Climatically and environmentally driven landscape changes – a perspective of woody species

Habilitation Thesis

to obtain the *Venia docendi* in the Field of Applied and Landscape Ecology (*Aplikovaná a krajinná ekologie*) at the University of South Bohemia (USB), České Budějovice

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Field of study: Applied and Landscape Ecology (*Aplikovaná a krajinná ekologie*)

Form of the habilitation thesis: A set of published scientific papers supplemented by a commentary (*italics*) and related discussion. Only articles published in the Journal papers with Impact Factors were used for the submitted habilitation thesis. The applicant (J. Lehejček) is the first, corresponding, or the last author in the majority of works of which the thesis consists and declares significant mental share on all publications used.

The Statement

I declare that I have prepared the presented habilitation thesis entitled ***"Climatically and environmentally driven landscape changes – a perspective of woody species"*** independently using available literary sources and my scientific work results. I achieved the results of my scientific work in cooperation with colleagues from workplaces in the Czech Republic and elsewhere in Europe and the World from the time of doctoral studies until the writing of this work (period 2014 - 2025).

In the Czech Republic,
January – July, 2025

Mgr. *et* Ing. Jiří Lehejček, Ph.D.

Signature ………………………..

Preface

The submitted habilitation thesis documents my research results of the last years with a special focus on tundra and northern boreal forest development under dramatically changing climate and environmental conditions. The habilitation thesis is a compilation of related publications supplemented by commentary and general discussion.

I would like to thank the Czech Republic and European Union and their institutions which – although far from being perfect – provide fair, safe and stimulating environment for education, studying, research and life. Obviously, those democratic institutions would not exist without people and their everyday care. By submitting this habilitation thesis and together with my related work I would like attempt to modestly move from being mainly a consumer of abovementioned achievements to taking active role in their further production and safeguarding.

I finally want to warmly thank all my teachers, colleagues and to family members. Especially to my grandparents and parents as for them the well-being and education of their kids have always been the absolute priority.

My special thanks belong to my beloved wife Hana. She has always tolerated and often even supported my stupid jokes, nutty manners, long field works and overall course of my life which I gracefully call “justification of existence” but it is often nothing but egoistic behaviour. She is my compass and right borders. I am also mainly responsible for all the troubles she has to solve when we are raising our great kids, Šimon, Vavřinec, and Meda.

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Úvod (CZ)

Všechny tři člověkem způsobené planetární krize (klimatická změna, úbytek biodiverzity a znečištění) se propisují do životního prostředí i krajiny (Rockström et al., 2025). Ta na ně reaguje, je jimi přetvářena a sama je usměrňuje. Dynamika změn je v historickém měřítku bezprecedentní a přímé analogie dopadů jsou proto omezené (Tubi et al., 2022). Porozumění těmto dopadům je přitom zcela zásadní nejen z pohledu základního výzkumu, ale především pro bezpečnost společnosti a její adaptace na budoucí environmentální vývoj (Abbass et al., 2022). Proxy archivy, jakožto pasivní záznamníky, nejenže nabízí relativně přesný a přehledný pohled do minulosti, tam kde přímá pozorovaní chybí, ale část z nich je a bude i samotnými aktéry environmentální dynamiky (IPCC, 2021).

Mezi takové patří dřeviny. Letokruhový záznam nabízí staletí, mnohdy i tisíciletí dlouhý klimaticko-environmentální přehled na (sub-)annuální stupnici. Zároveň mají jednotlivé druhy dřevin často obrovské areály rozšíření, což umožňuje studium environmentu v měřítcích celých biomů, nebo kontinentů. Tato „globalizace poznání“ skrze letokruhový výzkum konkrétní dřeviny je však možná zejména v chladnějších biomech světa (boreální lesy a tundra), které jsou charakteristické nižší komplexitou a tedy i menší druhovou pestrostí dřevin, avšak významnějším geografickým rozšířením jednotlivých druhů (Weiser et al., 2007). Zároveň jsou dřeviny a ekosystémy, které spoluvytváří, významnou součástí biodiverzity, globálního cyklu uhlíku i recipienty znečištění. Budoucí vývoj všech tří planetárních krizí na ně tak nejenom přímo dopadá, ale současně jej přímo ovlivňují.

Metody, které využívá dendrochronologie k výzkumu letokruhů tak mohou poskytovat plastický obraz environmentálního vývoje krajiny, resp. adaptací dřevin na něj, současně však nabízí i cenné předpoklady budoucí dynamiky ekosystémů v dramaticky se proměňujících podmínkách (Fritts, 1976). Dendrochronologie pracuje velmi často s prahovými hodnotami externích podmínek, které limitují, resp. podněcují růst (Cook et Kairiūkštis, 1990). S nárůstem extremity klimatického systému a jeho celkovému posunu k vyšším teplotám bude těchto prahových hodnot dosahováno častěji (Allen et al., 2010; Tumajer et al., 2025). Dřeviny tak nepředstavují jen nástroj k porozumění měnících se podmínek, ale jsou i předmětem zájmu, jelikož jsou významným rezervoárem uhlíku i biodiverzity a jako takové mohou být v ohrožení.

Předložená habilitační práce studuje klimaxové dřeviny, klíčové environmentální fenomény, dvou výše zmíněných biomů severní polokoule. Jejím cílem je prohloubení porozumění dopadům klimatické a environmentální změny na růst a prosperitu vybraných dřevin, přičemž zároveň anticipuje budoucí trendy environmentálního vývoje, dynamiku změn vegetace a v konečném důsledku i dopady na biologickou rozmanitost tundry a boreálních lesů.

1 Introduction

All three human-caused planetary crises (climate change, biodiversity loss and pollution) are being imprinted in the environment and the landscape (Rockström et al., 2025). The environment and landscape respond to them, are transformed by them and themselves regulate them. Nevertheless, the dynamics of change is unprecedented on a historical scale and direct analogies of the impacts are therefore limited (Tubi et al., 2022). Understanding these impacts is therefore essential not only from the perspective of basic research, but above all for the safety of society and its adaptation to future environmental developments (Abbass et al., 2022). Proxy archives, as passive recorders, offer a relatively accurate and clear view into the past where direct observations are lacking, but some of them are and will be the actors of environmental dynamics themselves as well (IPCC, 2021).

These include trees and shrubs. The annual ring record offers a centuries-long, often even millennia-long climate-environmental overview on a (sub-)annual scale. At the same time, individual species often have vast distribution, which allows the study of the environment on the scale of entire biomes or continents. However, this "globalization of knowledge" through annual ring research of a specific species is possible especially in the colder biomes of the world (boreal forests and tundra), which are characterized by lower complexity and therefore lower species diversity of woody species but at the same time by a more significant geographical distribution of individual species (Weiser et al., 2007). Moreover, such woody species and their ecosystems are a significant part of biodiversity, the global carbon cycle and recipients of pollution. The future development of all three planetary crises is closely linked and bidirectionally affected by shrubs and trees.

