other European countries has lost many ecologically sustainable peatlands due to extensive melioration in the mid-20th century for agricultural or forestry purposes and for peat excavation. Today, the main focus is on sustainable management and restoration of mires. To ensure that the best possible methods of sustainable management are implemented, a full comprehension about the long-term processes and impacts of ditching to the mire ecosystem is needed. Dendrochronological research can help better understand the effects of both natural and anthropogenic environmental changes on trees growing in Estonian mires.

This research aims to establish the effects of drainage to the radial increment of Scots pine (*Pinus sylvestris* L.) growing in ombrotrophic Kauru, Tellissaare, Umbusi and Koordi raised bogs in Central Estonia by using the transect method. Radial growth series were analysed and compared with local temperature, precipitation and snow coverage measurements in order to determine the correlation at different distances from the ditch. The documented drainage years were specifically focused on to see if the drainage effects overcome the climate influences. To determine the significant changes in tree growth, a relative radial increment model (Nowacki and Abrams 1997) was implemented on the tree-ring chronologies.

The results contribute to the comparison of drainage effects on different distances from the ditch and therefore provide detailed information about the spatial as well as temporal dimensionality of the drainage impact zones for trees growing in mires.

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Towards a network of Amazonian tree-ring chronologies

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KEY WORDS: Amazonia, Brazil, Bolivia, hydroclimate

Tree-ring records have greatly furthered our understanding of past environmental and climatic change across the world, but these records are not equally distributed across space. The regions around the equator represent some of the last frontiers of dendrochronology. The importance of annually-resolved paleoclimatic records from the tropics is perhaps greater than from anywhere else on the planet. Brazil is not only expected to experience great changes in the face of anthropogenic warming, but the hydroclimate of the Amazon basin is also strongly connected to the El Niño Southern Oscillation. Despite being the most diverse forest ecosystem on Earth, estimated to contain more than 16,000 species of trees, independently validated tree-ring chronologies have only just begun to be produced for Amazonia. A collaborative effort involving researchers from North and South America are in the progress of constructing ring-width chronologies from the Bolivian and Brazilian Amazon, as well as from the transitional seasonal dry forest in eastern Brazil. Here, we present the preliminary results on *Bertholletia excelsa*, *Cedrela* sp., *Centrolobium microchaete*, and *Macrolobium acaciifolium*.

Timber trade and Frisian farms (NL)

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KEY WORDS: dendrochronology, dendroprovenancing, building history, timber trade

As part of a large scale study of the development and typology of historical Frisian farms (in the north of the Netherlands) dendrochronological research has been carried out. Per April 2017 around 950 cores from circa 120 farms have been collected. Preliminary results show that virtually all construction timbers were imported. The dendrochronological dates range from the late 15th to the late 19th century. Along this date range a shift is observed in both species and origin of the timbers. For the oldest buildings, oak (*Quercus spp.*) was used. This makes way for pine (*Pinus sylvestris* L.) and in more recent periods for spruce (*Picea abies* Karst.). The provenance of the timbers also changes throughout this period. Oak was imported from southern Norway and nearby areas in Germany up to the middle of the 17th century. For coniferous species various - and increasingly remote - timber sources in Scandinavia and the Baltic countries were used. The import of timber from numerous sources has the effect that it is more difficult to date buildings from the mid-18th century onwards despite more written sources being available because a larger network of chronologies is required. As a consequence, mapping the trade networks along the Baltic and North Sea coasts through dendrochronology becomes essential in order to date these buildings.

Building and renovation history of Vilnius and Kaunas churches: dendrochronological dating and historical sources

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KEY WORDS: Scots pine, tree rings, sapwood, dating, Lithuania

We present the application of dendrochronological dating of the renovation and reconstruction works of the churches in the Kaunas and Vilnius regions of Lithuania. Researchers in Lithuania investigating the pieces of art and architecture very often encounter with the lack of reliable historical sources. This is because many written sources were lost during various historical devastation events, wars, disturbances and occupations. The remaining sources were dispersed not only among different Lithuanian institutes, but are also stored in archives in Poland, Russia, Belarus, Germany, France, etc. Therefore, Lithuanian art historians and architects often should trust the formal analysis method and attribution application, i.e. analysis of style, materials and ornaments, but not the written historical sources. Hence, the attribution results are determined by professional experience, which does not protect from mistakes. Therefore, dendrochronological dating of wooden constructions may complement the historical knowledge and architectural investigations.

