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Potential of *Thuja plicata* and *Chamaecyparis lawsoniana* in the context of global climate change in the Czech Republic

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Abstract: The introduction of non-native tree species is considered a potential adaptation strategy to global climate change (GCC) in the forestry sector. As some of the most widespread native species are undergoing stand disintegration due to both abiotic and biotic stressors, the search for alternative species becomes essential. These species can overwhelm native species with both production potential and adaptation to a changing climate. The research focused on climate-growth relationships of two introduced species of the *Cupressaceae* family, western redcedar (*Thuja plicata* Donn ex D. Don) and Lawson's cypress [*Chamaecyparis lawsoniana* (A. Murray) Parl.], in comparison with the native Scots pine (*Pinus sylvestris* L.) in the northeast part of the Czech Republic. The constructed tree ring chronologies were used as a basis for dendroclimatological analyses: basal area increment (*BAI*), linear growth trends, Pearson's correlations between climate variables and growth, resilience indices and others. Among the analysed species, *Thuja plicata* revealed the highest *BAI* and the most positive growth trend in the last 35 years, with values 2–3 times higher. The *Chamaecyparis lawsoniana* exhibited the highest negative correlation with mean summer temperatures. In general, *Pinus sylvestris* showed the highest correlations with precipitation. No clear pattern in resilience indices has been observed. Among the two introduced tree species examined, *Thuja plicata* emerges as a particularly promising candidate for future application in Central European conditions under ongoing GCC.

Keywords: climate signal; dendrochronology; introduced tree species; tree ring analysis

The changes in global surface temperatures and precipitation regimes are one of the key factors driving plant development and growth (Adams et al. 2012). According to various climate models, in the following decades we expect an increase in mean temperature, changes in the distribution of rainfall or an increase in the number of extreme events (Cavin et al. 2013). These changes can lead to increased mortality, alteration in ecosystem productivity, etc. (Adams et al. 2012).

Using non-native tree species may be a way to implement proper silvicultural interventions to support adaptation of forest ecosystems to the mentioned negative factors (Ennos et al. 2019). Understanding the resilience and resistance of tree species is essential for evaluating

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their potential to adapt to different environments. Variations in temperature and water availability over time lead to site- and species-specific differences in tree-ring width, providing insights into the growth patterns of tree species in response to global climate change (GCC) (Lloret et al. 2011).

The impact of GCC on native species in Central Europe is relatively well documented (Bosela et al. 2021; Treml et al. 2022). However, the results of studies are often controversial and site-specific (Bhuyan et al. 2017; Pretzsch et al. 2023; Zolles et al. 2025). As a result of the massive decay of coniferous stands (especially growing on inadequate sites) in the Czech Republic in recent decades, forest owners and managers tend to look for alternatives among introduced (non-native) tree species (Krejza et al. 2021; Novotný et al. 2023). Currently, introduced tree species occupy approximately 1.82% of the forest area of the Czech Republic (Beran 2018). In comparison, in Europe, non-native tree species cover approximately 4% of forest land (Wohlgemuth et al. 2022). In the area of the Czech Republic, the most promising introduced species are considered Douglas fir [*Pseudotsuga menziesii* (Mirb.) Franco], red oak (*Quercus rubra* L.), black locust (*Robinia pseudoacacia* L.), northern red oak (*Quercus rubra* L.), European larch (*Larix decidua* Mill., considered semi-native), and grand fir [*Abies grandis* (Douglas ex D. Don) Lindl.], due to their relatively high productivity, partial tolerance to drought, and resistance to some native pests and pathogens (Novotný et al. 2023)

Species of the family *Cupressaceae* are generally widely used in horticulture and landscape architecture in central Europe (Jakhbarova et al. 2023). In forestry, usage is very sparse and possible risks connected with wider use must be considered both from possible biological damaging agents (Keszthelyi, Somfalvi-Tóth 2024) and from potential negative effects on soil and environment (Imper, Zobel 1983; Strobel et al. 2005). However, according to various research, species of this family can be a suitable alternative to native species in multiple ways (Schlüter et al. 2015; Ivashchenko, Adamenko 2018). *Thuja plicata* and *Chamaecyparis lawsoniana* are probably most promising for forestry usage of this family in the conditions of Central Europe.