The methods used by dendrochronology to research annual rings can thus provide a comprehensive picture of the environmental development of the landscape, as well as the adaptations of woody plants to it (Fritts, 1976). Simultaneously, they also offer valuable assumptions about the future dynamics of ecosystems in dramatically changing conditions. Dendrochronology very often works with threshold values of external conditions that limit or stimulate growth (Cook et Kairiūkštis, 1990). With the increase in the extremes of the climate system and its overall shift towards higher temperatures, these threshold values will be reached more often (Allen et al., 2010; Tumajer et al., 2025). Thus, woody plants are not only a tool for understanding changing conditions, they are also a subject of interest themself, as they are a significant reservoir of carbon and biodiversity and as such may be at risk.

The presented thesis studies climax woody species, key environmental phenomena, of the two aforementioned biomes of the Northern Hemisphere. Its aim is to provide better understanding of the impacts of climate and environmental change on the northern woody species growth. At the same time, it anticipates future trends in environmental development, the dynamics of vegetation and landscape changes and ultimately the impacts on biodiversity in tundra and boreal forest bioms.

2 Dwarf tundra shrubs growth as a proxy for late Holocene climate change

Publication 1 by **Lehejček, J.** - *Review paper*

The general objective of the first part of the paper was to present comprehensive information about tundra shrub research for paleoecological, especially paleoclimatological purposes. Second part of this review deals with the influence of climate and site characteristics on length of plant's growth. Provided review may be understood as the issue opening work portraying the basic principles and potentials.

Research on dwarf tundra shrubs is still relatively immature and faces many difficulties. Not only those related to growth in the harsh environments but technically also the correlation of growth chronology with climate is usually weaker than the one from nearby tree chronologies (e.g. Zongshan et al., 2013). Such investigations can nevertheless extend usage of dendroecological studies into new climatic zones and therefore might help to understand future environmental changes, their drivers and impacts in the Arctic and alpine ecosystems (Woodcock et Bradley, 1994).

Higher summer temperatures are believed to be the most positively influencing the shrub growth (e.g. Buchwal et al. (2013) for *Salix polaris* and mean JJA temperatures ($r = 0.70$, $P < 0.01$); Zhongshan et al. (2013) for *Rhododendron przewalskii* and April, July temperatures ($r = 0.326$, $P < 0.05$); Hallinger et al. (2010) for *Juniperus nana* and June + July temperatures ($r = 0.4$, $P < 0.05$); Blok et al. (2011) for *Salix pulchra* and early summer temperature ($r = 0.73$, $P < 0.01$). Ring width can be regarded as a variable integrating temperature conditions during the main growing season at particular localities. However, special cases where local setting can eliminate this strongest climate effect of growing season are reported. Therefore, deep knowledge of local environment and specie´s ecology is fundamental.

The longest life spans of tundra shrubs are usually achieved at sites with an intermediate level of soil moisture with rather limited nutrient supply, and at undisturbed sites (Schweingruber et Poschlod, 2005). That is why detailed reconnaissance of the field is crucial to obtain the longest possible chronology. The field sampling should not concentrate only on the oldest plants since their growth becomes deteriorated with age but should aim on population age diversity to strengthen and make the climate signal more reliable over the whole chronology.

Despite many successes achieved with tundra shrub-ring width investigations, studies should also focus on the other growth parameters (lumen areas, lumen perimeters, cell wall thicknesses etc.) to strengthen the climate/growth correlation (see Lehejček et al., 2017).

In spite of outlined constrains, tundra shrubs present enormous and valuable archive not only for paleoclimatology but also for paleoecological reconstructions. Samples of dwarf tundra shrubs provide high-resolution year-to-year information on climate variation based on annual rings.

Access to the manuscript: **Lehejček, J.** (2015): Dwarf tundra shrubs growth as a proxy for late Holocene climate change. *Czech Polar Reports* 5 (2): 185-199. https://doi.org/10.5817/CPR2015-2-16

2.1 The annual growth rings beyond the tree line – a case study from Greenland

Publication 2 by **Lehejček, J.**, Svoboda, M. - *Journal paper with Impact Factor*

In this paper we present findings on J. communis L. (Cupressaceae) annual growth rings and their direct relation to climate. So far, this is done without other growth parameters at a cellular level. The work proved Juniperus communis to be a valuable environmental proxy for climate reconstructions synchronised with other proxy archives.

Individuals of *Juniperus communis* (n = 41) from Kobbefjord, Greenland were investigated. Annual rings were measured along the longest axis of the basal stem discs, cross-dated, and detrended. More than 2 centuries long chronology was presented. From all tested climate variables, only mean summer temperature showed strong and significant positive relationship to mean annual ring increments ($r = 0{,}51$, $p < 0{,}001$, glk = 0,6). Moving window correlation for those integrated June/July/August temperatures and mean annual growth ring increment remained stable over the 20th century. The development of mean summer temperatures was reconstructed and linked with the trends from other archives (ice cores, census of local population). The end of Little Ice Age is also clearly visible in the record

Access to the manuscript: **Lehejček, J.**, Svoboda, M. (2017): The annual growth rings beyond the tree line – a case study from Greenland. *Reports of Forestry Research* 62 (2), 101-108. https://www.vulhm.cz/files/uploads/2019/02/485.pdf

2.2 Wood-anatomy of *Juniperus communis*: a promising proxy for paleoclimate reconstructions in the Arctic

Publication 3 by **Lehejček, J.**, Buras, A., Svoboda, M., Wilmking, M. - *Journal paper with Impact Factor* (**Q2**)

In Lehejček et al. (2017) we investigated ecology of Juniperus communis using quantitative wood anatomy allowing for more detailed insight into climate-environmental sensitivity at the cell level. We also aimed for understanding of growth-age trends of cell parameters in order to disentangle climate induced growth variations and those driven by internal nature of shrub. Only if age trends are correctly analysed (detrended), then chronologies can be used as reliable environmental proxy.

Annual ring-widths and cell anatomical parameters of 20 individuals from south-west Greenland were measured to test for age-related trends in the proxy time series and to correlate them with past climatic conditions. A clear age trend in the investigated growth parameters (ring-widths, conduit-lumen areas, and cell wall thicknesses) was documented, which indicated the need for detrending the time series prior to possible climate correlation analyses and climate or environmental reconstructions. Notably, prostrate growth forms of *J. communis* do not exhibit the general trend of an exponential widening of the conduit-lumen areas during ontogeny, as has been observed for many tree species (Carrer et al., 2015), but their conduit lumens stop to increase in size at some point. This is possibly caused by a combination of extreme climate and physiological adaptations, which result in a prostrate growth form. Of the tested growth parameters, only detrended cell wall thickness showed stable correlations with summer temperature and the summer standardized precipitation evapotranspiration index (SPEI). The other growth parameters did not pass cross-calibration verification analyses, although for ring-widths we found the strongest climate correlations. Despite the fact that the ecophysiological processes behind our observations (i.e. reduced cell wall thickness combined with wider rings under dry conditions in the vegetation season) yet are not fully understood, the potential of *J. communis* for climate reconstructions was recognised. To our knowledge, this was the first demonstration of using cell anatomical parameter of *J. communis* shrubs as palaeoclimatological proxy for the Arctic.