We have investigated the timber (containing a part of sapwood) collected during the Soviet times from 10 gothic and baroque churches and the Kaunas City Hall, which was an Orthodox church in the 19th century. Five churches are located in the Kaunas region and five in the Vilnius region. The dates received from the earlier dating were revised considering the recent results of the pine sapwood estimation.

The possibility of dendroclimatological reconstruction of data characterising past winters in the Baltic States

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KEY WORDS: dendroclimatology, Scots pine, winter-spring temperature, Baltic states

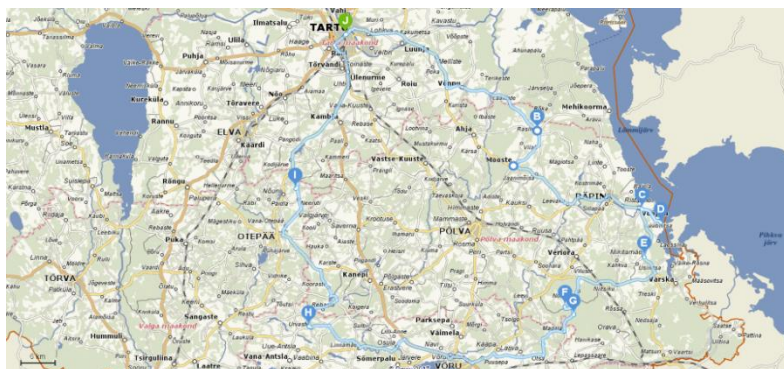
In European countries, tree-ring chronologies for Scots pine (*Pinus sylvestris* L.) are used as proxies mainly for the reconstruction of data characterising the mean air temperatures during the summer months of past years. The mean air temperature in the warmest season of the year is generally expressed as the factor most significantly influencing the annual growth of pine tree rings in the area at the northern timberline as well as in upland areas, where the air temperature is lower in any case. In the southern part of Scandinavia, in the Baltic States and at least in the north part of Poland and Germany, and likewise in Belarus and western Russia, the annual radial growth of Scots pine is most significantly influenced by the mean air temperature in late winter and early spring. In view of this, it was interesting to ascertain whether the dendrochronological data for pine growing in the present-day Baltic States might be used to characterise past winters.

It has been established in the course of a small-scale study that annual variation in ring width of pine permits a more accurate characterisation of particularly cold or warm winters that lasted for a fairly long period across a large territory. This is indicated by pointer years relating to these areas, for which the character of change in mean winter-spring air temperatures and pine ring width corresponded in more than 80% of cases. The mean winter-spring temperature for other years could not be characterised so clearly.

The excursion to Southeastern Estonia on Friday, 8 September

Guided by Taavi Pae, Jaan Pärn and Alar Läänelaid

We chose the southeastern corner of Estonia mainly for its vicinity to the conference town, as our excursion time is limited. Every other part of the country has its own attractions. Southeast Estonia is just one peculiar part of Estonia. Be aware that the Seto culture is not characteristic for the rest of Estonia. We omit our top level forest research stations (key words: Järvselja, Soontaga) as they are not suitable for large groups. Also we will not visit the archaeological excavations that are going on in Tallinn and elsewhere.



Route of the excursion, 250 km in total

<https://kaart.delfi.ee/?bookmark=foe72e3797453e4f8d715bbaae1446c2>

11:15 Bus departure from Tartu (46 Vanemuise St).

12:00–12:20 Rasina giant white willow (*Salix alba*). According to folk memory, in spring 1879 farmer Karel Punning stuck a horse-driving rod into the soil and found later that the rod had grown leaves. The giant willow is under nature protection since 1972. In 2000 the wooden supports were installed under the big branches of the tree. The circumference of the willow at 0.3 m height was 10.92 m, height 20 m and age estimated between 120–150 years (Relve 2003). Probably one of the thickest white willows in the word (according to *Monumental trees* the thickest one is a 9.10 m girth white willow in France



Rasina giant white willow

<https://www.monumentaltrees.com/en/world-whitewillow/>).