Thuja plicata naturally occurs in the western part of North America, ranging from northern California to southeastern Alaska, extending from the Pacific coast to the Cascade-Coastal Mountain Ranges and in a large area on the west side of the Rocky Mountains (Minore 1990). Within the natural range, two major subparts can be distinguished: coastal and interior. Both parts are under maritime influence; however, the interior part is generally colder and drier (Franklin, Dyrness 1973). Although interior populations are more drought-tolerant, the eastern and southern limits of the range are defined by low moisture. Low moisture is also a reason for the gap between the Cascade-Coastal Mountain Ranges. The northern limit of the natural range is characterised by low temperatures (Klinka, Brisco 2009).

Chamaecyparis lawsoniana is endemic to the Klamath Mountain region of southern Oregon and northern California, with small, scattered populations further inland (Zobel 1990). As its natural range is extremely small, it can survive in a wide variety of conditions (Ohmann 1984). The natural range is under a strong maritime influence with a low rainfall summer period. In coastal and Coquille River valley parts of the range, in summer, there are air streams of maritime moist air, which cause outstanding growth in this part of the range (Zobel 1990). *Chamaecyparis lawsoniana* prefers medium-textured soils with consistent summer moisture, but it can also grow in drier conditions and can cope with a wide range of conditions and soil types (Houston Durrant, Caudullo 2016).

The basic climatic characteristics of the natural range of *Chamaecyparis lawsoniana* and *Thuja plicata* are listed in Table 1.

The study investigates the climate-growth relationships of three tree species, western redcedar (*Thuja plicata*; TP), Lawson cypress (*Chamaecyparis lawsoniana*; CL) and Scots pine (*Pinus sylvestris*; PS) as reference native species (which can grow in a wide range of ecological conditions) in the Czech Republic. The conclusions of this study can serve as a basis for possible future use of the studied non-native species in the forestry sector. Based on this objective, our hypotheses (H) were as follows:

H_1: Growth of both TP and CL will be limited mainly by summer high and winter low temperatures, as well as insufficient rainfall during the spring and summer months.

H_2: Native PS will show the most favourable values in terms of resilience indices, since its adaptation to extreme events and local climate conditions.

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Table 1. Characteristics of the study site (Vítkov) and growth conditions in the natural range of TP (Minore 1990) and CL (Zobel 1990)

Site	Altitude (m a.s.l.)	*MPT* (mm)	*MAT* (°C)	Soil type	Typology
Vítkov	500	621.12	7.9	Modal Cambisol*	*Fagus trophica***
TP inland	320–2 130	710–1 240	4.4–10.0	a wide range of soil properties	Port-Orford-cedar***
TP coastal	sea level to 1 190	890–6 600	6.0–11.0		
CL	1–1 520	1 000–2 252	5.2–11.3	a wide range of soil properties	western redcedar, western redcedar – western hemlock***

*Soil type according to IUSS Working Group WRB (2022); **site classification according to Viewegh et al. (2003); ***forest cover types according to Eyre (1980); TP – western redcedar (*Thuja plicata*); CL – Lawson cypress (*Chamaecyparis lawsoniana*); *MPT* – mean annual precipitation; *MAT* – mean annual air temperatures for 1920–2023

MATERIAL AND METHODS

Study site. For study purposes, we chose an even-aged forest stand located in the northeast part of the Czech Republic near the city of Vítkov (Figure 1). The tree stand was artificially established on a clear-cut area between the years 1900 and 1905 as a mixture of TP and CL mixed in rows with a surrounding belt of *Pinus strobus* and PS. The stand was actively managed until the 1980s. Since then, only irregular sanitary cuts focused on the removal of dead individuals have been performed. Basic information about growth conditions of the study site and in the natural range of TP and CL are listed in Table 1. Mean annual temperature and seasonal precipitation at the Vítkov study site are shown in Figure 2. According to the Köppen-Geiger climate classification, the study site has a Dfb climate type (warm-summer humid continental climate) (Peel et al. 2007).