Access to the manuscript: **Lehejček, J.**, Buras, A., Svoboda, M., Wilmking, M. (2017): Wood-anatomy of *Juniperus communis*: a promising proxy for paleoclimate reconstructions in the Arctic. *Polar Biology* 40 (5): 977 - 988. https://link.springer.com/article/10.1007/s00300-016-2021-z

2.3 Influence of larval outbreaks on the climate reconstruction potential of an Arctic shrub

Publication 4 by Wilmking, M., Buras, A., **Lehejček, J.**, Van Der Maaten, E., Lange, J., Shetti R. - *Journal paper with Impact Factor* (**Q1**)

Despite promising results with the Arctic shrubs, many challenges affect the record they provide. Disturbance agents are phenomena which blur the climate reconstruction on one side but if detected in tree-rings they also comprehend the environmental knowledge which is often closely linked with climate change. In this paper we portray the effects of biotic disturbance on shrub growth.

Environmental reconstructions are incomplete if climate signal is not decoupled with other factors affecting growth (*i.e.* disturbances). Differentiation between herbivory and climatically induced growth depressions represents important example (e.g. Kozlov et al., 2017). One of the most common Arctic shrubs, *Alnus viridis* was used as a test case to address this question. Shrub-ring widths and cell wall thicknesses were measured and site chronologies of each parameter were built. Climate-growth relationships were analysed and their stability was tested over time. A pointer-year analysis was applied to detect growth depressions. Correlations with climate data showed strong significantly positive and stable correlations between summer temperatures and ring-width with the exception of the recent decade. A climate reconstruction model failed stability tests, when the complete period of record was used for calibration and verification. Wood anatomy analysis uncovered the occurrence of unusual cell structure (very thin cell walls) in the exceptionally narrow ring of 2004, a recorded insect outbreak year in other parts of Greenland. When excluding the affected ring and a recovery period, the reconstruction model passed all tests, suggesting that the unusual 2004 ring was not climate driven, but rather the result of an insect attack. When combining anatomical analysis with traditional ring-width measurements, a step further is taken in potentially distinguishing small rings caused by insect attacks from small rings formed in climatically challenging years. Such approach provides useful methodological combinations to enable more robust climate-environmental reconstructions in areas where other records are extremely sparse.

Access to the manuscript: Wilmking, M., Buras, A., **Lehejček, J.**, Van Der Maaten, E., Lange, J., Shetti R. (2018): Influence of larval outbreaks on the climate reconstruction potential of an Arctic shrub. *Dendrochronologia* 49, 36-43. https://doi.org/10.1016/j.dendro.2018.02.010

2.4 Alpine and Arctic tundra shrub populations show similar ontogenetic growth trends but differing absolute growth rates and lifespan

Publication 5 by **Lehejček, J.**, Trkal, F., Doležal, J., Čada, V. - *Journal paper with Impact Factor* (**Q1**)

Ontogeny, growth rates and lifespan are important parameters of shrub growth from two points of view. All are crucial ecological characteristics which need to be considered in environmental studies employing annual rings. But they also exhibit future prospects of tundra shrub performance in changing climate. In Lehejček et al. (2023) we evidenced plastic adaptations of shrubs to different climate conditions with increased growth rates, reduced lifespan but stable ontogeny under more temperate climate which is foreseen for the Arctic in close future.

Ontogenetic trends in primary (apical) and secondary (stem thickening) growth of plants in Arctic (Svalbard, Norway) and alpine (Krkonoše, Czechia) populations of the black crowberry (*Empetrum nigrum*) – the dominant and climax plant species of certain tundra communities – were analysed. The environmental conditions in alpine areas are more favourable for plant growth than those in the High Arctic, where temperatures are lower, there is less precipitation and soils are shallower, among other differences. These differences were clearly reflected in significant distinctions in absolute growth rates and shrub age between the populations under study. However, almost no divergence in ontogenetic growth trends between the populations (based on ring-width measurements made from the base to the top of plants, known as serial sectioning) was found. In both populations, primary and secondary stem base growth decreased over the course of ontogeny. No significant differences in the slope of the trends were found in either primary or secondary stem base growth. Ontogenetic trends in the shrubs analysed were, thus, surprisingly stable despite the prominently dissimilar environmental conditions. *Empetrum* plants have adapted to the different environments by altering their absolute growth rate only. This adaptation has probably also resulted in the different longevity of plants constituting the study populations, confirming the theory that slower-growing plants live longer (e.g. Zverev et al., 2008; Büntgen et al., 2019; Tumajer et Lehejček, 2019).

Access to the manuscript: **Lehejček, J.**, Trkal, F., Doležal, J., Čada, V. (2023): Alpine and Arctic tundra shrub populations show similar ontogenetic growth trends but differing absolute growth rates and lifespan, *Dendrochronologia* 126046, https://doi.org/10.1016/j.dendro.2022.126046

3 Shrubs shed light on 20th century Greenland Ice Sheet melting

Publication 6 by Buras, A., **Lehejček, J.**, Michalová, Z., Morrissey, R., Svoboda, M., Wilmking, M. - *Journal paper with Impact Factor* (**Q2**)

After throughout research of tundra shrub ecology, ontogeny trends, climate-growth relationship, disturbance effects, etc. beforehand we could approach to sound environmental reconstruction based on multiparameter shrub proxies. Juniper shrubs formed thicker cell walls in warmer and more humid summers, thus, in the conditions which are the most favourable for ice melt. We could, therefore, reconstruct and verify the 20th century Greenland Ice Sheet melting.

The Greenland Ice Sheet (GrIS) is a key element of the global climate system and thus knowledge about its melting in the past is desirable (Lenaerts et al., 2015). However, instrumental GrIS-melt records only date back until 1979 and climate data reconstructions covering the 20th century differ with respect to absolute values (Hanna et al., 2014). To extend our knowledge about the Greenland Ice Sheet dynamics the potential of shrub ring-widths and wood-anatomy as proxies for GrIS-melt was examined. Significant correlations between shrub cell-wall thickness and regional GrIS-melt was found. A respective transfer function calibrated over the period 1979 to 2007 successfully passed model calibration-verification tests and explained 42% of GrIS-melt variability. Consequently, the first GrIS-melt reconstruction based on shrub wood-anatomy covering the period 1909 to 2012 was presented and compared against two temperature-based reconstructions. For the period prior to 1930 the new reconstruction contrasts with existing literature but generally confirms that most recent record melt rates are amongst the highest since the early 20th century. The sensitivity of shrubs to climate and environmental change highlights the potential of using multiparameter shrub proxies in applied ecology research.