12:45 Crossing the border to the Seto country.

Võõpsu Chapel is located at the place of a medieval village cemetery that is out of use since about mid-19th century. Small Orthodox village chapels (*tsässon* in Seto dialect) were characteristic for the Seto region, the western corner of medieval Pskov Principality. Seto became a part of Estonia when the republic was established in 1918. Orthodox religion intertwined with remnants of Pagan beliefs is characteristic for Seto while the rest of Estonians are Protestant (Lutheran) by background. Besides the religion and folk culture, the Seto people can be distinguished from their dialect. Characteristically for the landscape the farms are small, surrounded by fencing, and the houses are close together. (<http://www.estonica.org>)



Võõpsu Chapel

Dendrochronological investigation has revealed the date of Võõpsu Chapel as 1709 (overlap 104, $t = 9.49$, *Gleichläufigkeit* 78.2 at 99.9 significance level, Läänelaid *et al.* 2005). The building was repaired in 2010 and is under national protection as a historical monument. This is the biggest *tsässon* in Estonia.

13:00–13:45 Lüübnitsa Village, known since 1582, is located at the shore of Lake Peipus. The population of the village is 91 inhabitants (2011). The village is widely known by its fishing and onion-farming traditions. A view to the Remda peninsula and the Kolpino island in Pskov Region of Russia.



Lüübnitsa is known by its onion-farming traditions

Lake Peipus is the fifth-largest lake in Europe with a total area of 3555 km². It is a transboundary lake between the EU and Russia which relies heavily on international cooperation. The lake can be divided into three parts: Lake Peipus proper (2610 km²), Lake Pskov (710 km²), and, connecting the two, the narrow (the width at the narrowest point is 3 km) and deep Lake Lämmijärv ('Warm Lake' 235 km²). Here the lake is the deepest (maximum depth 15.3 m). 44% of the water area of Lake Peipus is located in the territory of Estonia. The water capacity of the lake reaches up to 25 km³. Most of the lake's catchment area is located in Russia, with the Velikaya river being the largest tributary.

In spring, after the snow melts, the water table rises by nearly a metre. That causes the flooding of the lower shore areas of the lake. During the peak water table, the area

of the lake may increase by about 780 km². The water table is the lowest in October. This is because of the intensive evaporation and small water inflow during the summer. In the autumn, water inflow starts to increase due to the rains. Fluctuations of water table depend on alteration of dry and wet periods. Thirty-year cycles of water-table fluctuation are distinguishable.

Sometime in the 16th or 17th century, Russian settlers came to the western and northern shores of the lake. Among them were a large number of Old Believers who had been persecuted in their homeland. Old Believers have preserved their customs and traditions. The floodplain soils they settled in were not suitable for cereals cultivation but only for vegetable, especially onion and cucumber farming. Fishing has always been one of the main sources of subsistence in these villages. Lake Peipus is one of the best



A panorama view from the Lüübnitsa observation tower

fishing lakes in Europe. Average annual catch is approximately 10,000 tons; thus, the productivity of the lake is about 30 kg/ha. Commercial fish species (in order of price per kg) include pike-perch, vendace, pike, perch, bream, and sparling. Ice fishing is very popular: in winter, several thousand anglers can be seen during some weekends. Between and behind the fishermen's dwellings, greenhouses and onion beds can be seen. This creates a unique village landscape. (<http://www.estonica.org>)

14:00–14:30 Mikitamäe Chapel (*tsässon*) was moved from the old cemetery by about a hundred metres southward in the 1960s. The old cemetery was out of use since the 1830s. At the end of the 1990s it was concluded that the old chapel cannot be restored and a new chapel was built. Nevertheless the old chapel was investigated and restored in the 2000s. According to the dendrochronological date 1693 (overlap 104, $t = 6.58$, *Gleichläufigkeit* 69.9 at 99.9 significance level) the old chapel was most likely built in 1694 (Läänelaid *et al.* 2005). The old chapel was re-inaugurated in 2009. It is the second-oldest preserved wooden building in Estonia (after the old wooden church on Ruhnu Island from 1644). It is notable that the logs of the chapel were cut by axe (crashes on the ends), because the saw was not in use in Estonia in that time. Traditionally raw timber was used for building with axe.