Sampling. We sampled a total of 41 individuals (19 TP, 10 CL and 12 PS) at the study site. For sampling, all living individuals present at the plot were chosen regardless of their class (dominant, co-dominant, suppressed). Basic dendrometric characteristics were as follows: mean diameter at breast height (*DBH*) of TP 65.2 cm (ranging from 43 cm to 80 cm), CL 33 cm (ranging from 24 cm to 40 cm) and PS 44.9 cm (ranging from 32 cm to 58 cm). Mean measured height was 33 m in the case of TP (ranging from 26 m to 35 m), 19 m for CL (ranging from 16 m to 22 m), and the mean height of PS was 26 m (ranging from 22 m to 28 m). Trees were sampled using a Pressler increment borer (Haglöf,

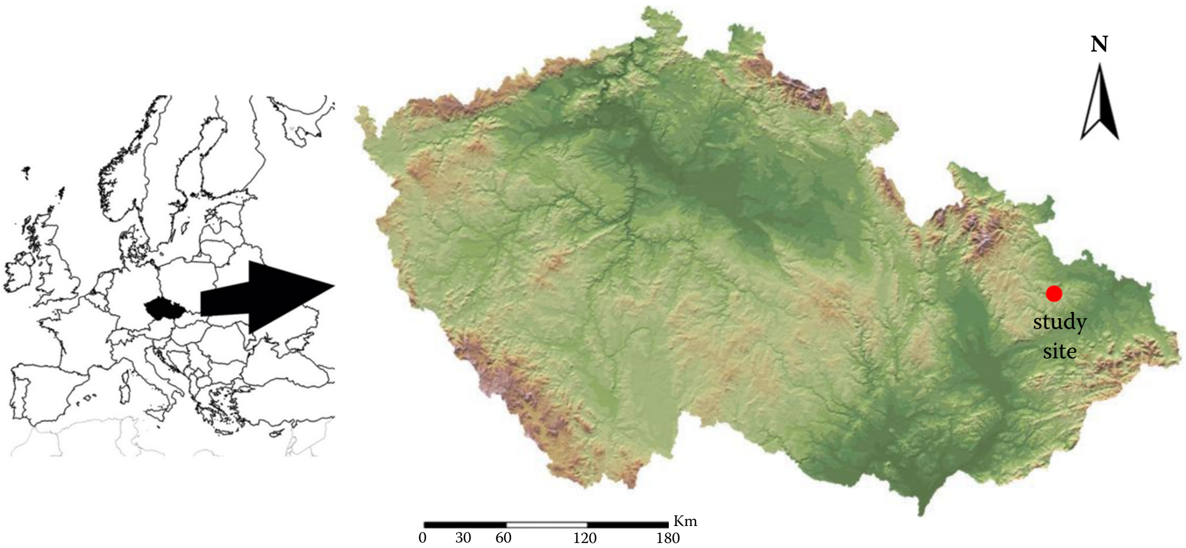

Figure 1. Localisation of the Vítkov study site

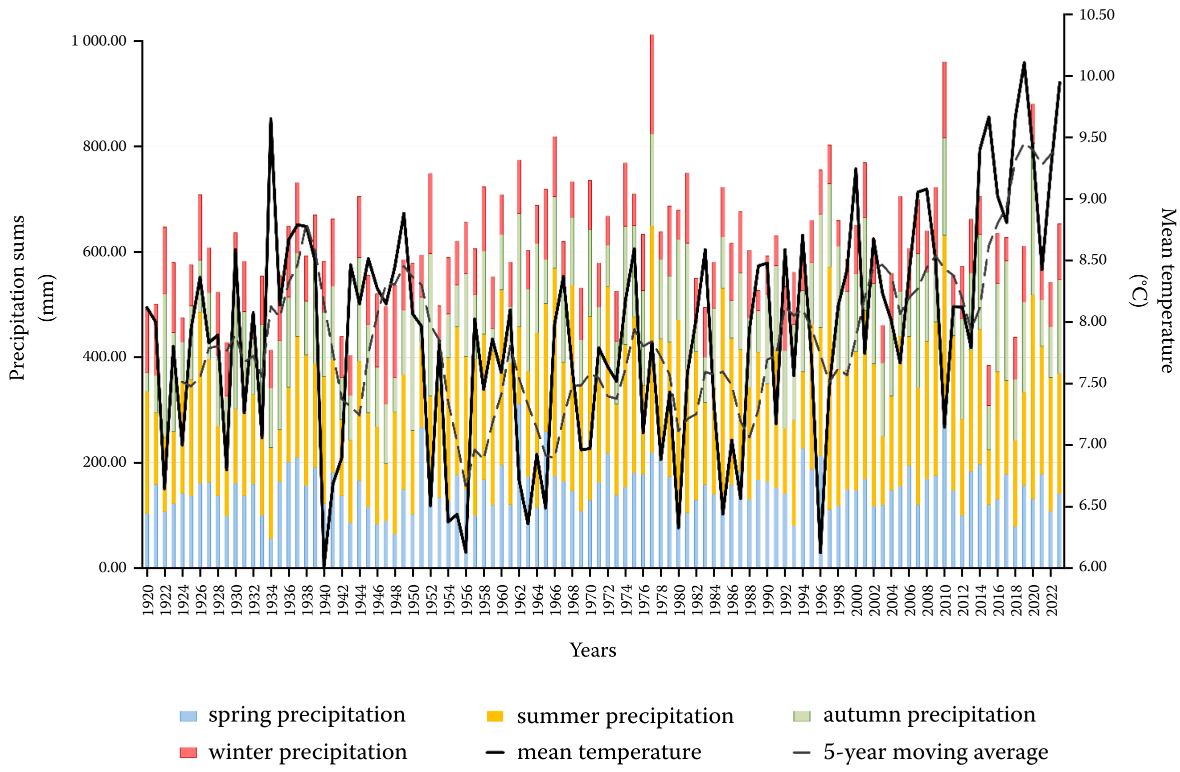

Figure 2. The course of the mean annual temperature and seasonal precipitation at the Vítkov study site

Sweden) at breast height in two opposite directions (W and E). In case of trees growing on a slope, cores were obtained in a contour direction to avoid the presence of reaction wood. Cores were stabilised in wooden bars and sanded in a laboratory using sandpaper with different grain sizes from 80 to 800 (Stokes, Smiley 1996).

The sanded cores were scanned using the Epson Perfection V600 Photo scanner (Seiko Epson Corporation, Japan) into .jpg format. After that, samples were measured using CooRecorder and CDendro software (Version 9.8.1, 2022) (Maxwell, Larsson 2021). After measuring, cross-dating was performed in CDendro visually and by statistical approaches, specifically with the use of the Baillie Pilcher *t*-value (Baillie, Pilcher 1973) and the Gleichlaufigkeit coefficient (Buras, Wilmking 2015; Scharnweber et al. 2019).