Access to the manuscript: Buras, A., **Lehejček, J.**, Michalová, Z., Morrissey, R., Svoboda, M., Wilmking, M. (2017): Shrubs shed light on 20th century Greenland Ice Sheet melting. *Boreas* 46(4): 667-677. https://doi.org/10.1111/bor.12244

4 Growing faster, longer or both? Modelling plastic response of *Juniperus communis* growth phenology to climate change

Publication 7 by Tumajer, J, Buras, A., Camarero, J.J., Carrer, M., Shetti, E., Wilmking, M., Altman, J., Sanguesa-Barreda, G., **Lehejček, J.** - *Journal paper with Impact Factor* (**D1**)

As global interest of tundra shrub research in general and juniper in particular has increased over the last decade I could invite other researchers to so called "juniper network". Nowadays, it consists of more than 20 sites over the Northern Hemisphere and is contributed by global research community. The first study published based on this network highlights the plasticity in growth phenology of widely distributed juniper shrubs to climate warming: an earlier onset of cambial activity that offsets the negative effects of summer droughts in the Mediterranean and, conversely, an intensification of growth rates during the short growing seasons in the Arctic. Such plastic growth responsiveness allows woody plants to adapt to the local pace of climate change.

Vaganov–Shashkin process-based model of wood formation (Vaganov et al., 2006) was applied to estimate the trends in growing season duration and growth kinetics of Northern Hemisphere *Juniperus communis* communities since 1940. The simulations indicated regional differences in growth dynamics and plastic responses to climate warming. The mean growing season duration was the longest at Mediterranean sites and, recently, there has been a significant trend towards its extension of up to 0.44 days/year. However, this stimulating effect of a longer growing season was counteracted by declining summer growth rates caused by amplified drought stress. In contrast, durations of growing seasons in the Arctic show lower and mostly non-significant trends. However, spring and summer growth rates follow increasing temperatures, leading to a growth increase of up to 0.32 %/year. The results provided new insight into the spatial and temporal growth variability of the woody plant with the widest global distribution. The high simulated plasticity of growth dynamics might constitute a crucial predisposition that enabled *J. communis* to colonize a large geographical area and to survive under or even benefit from environmental instability.

Access to the manuscript: Tumajer, J, Buras, A., Camarero, J.J., Carrer, M., Shetti, E., Wilmking, M., Altman, J., Sanguesa-Barreda, G., **Lehejček, J.** (2021): Growing faster, longer or both? Modelling plastic response of *Juniperus communis* growth phenology to climate change; *Global Ecology and Biogeography*, 1-16. https://doi.org/10.1111/geb.13377

4.1 Old Juniper Troll stand – The oldest shrub population from Scandinavia

Publication 8 by **Lehejček, J.**, Roman, M., Lexa, M., Aspholm, P.E., Mašek, J. - *Journal paper with Impact Factor*

After exploring the role of longevity in shrub plastic responses to environmental change we exploited the oldest population in our dataset deeper. Old plant communities are of utmost importance for nature conservation, carbon sequestration, as well as gene pool maintenance. We dated and provided a growth chronology of the oldest living shrub population (190 ± 148 years) from Scandinavia with the oldest individual being 683 years old.

Shrub populations occurring in extreme environments beyond abiotic tree-lines provide diverse ecosystem services and have potential as proxy archives because they often inhabit areas with scarce and short instrumental records (Körner, 2017; Lehejček et al., 2017). Though, it is not always easy to find such populations and sample as they often inhabit inaccessible places frequently with conservation status. Most common habitat for ancient *Juniper* communities is rock or a boulder field moderately disturbed by rock fall or other mass movement which does not allow for permanent erect woody species establishment (Adams, 2008). In fact, such environment is more stable for utilization of *Juniper* potential for longevity than zone between tree and shrub line as this zone is often shifted with changing climate. Thus, combination of both provides the best conditions for longevity: abiotic tree line at or above biotic tree line. Such population was described in Scandinavian tundra (Kola peninsula, Norway). The age of the oldest individual dated back to 1331 represents a conservative estimate, as shrubs in extreme environments do not form even a single row of cells in some years. The cross-dating issues of poorly growing shrubs do not fully allow to rely on climate sensitivity of the juniper population studied. Old populations present an important gene source in plant recruitment, particularly in the context of the present environmental change (Myers-Smith et al., 2011).

Access to the manuscript: **Lehejček, J.**, Roman, M., Lexa, M., Aspholm, P.E., Mašek, J. (2024): Old Juniper Troll stand – The oldest shrub population from Scandinavia. *Journal of Forest Science* 70(4):176-184. https://doi.org/10.17221/118/2023-JFS

4.2 Plant–soil interactions in a deglaciated landscape: roots reflect environmental severity

Publication 9 by **Lehejček, J.**, Huseynli, A., Luláková, P., Křížová, P., Hájek, T., Němeček, K., Drábek, O., Valášek, P., Valášek, P. JR, Tejnecký, V. - *Journal paper with Impact Factor* **(Q2)**

Shrub communities also play crucial role in the colonisation of young tundra and this role is expected to increase with ongoing warming not only in the Arctic but in deglaciating mountains as well (see chapter 2.4 for comparison or Lehejček et al., 2023). Therefore, in Lehejček et al. (2025) we studied root exudation which is among the key factors providing necessary nutrients to plant growth and primary succession of deglaciated landscape. Arctic willows exude more under more severe conditions of poorly developed initial soils but in the fully vegetated tundra with high plant competitions. More developed soils which are not yet fully covered by vegetation are however less demanding environment and willows exude less.

Root exudation, influenced by root tissue environment, enhances the expansion of shrubs in the Arctic. It plays a part in nutrient acquisition by plants and thus the growth of whole communities. However, the extent to which exudation and root tissue environment develop to achieve sufficient nutrient uptake in deglaciating and shrubifying Arctic tundra remains unknown. We studied the content of biogenic elements in soils of different maturities following deglaciation, the age structure of the climax species Salix polaris, exudation by its roots, and the concentrations of different nutrients in its roots and leaves in the forefield of the Nordenskiöld glacier in the Svalbard archipelago. Polar willow shrubs have a greater relative propensity towards exudation under more severe environmental conditions. The least developed root system of shrubs in the youngest soils as well as the highest vegetation competition level increases the potential of exudation.

Access to the manuscript: **Lehejček, J.,** Huseynli, A., Luláková, P., Křížová, P., Hájek, T., Němeček, K., Drábek, O., Valášek, P., Valášek, P. JR, Tejnecký, V. (2025): Plant–soil interactions in a deglaciated landscape: roots reflect environmental severity. *Scandinavian Journal of Forest Research*, 1–11. https://doi.org/10.1080/02827581.2025.2563598

5 Boreal tree-rings are influenced by temperature up to two years prior to their formation: a trade-off between growth and reproduction?