Mikitamäe Chapel

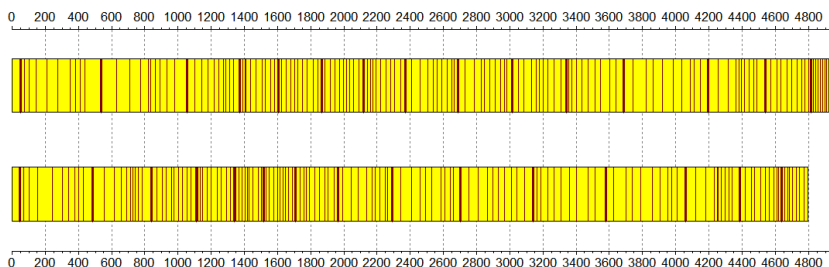
Drive by the Ilumetsa meteorite craters. The group of craters formed from meteorite impacts 6600 years ago: Põrguhaud ('Hell Hole', 80 m diameter, 4.5 m depth), Sügavhaud ('Deep Hole', 50 m diameter, 4.5 m depth), Kuradihaud ('Devil Hole', 24 m diameter, 1 m depth), and Tondihaud ('Ghost Hole'). Their meteoritic origin was discovered only in 1938. Meteoritic substance was not found. The floor of Põrguhaud is covered with a layer of peat down to 2.5 metres deep.
<https://www.visitestonia.com/en/ilumetsa-meteorite-craters>

15:00-17:00 Picnic and walk in the Meenikunno bog. The Meenikunno bog trail runs on 2.4 km boardwalk over the bog and 0.8 km sand path through dry boreal forest. There are information points introducing the bog and forest along the trail. There are observation towers and shelters at both ends of the trail.

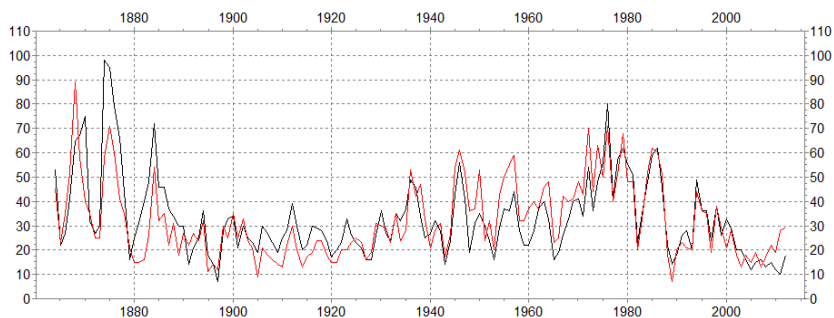


Meenikunno bog

Two centuries ago one fifth of the Estonian territory was covered by natural peatlands. Today only 5.5% are natural mires and an additional 3.1% are swamp and bog forests. Traditionally our mires are divided into fens, transitional and raised bogs. Meenikunno falls into the raised bog type with its oligotrophic peat layer and specific plant species. There are pools and hummocks on the bog. The depth of the peat layer extends to several metres. Scots pine (*Pinus sylvestris*) is the dominant tree species (Masing 1997). Due to high water table and lack of nutrients the growth of pines is very slow.



Increment cores of pine No. 53 from the Esäkeste bog (near Rasina), N and S radius, bored at 0.5 m height. Ring widths in 0.001 mm units. Tree age 149 years, trunk diameter with bark 10.7 cm.



Tree-ring widths of pine No. 53 from the Esäkeste bog (near Rasina), N and S radius (red) at 0.5 m height. Ordinate – ring width in 0.01 mm units.