After cross-dating, data were exported in .rwl format and imported to R for statistical analyses (R Core Team 2024). To assess the productivity of particular tree species, annual basal area increment (*BAI*) was computed from undetrended data. To filter out non-climatic influences, individual series were detrended using a cubic spline with a 50% frequency response at 30 years (Klesse et al. 2016). To obtain long-term growth trends, we also detrended data using a cubic spline with a 50% frequency response at 90 years (Cook, Peters 1981). The detrended chronologies were pre-whitened and averaged to create site chronologies using a robust bi-weight mean. Descriptive statistics were calculated to assess the quality of tree-ring chronologies (Table 2). To evaluate the influence of the previous year's growth on the current year, the average first-order autocorrelation across all series, with its standard deviation [mean SD (*Ar*1)], was calculated for undetrended data (Speer 2010). For detrended data, the expressed population signal (*EPS*) and the mean interseries correlation (*rbar*) were calculated. *EPS* estimates how well the selected sample represents the total population, signal-to-noise ratio (*SNR*) quantifies the strength of the standard signal (shared variance among tree-ring series) relative to the unexplained individual variance (noise), and *rbar* is a measure of the strength of a standard signal (Buras 2017). All descriptive statistics were computed using the R package 'dplR' (Bunn 2008).

Data analysis of climate-growth relationships. To assess linear growth trends, the common timespan of tree ring series was divided into three equally long periods with different climatic characteristics.