Publication 10 by Tumajer, J. *et* **Lehejček, J.** - *Journal paper with Impact Factor* (**D1**)

Large spatial and between-tree variability has recently been observed in the response of boreal forests to ongoing climate change, spanning from growth stimulation by increasing temperatures to drought limitation. To predict future responses of boreal forests, it is necessary to disentangle the drivers modulating the temperature-growth interaction. Transition zone between tundra and boreal forest has already become dynamic margin and better understanding of growth and reproduction of boreal forest can help predict future landscape change. We discovered important growth-reproduction trade-off as a possible factor modulating the response of boreal forests to summer temperatures which enhances the reproduction of boreal forest near tree line and thus also colonization of new formerly tundra dominated territories.

Two inventory plots (at a boreal treeline and closed-canopy forest) were established and site chronologies in *Picea glauca* stands at the transition between boreal forest and tundra in Northern Quebec, Canada were assembled. All chronologies were correlated with climatic data to identify the course of climatic conditions driving variability in tree-ring widths. The results showed that the growth of *P. glauca* correlates significantly with summer temperature in tree-ring formation years and during up to two prior summers. Tree-ring width was positively influenced by summer temperatures in tree-ring formation year and two years prior to tree-ring formation. In addition, climate-growth correlations indicated a negative effect of summer temperature one year before tree-ring formation at the closed canopy forest site. The pattern of climate-growth correlations is tightly synchronized with previously published patterns of climate-reproduction correlations of *P. glauca*, suggesting a growth-reproduction trade-off as a possible factor modulating the response of boreal forests to summer temperatures (*sensu* Roland et al 2014). However, the response to summer temperatures one year before tree-ring formation is significant only in mature (old, large and dominant) individuals at the closed-canopy site. The inverse pattern of temperature-growth correlations during a sequence of three years challenges predictions of how boreal forests respond to climate change.

Access to the manuscript: Tumajer, J. *et* **Lehejček, J.** (2019) Boreal tree-rings are influenced by temperature up to two years prior to their formation: a trade-off between growth and reproduction? *Environmental Research Letters* 14 124024. 10.1088/1748-9326/ab5134

5.1 Linkage between growth phenology and climate-growth responses along landscape gradients in boreal forests

Publication 11 by Tumajer, J., Altman, J. *et* **Lehejček, J.** - *Journal paper with Impact Factor* (**D1**)

Boreal forests also represent an important carbon sink and, therefore, significantly contribute to climate change mitigation. Tree-ring width series of boreal species reflect climate variation at the moment of tree-ring formation but also lagged climatic effects from dormancy preceding tree-ring formation and antecedent growing seasons. However, little was known about how the growth sensitivity to climate in specific intra-annual periods varies across the landscape. Here, we assessed growth responses to climate variation during the 45 months preceding the tree-ring formation for nine boreal stands of Picea glauca and Picea mariana distributed along the gradients of elevation and slope aspect in northern Quebeck, Canada. We concluded that i) boreal forest tree growth is shaped by current, dormant, and antecedent climatic factors; ii) Growing season varies between 100 days at treelines and 150 days in the lowland; iii) At treelines, growth responds to climatic effects current to tree-ring formation; iv) At lower elevations, growth is sensitive to dormancy and antecedent climate. Boreal forest dynamics remains key phenomenon for environmental and landscape projections and taiga/tundra transition zone is crucial playing field for interpreting different scenarios.

Process-based modelling of wood formation and remote sensing data were combined to determine growth phenology at each site. Next, intra-annual seasons with significant climate growth correlations was classified based on the timing of dormancy and growth periods. Both the phenology and the climate-growth relationships systematically shifted with elevation and, to a lower extent, also with slope orientation at the treeline. The mean duration of the growing season varied between 100 days at treelines above 900 m and 160 days at lowlands below 500 m. The growth at treelines was stimulated by temperature in the summer of the tree-ring formation year and two years before tree-ring formation. The period of significant climate-growth correlations during the current summer did not exceed three months in agreement with the local duration of the growing season. The growth of trees in lower elevations was instead stimulated by high temperature during the dormancy periods but restricted by high temperature in antecedent summer seasons. In conclusion, it highlights the linkage between the timing of climate-growth sensitivity and growth phenology, primarily determined by proximity to the treeline. Consequently, accounting for landscape gradients in growth phenology is crucial for upscaling the climatic limits of boreal stands' growth as climate change progresses.

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6 Discussion

Prospects of tundra biome delivered by annual rings

Due to lack of long instrumental climatic records and their spatial scarcity (Weijers et al., 2010) as well as often missing written sources from colder areas, studies focusing on proxy archives and environmental reconstructions from those regions are important evidence of past environmental-climatic variations and base for future projections (AICA, 2005). Northern tundra and its southern transitional zone to boreal forests has been for long time considered to be the most dynamic and sensitive environment, where the climate change and environmental shifts are pronounced the most significantly (e.g. already Beniston et Innes, 1998; Serreze et al., 2000). Those biomes have relatively low woody species diversity hence large geographical species population distributions (Weiser et al., 2017). Such spatial species vastness allows for exploiting available proxy archives and interpret results on (sub-)continental or even hemispherical scale. That gives us powerful tool to assess large environmental and landscape trends.

Long-live, circumpolar, and relatively abundant tundra shrub *Juniperus communis* L. is considered to be such suitable environmental archive (Pelizarri et al., 2016; Lehejček et al., 2017; Buras et al., 2017; Tumajer et al., 2021). Its territory spans all continents of the Northern Hemisphere and most of its biomes (Adams, 2008). It has shown a good potential for environmental reconstructions because of its growth ecology as well as ecological performance on the boreal/tundra transition (e.g. Lehejček et al., 2024). Growth plasticity (*sensu* Tumajer et al., 2021) makes this species well suitable for adaptation to accelerated climate change in future but at the same time its enormous longevity spanning back over several centuries allows for past environmental and climate reconstructions. Moreover, recent nature conservation and climate change mitigation initiatives increasingly focus on research and protection of ancient woodlands and old-growth populations, as nature preservation practitioners and ecologists better understand and recognize their multiple and unique environmental benefits (Pimm et al., 2018; Di Marco et al., 2019), including their key role as carbon sinks (Luyssaert et al., 2008; Keith et al., 2022). Ecosystems with the presence of old individuals promote – among other ecosystem services – further carbon storage because of their long residence times (Kangas et Ollikainen, 2022). Old shrub communities will also likely serve as important genetic reservoirs for shrub expansion towards the new limits in accelerated pace of climate and environmental dynamics (Myers-Smith et al., 2011). It is, therefore, essential to investigate and preserve old populations (Keith et al., 2022).