The bog is surrounded by a kame field. A kame is a moundlike hill of poorly sorted drift, mostly sand and gravel, deposited at or near the terminus of a glacier. A kame may be produced either as a delta of a meltwater stream or as an accumulation of debris let down onto the ground surface by the melting glacier. Between the kames, kettles are formed. The kame field is covered by dry boreal pine forest. Estonia belongs to the northern part of the mixed-forest subzone of the temperate forest zone. Dry boreal forests are pure *Pinus sylvestris* stands with *Vaccinium vitis-idaea* growing under the pines in drier and more nutrient-poor places. Other characteristic species include mosses, in particular *Pleurozium schreberi* and *Polytrichum commune*. Of herbs, *Pulsatilla* spp. and *Melampyrum pratense* are characteristic. Forests growing on moister soils in the kettles have an understory formed by *Picea abies*, and *Vaccinium vitis-idaea* is replaced by *Vaccinium myrtillus*. The Estonian term for dry boreal forests *palu* refers to forest fire, which used to be the main factor inducing natural regeneration of forests of such type before the introduction of modern forest-fire prevention. (<https://www.britannica.com>; <http://www.estonica.org>)

17:10-17:40 Giants of Ootsipalu Valley - the tallest Scots pine in the world, h=46.6 m (2015) (*Monumental trees*, https://www.monumentaltrees.com/en/est/polvamaa/veriora/11966_ootsipalu/23314/), and the tallest Norway spruce in Estonia, h=48.6 m (2015) (Relve 2015).

The age of the trees is estimated as 140-160 years (H. Relve) or over 214 years (https://www.youtube.com/watch?v=Dn3Eu_B4uXo). These trees were discovered and precisely measured quite recently, in 2015. Until that the tallest spruce known in Estonia was 44.1 m and the tallest pine known in Estonia was 42.4 m, both growing at Järvelja.



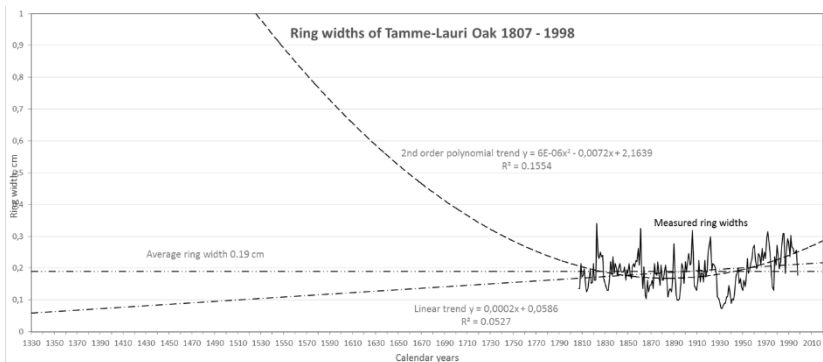
The Ootsipalu Pine – the tallest Scots pine in the world



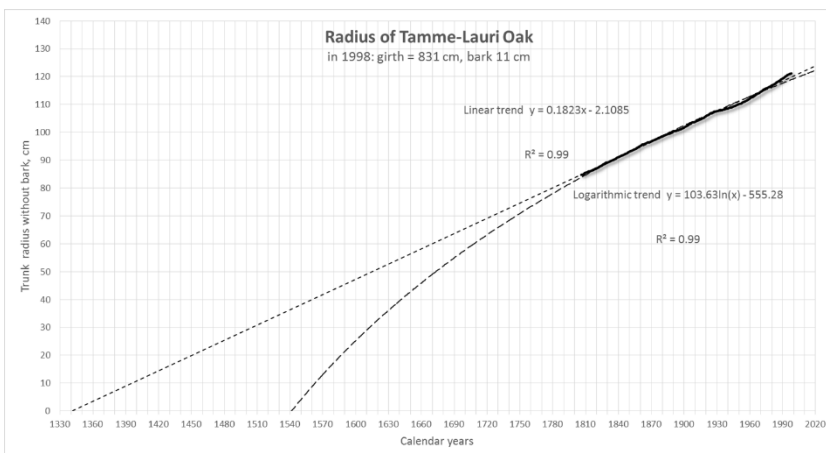
The Ootsipalu Spruce – the tallest Norway spruce in Estonia

In Estonia, there is one native pine species, Scots pine (*Pinus sylvestris* L.), and one native spruce species, Norway spruce (*Picea abies* Karst.). Pine forests are the most widespread in Estonia. Together with spruce, they make up the bulk of Estonian forests. At present, about 49% of the territory of Estonia is forest (Estonian Environment Agency 2017). Economically pine and spruce have been the most valuable tree species used as construction wood through centuries.