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Table 2. Climate and tree ring chronologies statistics

Species	No. Series	*Avg. Ser. Lng.*	Timespan	Mean SD (*Ar*1)	*rbar*	*EPS*	*SNR*
TP	19	76.53	1924–2024	0.62	0.28	0.88	7.22
CL	10	97.10	1921–2024	0.69	0.32	0.82	4.61
PS	12	90.00	1880–2024	0.57	0.46	0.91	10.35

TP – western redcedar (*Thuja plicata*); CL – Lawson cypress (*Chamaecyparis lawsoniana*); PS – Scots pine (*Pinus sylvestris*); No. Series – number of measured trees; *Avg. Ser. Lng.* – length of the average tree ring series; mean SD (*Ar*1) – first-order autocorrelation; *rbar* – the mean inter-series correlation; *EPS* – expressed population signal; *SNR* – signal-to-noise ratio

Division was based on breakpoint analysis using the R package 'strucchange' (Zeileis et al. 2002). Based on tree ring width indices computed using a 100-year spline, we were able to define growth trends for each period.

For the same periods, bootstrapped correlations between standardised tree ring chronologies and monthly climate variables were computed using the R package 'dplR' (Bunn 2008).

The climate-growth relationships were also evaluated using Pearson's correlation method on a daily basis using the R package 'dendroTools' (Jevšenak 2020) and its function daily_response for both actual and preceding years. Climate responses were calculated for the period of their overlap for both the prior and current year, with window sizes ranging from 1 to 270 days.

Since climate-growth relationships can differ in time (Mérian et al. 2011), the temporal stability of these relationships was evaluated. We applied the moving window correlation, systematically subdividing the data into 20-year intervals from 1921–1940 to 2004–2024. For each of these subperiods, we computed the climate-growth relationships between tree-ring indices and monthly climate characteristics of precipitation, temperature and *SPEI* (standardised precipitation evapotranspiration index) (Vicente-Serrano et al. 2010).

To assess response to extreme climatic events (i.e. extreme drought or extreme temperatures, etc.), we calculated tree-ring-based resilience components according to Lloret et al. (2011) and van der Maaten-Theunissen et al. (2021). Four indices were chosen: (*i*) resistance (*Rt*); (*ii*) recovery (*Rc*); (*iii*) resilience (*Rs*); (*iv*) average relative growth reduction (*ARGR*) (Lloret et al. 2011; van der Maaten-Theunissen et al. 2021). These calculations were performed using the R package 'pointRes 2.0' (van der Maaten-Theunissen et al. 2021). To assess if there is a significant difference between the studied sites, we performed a Wilcoxon signed-rank test due to the non-normal distribution of data (Jevšenak, Saražin 2023).

RESULTS

Tree-ring chronology characteristics. Table 2 shows the basic statistical characteristics of the tree ring series. In terms of the trees measured, the minimum number required for a good chronology was met. When assessing the autocorrelation, significant effects of the previous year's conditions on growth are evident, especially in the case of CL. At the same time, it can be concluded from *EPS* values (expressed population signal) that, from a statistical point of view, the used chronologies are representative and suitable for future analyses, as all monitored tree ring series meet the required range of values.

Growth trends. Based on the results presented in Figure 3, TP exhibited a higher basal area increment than both other species. TP first surpassed CL in the 1940s and subsequently exceeded the older PS stands in the late 1950s. All observed species exhibit a similar pattern of *BAI* fluctuation in both negative and positive pointer years. The *t*-test verified the significance of the differences in growth between species. Where a significant statistical difference was confirmed. The *t*-test values were 8.43411E^{-19}.

Figures 4–6 present linear growth trends for the following periods: 1924–1957; 1957–1990, and 1990–2024. Presented growth trends are based on tree ring width indices (*TRWi*) calculated using a spline with a wavelength of 100 years. In the period 1924–1957, only PS exhibited a positive growth trend while TP and CL exhibited a negative trend. In the second period (1957–1990), the growth trend was positive in all three cases. The most positive growth trend was observed in the case of CL, followed by PS and TP. In the third period, 1990–2024, TP achieved the best