Nevertheless, deficiencies in northern shrub research in general and juniper in particular remain. Although shrubs usually share a similar response to regional macroclimate, their local response might be altered by site-specific conditions (Buchwal et al., 2020). Indeed, according to Tumajer et al. (2021) the true local response of *J. communis* to future climate change might be shifted by climatically triggered abrupt events (e.g., pathogen outbreaks, growth–reproduction trade-offs; Prendin et al., 2020; Shetti et al., 2018), pollution (Kirdyanov et al., 2020), snow dynamics (Bjorkman et al., 2015; Pellizzari et al., 2014) or interactions between sympatric species (Sánchez-Salguero et Camarero, 2020). Although cambial activity is currently not assumed to be limited by the rate of photosynthesis even at the harshest sites (Körner, 2015), growth trends of *J. communis* populations might possibly decouple in the future. Significant increases of CO_2 atmospheric concentrations and the potential of individual populations to adjust their rates of photosynthesis remains subject of future research. Similarly, juniper extreme longevity phenomenon as well as its large longevity differences between inhabited environments remain important part to be understood before even more conclusive remarks can be articulated on its climate/environmental – growth relationship.

Prospects of boreal biome delivered by annual rings

Boreal forests and adjacent ecotonal transition zones (tundra and temperate forests), covering 22% of the terrestrial surface, provide various ecosystem services such as carbon sequestration, climate regulation, or unique biodiversity (Girona et al., 2023). Ongoing climate and environmental (including disturbance) shifts and their feedback loops of historically unprecedented extent pose a substantial threat to boreal forests resistance and resilience (Gauthier et al., 2015; IPCC, 2021). These impacts can have cascading effects leading to changes in boreal forest productivity, distribution, structure, and diversity (e.g. Tumajer et Lehejček, 2019). Hence, understanding boreal forest responses to past, current, and future climate change is of global relevance (Tagesson et al., 2020; Girona et al., 2023).

One of the most significant responses of boreal forests to increasing temperature is a shift in forest composition, where certain woody species become better adapted to warmer conditions and others become less competitive (Mekonnen et al., 2019; Baltzer et al., 2021). Simultaneously, warming may, to certain extent, stimulate the boreal tree growth and thus affect overall forest productivity (D'Orangeville et al., 2018). However, the eventual positive effect of warming on productivity can be compromised by the impacts of drought (Sánchez-Pinillos et al., 2022; Liu et al., 2023). Boreal forests with higher tree species and structural diversity nevertheless generally exhibit higher resistance to environmental change (D'Orangeville et al., 2023).

Climate change is also often associated with different trends in the frequency and severity of disturbances (Seidl et al., 2017). Increase in temperatures (mainly winter) facilitate the risk of insect outbreaks in previously hostile area, with especially northern boreal forests becoming more vulnerable to outbreaks (Pureswaran et al., 2018). Drier and warmer summer climate, on the other hand, create conditions favorable for fires and together these factors are often responsible for substantial forest losses and/or degradation (Scholten et al., 2021; Fan et al., 2023). Nevertheless, several recent studies identified that pest outbreaks dampen the fire risk (Meigs et al., 2016) as well as feedbacks of changing vegetation with increased dominance of deciduous trees (Mekonnen et al., 2019; Mack et al., 2021).

Distribution of boreal forests is thus expected to experience substantial area losses under warming climate and due to spherical shape of hemisphere also spatial loss of potential habitats (Boonman et al., 2022; Elsen et al., 2022). Specifically, it is projected that woody plant transgression intensifies over tundra and boreal forest will shift northwards, while temperate mixed forest replaces boreal forest at its southern edge (García Criado et al., 2020; Boonman et al., 2022). Importantly and in contrary to such natural hypothesis, Reich et al. (2022) discuss that climate-change induce failure of southern boreal forests may be faster than the northward temperate forest migration causing considerable concern given the ecosystem and its services provided. Nevertheless, to fully disentangle the future of boreal forest biome and its ecotonal transitions (temperate forest in the south as well as tundra in the north), it is necessary to understand the complex responses of various forest types as some tree species or their compositions and structural diversity may reduce the vulnerability of boreal forests to environmental change (Hisano et al., 2019).

As shown, the future distribution and climate change adaptation of boreal forests under environmental change is still ambiguous (but see e.g. Tumajer, Altman et Lehejček, 2023). Complex interactions between forests, climate change, and disturbances determine the future of boreal forest and they are specific for various forest types and local conditions (Dale et al., 2000; Randerson et al., 2006; Seidl et al., 2017; Mekonnen et al., 2019; Forzieri et al., 2021). The majority of existing studies focused on a certain part of environmental changes or a limited area (Marchand et al., 2018). In addition, study-specific methodologies largely prevent their comparability and thus deeper insight to complex boreal forest responses to conditions under change (Marchand et al., 2018). To overcome these limitations, it is crucial to employ uniform methodology across various boreal forest types, including the neighbouring biomes (temperate forest in the south and tundra in the north) (Reich et al., 2022) to comprehend species to forest type specific sensitivity to past, present, and future environmental changes at various spatial and temporal scales (Altman, 2020).

Records suitable for revealing the response of boreal forests (and its ecotonal transitions) to climate and environmental change differ greatly in their availability, length, and temporal and spatial resolution (Heinrichs et al., 2005; Ols et al., 2019). However, proxies with high spatiotemporal resolution, such as tree rings, provide a key long-term record of forest response to both, climate and environmental change, and thus reduce uncertainties in current understanding regarding the future of boreal forests (Girardin et al., 2021; Girona et al., 2023). In addition, tree-(or annual-)rings provide multiple parameters with different temporal resolution, such as xylem anatomical traits, earlywood and latewood width, growth patterns, resin ducts, or tree death and establishment dates. A proper combination of these parameters allows for the robust reconstruction benchmarks of the past climate and environment enabling comprehensive understanding of landscape change impact on boreal forests. To go beyond, it is thus necessary to develop a systematically and uniformly sampled network of study sites covering different spatial and temporal scales, and integrate them to the global climate change research (Babst et al., 2017; Heilman et al., 2022). Similarly to juniper network (e.g. Lehejček et al., 2024 or Tumajer et al., 2021) for beyond treeline environments such boreal forest network would be highly beneficial for sound understanding the boreal forest environment and its future trends and dynamics.

7 Conclusions, importance, and perspectives

Climate, environmental and landscape development are well documented in woody species growth tissues as they react to respective changes sensitively, over long period of time, and on a large geographical scale. Thus, they provide important and yet objective insight into related trends where direct or instrumental observations are missing. Nonetheless, environmental reconstructions are only part of applied ecology knowledge which woody species can offer. Future prospects of climate-environmental impacts on landscape change can be derived if climax (*i.e.* woody) species' ecology, adaptations, growth responses, or longevity is understood and contextualised (e.g. in network under the same methodology applied). We assume that the appropriate study fields are relatively less complex but climatically the most affected biomes – tundra and boreal forest – and their transitional (ecotonal) zones on both sides which host the most abrupt environmental changes. As such they could provide important analogues for future global courses. Climatically driven vegetation shift may further temporarily challenge the biodiversity and net carbon balance which does not necessarily place whole biomes at risk but rather – via human dependencies – may compromise societal development of communities and populations. Thus, such knowledge and its future deepening can make us more resilient to climate-environmental changes to come.