18:40-19:10 The Tamme-Lauri Oak at Urvaste (in Estonian *tamm* is the word for ‘oak’) is the thickest and probably the oldest tree in Estonia. The height of the tree is 17 m, its trunk circumference is 8.31 m (1998) measured at 1.3 metres from the ground. A legend tells that the tree got its beginning from a stick once pressed into the soil by Charles XII the King of Sweden. Another hypothesis argues that the oak is a remnant of an ancient Pagan sacrifice place. The exact planting year mentioned in the information label is a fairy tale for tourists.



Ring widths of Tamme-Lauri Oak 1807–1998. Dashed lines mark various trends: polynomial, arithmetic average and linear trend.



Extrapolation of earlier growth of the radius of the Tamme-Lauri Oak. The assumed onset of growth can differ two hundred years, depending on the trend-line type.

We cored the oak on 20 July 1998 to establish its age from tree rings. The trunk was hollow inside and the cores from the east (192 tree rings) and west side (165 tree rings) were extracted (Läänelaid 1998). Graphical extrapolation of the radial increment was used to assess the age of the tree (see the figures below).

The oak has been repeatedly hit by lightning, damaging the branches and hollowing out the centre. During restoration in the 1970s an old hideout of a Forest Brothers guerrilla group was found in the cavity. Seven people could stand inside the tree before it was filled with 8 tons of reinforced concrete. The tree is still viable, although it has lost its top because of the lightning strikes. The oak has been under nature protection since 1939.

The name of the oak comes from the Tamme-Lauri farmstead, which in turn got its name from Saint Lawrence a patron against fire. In Estonian folklore *Laurits* was considered a fire spirit who was believed to dwell in the tree, bringing bad and sometimes good luck.

The Tamme-Lauri Oak was depicted on the reverse of the ten-Kroon banknote (Estonian national currency) from 1992-2010; since 2011 we use the Euro).



The Tamme-Lauri Oak

(https://en.wikipedia.org/wiki/Tamme-Lauri_oak)

19:50-21:45 Dinner at Leigo. The Leigo tourist farm is located in a picturesque site. The traditional Leigo Lake Music Festival is a famous summer event known all over Estonia already for 20 years. Leigo is a place for various celebrations and meetings. The halls have large open fireplaces. In 2014, a tourist pavilion was completed in the courtyard, which fits well in the natural environment by providing protection from rain while allowing a scenic view of the lake. The Leigo farm landscape with its numerous artificial lakes is created by Mr Tõnu Tamm, the host of the tourist farm. (<http://www.leigo.ee/>)

22:30 Arrival to Tartu (46 Vanemuise St). Have a good night!

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<https://www.visitestonia.com/en/ilumetsa-meteorite-craters>

https://www.youtube.com/watch?v=Dn3Eu_B4uXo

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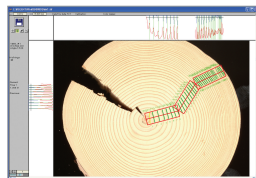
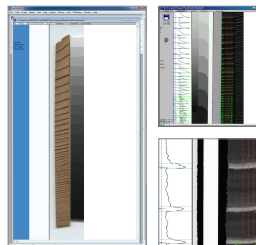
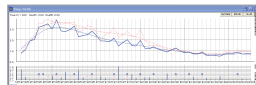


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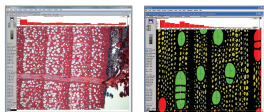
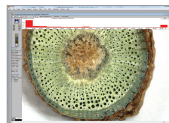
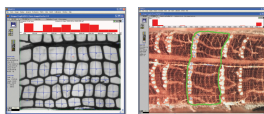


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