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9 Full publication profile of the author (period: 2014 - 2025)

9.1 Published papers in journals with Impact Factor included in the habilitation thesis (D1, Q1, Q2 highlighted)

1) Buras, A., **Lehejček, J.**, Michalová, Z., Morrissey, R., Svoboda, M., Wilmking, M. (2017): Shrubs shed light on 20th century Greenland Ice Sheet melting. *Boreas* 46(4): 667-677. https://doi.org/10.1111/bor.12244 **(Q2)**

2) **Lehejček, J.** (2015): Dwarf tundra shrubs growth as a proxy for late Holocene climate change. *Czech Polar Reports* 5 (2): 185-199. https://doi.org/10.5817/CPR2015-2-16 (Scopus)

3) **Lehejček, J.**, Buras, A., Svoboda, M., Wilmking, M. (2017): Wood-anatomy of *Juniperus communis*: a promising proxy for paleoclimate reconstructions in the Arctic. *Polar Biology* 40 (5): 977 - 988. https://link.springer.com/article/10.1007/s00300-016-2021-z **(Q2)**

4) **Lehejček, J.,** Huseynli, A., Luláková, P., Křížová, P., Hájek, T., Němeček, K., Drábek, O., Valášek, P., Valášek, P. JR, Tejnecký, V. (2025): Plant–soil interactions in a deglaciated landscape: roots reflect environmental severity. *Scandinavian Journal of Forest Research*, 1–11. https://doi.org/10.1080/02827581.2025.2563598 **(Q2)**

5) **Lehejček, J.**, Roman, M., Lexa, M., Aspholm, P.E., Mašek, J. (2024): Old Juniper Troll stand – The oldest shrub population from Scandinavia. *Journal of Forest Science* 70(4):176-184. https://doi.org/10.17221/118/2023-JFS

6) **Lehejček, J.**, Svoboda, M. (2017): The annual growth rings beyond the tree line – a case study from Greenland. *Reports of Forestry Research* 62 (2), 101-108. https://www.vulhm.cz/files/uploads/2019/02/485.pdf

7) **Lehejček, J.**, Trkal, F., Doležal, J., Čada, V. (2023): Alpine and Arctic tundra shrub populations show similar ontogenetic growth trends but differing absolute growth rates and lifespan, *Dendrochronologia* 126046, https://doi.org/10.1016/j.dendro.2022.126046 **(Q1)**

8) Tumajer, J, Buras, A., Camarero, J.J., Carrer, M., Shetti, E., Wilmking, M., Altman, J., Sanguesa-Barreda, G., **Lehejček, J.** (2021): Growing faster, longer or both? Modelling plastic response of *Juniperus communis* growth phenology to climate change; *Global Ecology and Biogeography*, 1-16. https://doi.org/10.1111/geb.13377 **(D1)**

9) Tumajer, J. Altman, J., **Lehejček, J.** (2023): Linkage between growth phenology and climate-growth responses along landscape gradients in boreal forests. *Science of the Total Environment* 905: 167153. 10.1016/j.scitotenv.2023.167153 **(D1)**

10) Tumajer, J. *et* **Lehejček, J.** (2019) Boreal tree-rings are influenced by temperature up to two years prior to their formation: a trade-off between growth and reproduction? *Environmental Research Letters* 14 124024. 10.1088/1748-9326/ab5134 **(D1)**

11) Wilmking, M., Buras, A., **Lehejček, J.**, Van Der Maaten, E., Lange, J., Shetti R. (2018): Influence of larval outbreaks on the climate reconstruction potential of an Arctic shrub. *Dendrochronologia* 49, 36-43. https://doi.org/10.1016/j.dendro.2018.02.010 **(Q1)**

9.2 Journal papers with Impact Factor not included in the habilitation thesis

12) Adam, M., Tomášek, P., **Lehejček, J.,** Trojan, J., Jůnek, T. (2021): The Role of Citizen Science and Deep Learning in Camera Trapping. *Sustainability* 13, 10287. **(Q2)**

13) Boonen, K., Shetti, R., Navrátil, T., Nováková, T., Rohovec, T., **Lehejček, J.** (2025): Atmospheric mercury pollution recorded in conifer tree rings: Disentangling the effects of tree-ring width, water content, and climate on mercury concentrations. *Dendrochronologia* 92, 26370. **(Q1)**

14) Duží, B., Osman, R., **Lehejček, J.**, Nováková, E., Taraba, P., Trojan, J. (2019): Mapping the citizen science in the post-socialist space: exploration of hidden landscape in the case of Czech Republic. *Moravian Geographical Reports 27 (4), 241 – 254.* **(Q2)**

15) Jevšenak, J. et al. (2024): Incorporating high-resolution climate, remote sensing and topographic data to map annual forest growth in central and eastern Europe, *Science of The Total Environmen*t, Volume 913, 169692, https://doi.org/10.1016/j.scitotenv.2023.169692. **(D1)**

16) Johanis, H.; **Lehejček, J.;** Tejnecký, V. (2022): An insight into long-term effects of biochar application to forest soils. *European Journal of Forest Research.* 141, 213–224. **(Q1)**

17) Kašpar, J., Tumajer, J., Altman, J., Altmanová, N., Čada, V., Čihák, T., Doležal, J., Fibich, P., Janda, P., Kaczka, R., Kolář, T., **Lehejček, J.**, Mašek, J., Hellebrandová, K.N., Rybníček, M., Rydval, M., Shetti, R., Svoboda, M., Šenfeldr, M., Šamonil, P., Vašíčková, I., Vejpustková, M., Treml, V. (2024): Major tree species of Central European forests differ in their proportion of positive, negative, and nonstationary growth trends. *Global Change Biology* 1:e17146. doi: 10.1111/gcb.17146. PMID: 38273515. **(D1)**

18) Konečný, O., Šerý, O., Zavadil, T., Duží, B., Kozumplíková, A., Trojan, J., Martinát, S., Novák, R., Kotek, O., **Lehejček, J.** (2024): Adapting rural communities to climate change: The undervalued potential of agricultural land, *Journal of Rural Studies* 111, 103391, https://doi.org/10.1016/j.jrurstud.2024.103391. **(D1)**

19) Lehejček J., Vávrů G., Wangchuk S., Svoboda M., Boonen K. (2025): Himalayan fir growth in central Bhutan reflects variability in temperature and precipitation. Journal of Forest Science 71(10): 516-524. doi: 10.17221/58/2025-JFS.

20) Mukosha, C.E., Moudrý, J., Lacko-Bartošová, M., Lacko-Bartošová, L., Eze, F.O., Neugschwandtner, R.W., Amirahmadi, E., **Lehejček, J.**, Bernas, J. (2023): The Effect of Cropping Systems on Environmental Impact Associated with Winter Wheat Production—An LCA "Cradle to Farm Gate" Approach. *Agriculture* 13, 2068. **(Q1)**

21) Roman, M., Chattová, B., **Lehejček, J.**, Tejnecký, V., Polická, P., Němeček, K., Houška, J., Nývlt, D. (2020): Shallow depositional basins as potential archives of palaeoenvironmental changes in southwestern Greenland over the last 800 years. *Boreas*. https://doi.org/10.1111/bor.12483 **(Q2)**

22) Shetti, R., Boonen, K., Smiljanić, M., Tejnecký, V., Drábek, O., **Lehejček, J.** (2024): Do trees repond to pollution? A network study of the impact of pollution on Spruce growth from Europe, *Environmental Pollution*, Volume 350, 124012 **(Q1)**

23) Svoboda, M., Janda, P., Bače, R., Fraver, S., Nagel, T., Rejzek, J., Mikoláš, M., Douda, J., Boublík, K., Šamonil, P., Čada, V., Trotsiuk, V., Teodosiu, M., Bouriaud, O., Biris, A., Sýkora, O., Uzel, P., Zelenka, P., Sedlák, V., **Lehejček, J.** (2013): Landscape-level variability in historical disturbance in primary *Picea abies* mountain forests of the Eastern Carpathians, Romania. *Journal of Vegetation Science* 25, 2, s. 386-401. **(Q2)**

24) Tejnecký, V., Luláková, P., Šantrůčková, H., Křížová, P., **Lehejček, J.,** Hájek, T., Mercl, F., Bárta, J., Němeček, K., Drábek, O. (2025) Arctic willow (Salix polaris) exudation as a driver of microbial activity and soil formation in the high arctic tundra. *Biogeochemistry* 168, 30. https://doi.org/10.1007/s10533-025-01222-x **(Q1)**

25) Tumajer, J., Kašpar, J., Altman, J., (…) **Lehejček, J.**, et al. (2025): Longer growing seasons will not offset growth loss in drought-prone temperate forests of Central-Southeast Europe. Nature Communications 16, 9535. https://doi.org/10.1038/s41467-025-64568-8 (D1)

9.3 Other peer-reviewed papers

26) **Lehejček, J.** (2017): Minulost vepsaná v letokruzích. *Vesmír* 96, 354.

27) **Lehejček, J.,** Svoboda, M., Čada, V. (2016): Minulost horských smrčin Šumavy. *Vesmír* 95, 648.

28) **Lehejček, J.,** Tumajer, J. (2020): Růst a ekologie stromů a keřů na hranici lesa. *Geografické rozhledy*, 30(1), 12–15.

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9.4 Scripts, textbooks, certified methods

29) de Porras Acuna, M. A.; Niggli, U.; Love, N.; Moeskops, B.; Padel, S.; Schmutz, U.; **Lehejček, J.**; Beck, A.; Müller, A.; Ulmer, K.; Chable, V.; Levidow, L. and Mulvany, P. (2018) Scientific evidence on how organic food and farming contributes to sustainable food security. TP Organics Research Briefing. TP Organics - European Technology Platform for Organic Food and Farming, B-Brussels

30) **Lehejček, J.**, Kavan, J., Otčenášek, J. (2016): Antarktický poloostrov, aspekty mezinárodní spolupráce při rozvoji environmentální ochrany a vědecko-technologické kooperace. Výzkumná zpráva vypracovaná pro Ministerstvo zahraničních věcí ČR v rámci projektu TAČR BETA TB050MZV014.

31) **Lehejček, J.**, Tejnecký, V. Johanis, H., Marečková, M., Kopecký, J., Drábek, O., Horák, J., Vlček, L., Šefrna, L., Klem, K., Houška, J. (2024): Method of biochar incorporation into forest and agricultural soil to increase habitat productivity and resilience. *Certified method.*

32) Považan, R., Kadlečík, J. (eds.), Affek, A., Aranyi, I., Černecký, J., Ďuricová, V., Favilli, F., **Lehejček, J.**, Mederly,P. & Švajda, J. (2021). The Carpathian Ecosystem Services Toolkit. State Nature Conservancy of the Slovak Republic, Banská Bystrica, 115 pp.

33) Valášek, P., **Lehejček, J.** (2018): Zatížení ovzduší a vody v krajině. *Univerzita Tomáše Bati ve Zlíně.* 161 pp.

9.5 Invited key note talks at related scientific gathering

34) **Lehejček, J.** (2023): Climate change impact on the landscape resilience. *Brown Bag Sessions.* Hochschule für Wirtschaft und Gesellschaft Ludwigshafen.

35) **Lehejček, J.** (2022): Stress factors of tree growth. *International Forestry Students' Association*, Annual Conference.

9.6 Significant conferences attended with reviewed abstract and oral contribution as a first author

36) **Lehejček, J.**, Michalová, Z. (2015): Growth parameters of *Juniperus communis* as a sensitive climate proxy for late Holocene, SW Greenland, Kobbefjord IN: *TRACE 2015-Tree Rings in Archaeology, Climatology and Ecology*. Andrea Hevia et Raúl Sánchez-Salguero (eds.). Sevilla, Spain.

37) **Lehejček J.**, Buras A., Svoboda M., Wilmking M. (2016): A new tool for paleoclimate reconstructions in the Arctic – Wood-anatomy of Juniperus communis IN: *TRACE 2016-Tree Rings in Archaeology, Climatology and Ecology*. Ireneusz Malik, Paweł Kojs, et Achim Bräuning (eds.). Bialowieža, Poland.

38) **Lehejček J.**, Buras A. (2016): Arctic shrubs – the environmental storytellers IN: *Polar Ecology Conference* 2016. Alex Bernardová et Jan Kavan (eds.). České Budějovice. Czech Republic.

39) **Lehejček, J.,** Burras, A., Shetti, R., Carrer, M., Camarera, JJ., Trojan, J., Wilmking, M. (2018): The common juniper wood traits network – a tool for environmental North Hemisphere reconstructions. *WorldDendro Conference 2018,* Thimpu, Bhutan.

40) **Lehejček, J.,** Buras, A., Shetti, R., Pellizzari, E., Wilmking, M. (2018): Call to complete the circumarctic juniper network – an environmental proxy. *Polar Conference 2018,* Davos, Switzerland.

41) **Lehejček, J.,** Trkal, F., Doležal, J., Čada, V. (2022): Alpine and Arctic tundra shrub populations show similar ontogenetic growth trends but differing absolute growth rates and lifespan. *Conference of Ecological Society of America 2022*, Montreal, Canada

42) **Lehejček, J.** (2025): Juniper longevity as a plastic response to environmental conditions. *WorldDendro Conference 2025*, Livingstone, Zambia