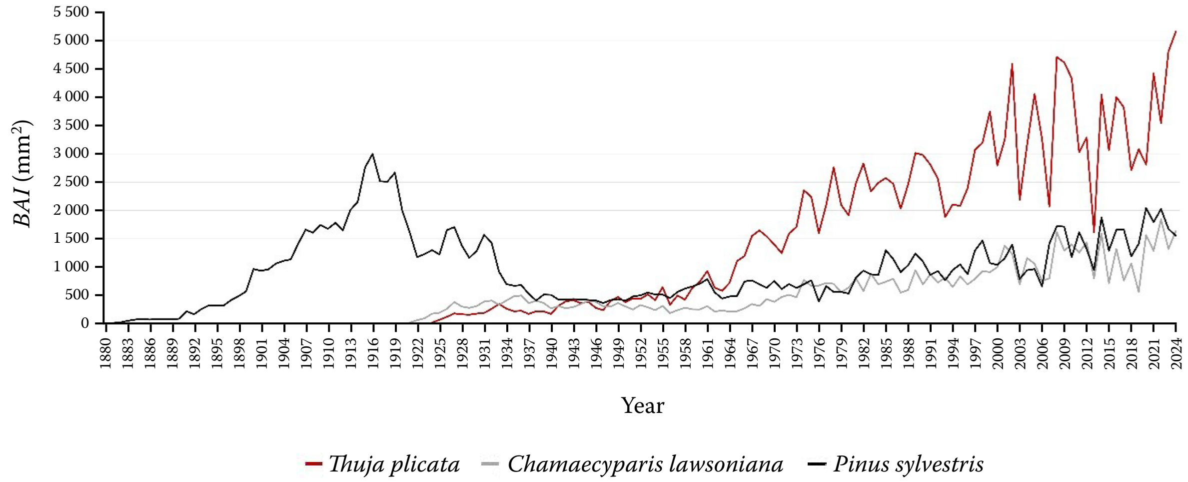

Figure 3. Retrospective basal area increment (*BAI*) for all studied species

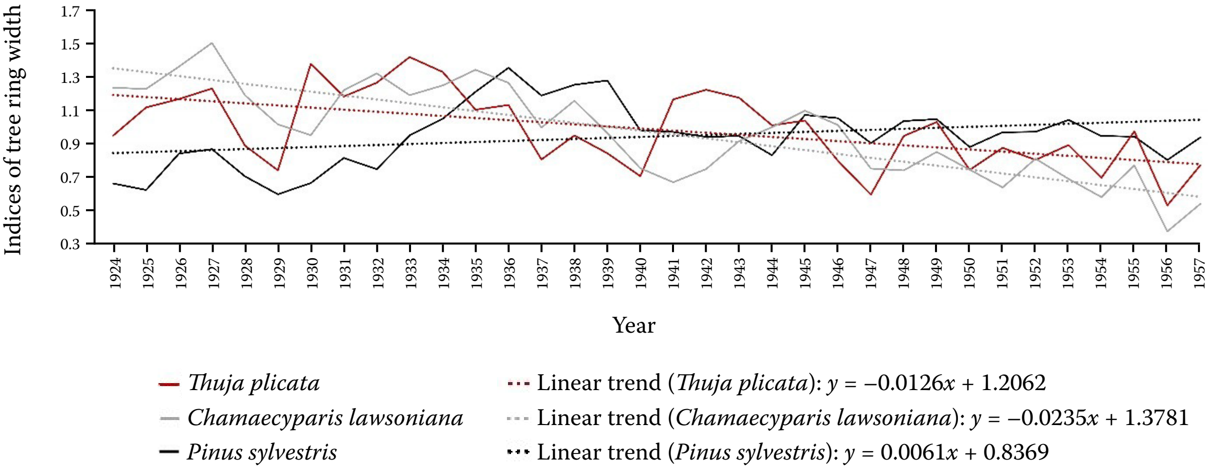

Figure 4. Linear growth trend for the period 1924–1957

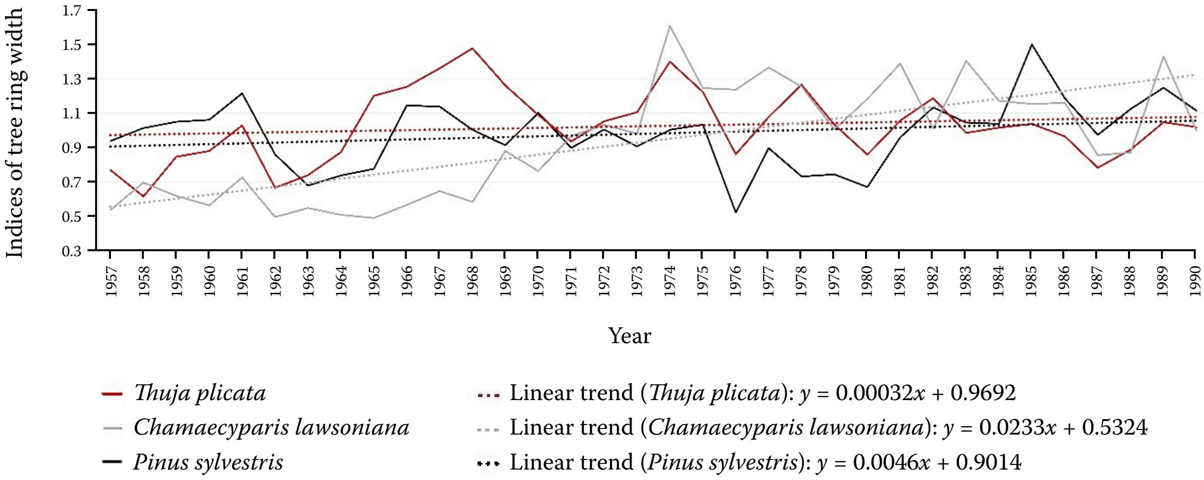

Figure 5. Linear growth trend for the period 1957–1990

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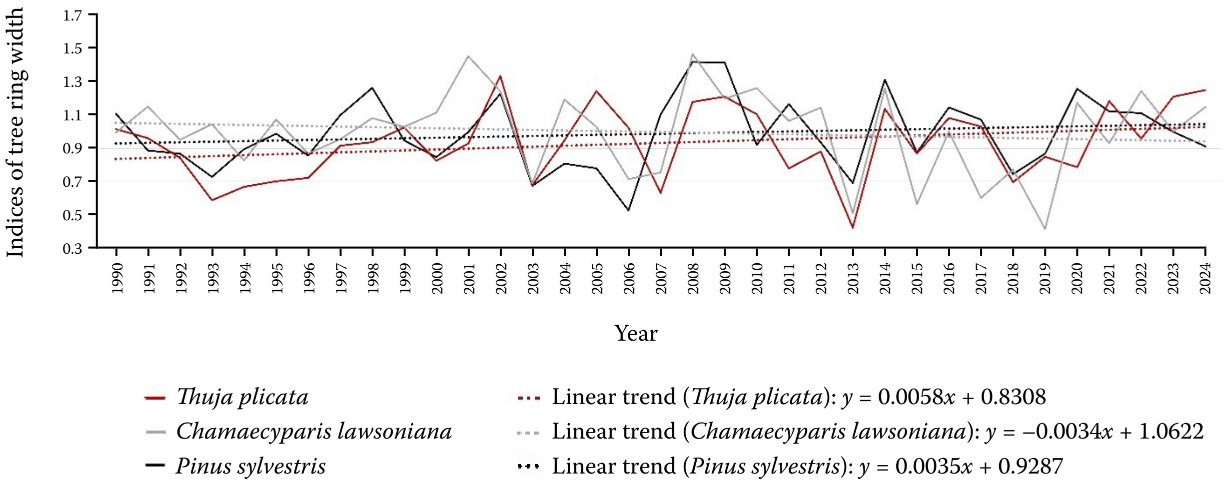

Figure 6. Linear growth trend for the period 1990–2024

values, followed by PS, which exhibited a positive growth trend, whereas CL showed a negative growth trend.

The effects of climate on growth. Results of Pearson's correlation coefficients are shown in Figures 7–9. In terms of correlation with monthly precipitation, none of the species was influenced in the first period. In the period after 1957, TP was negatively influenced by March precipitation, and PS was positively influenced by rainfall in December of the preceding year and January of the actual year. In the most recent pe-

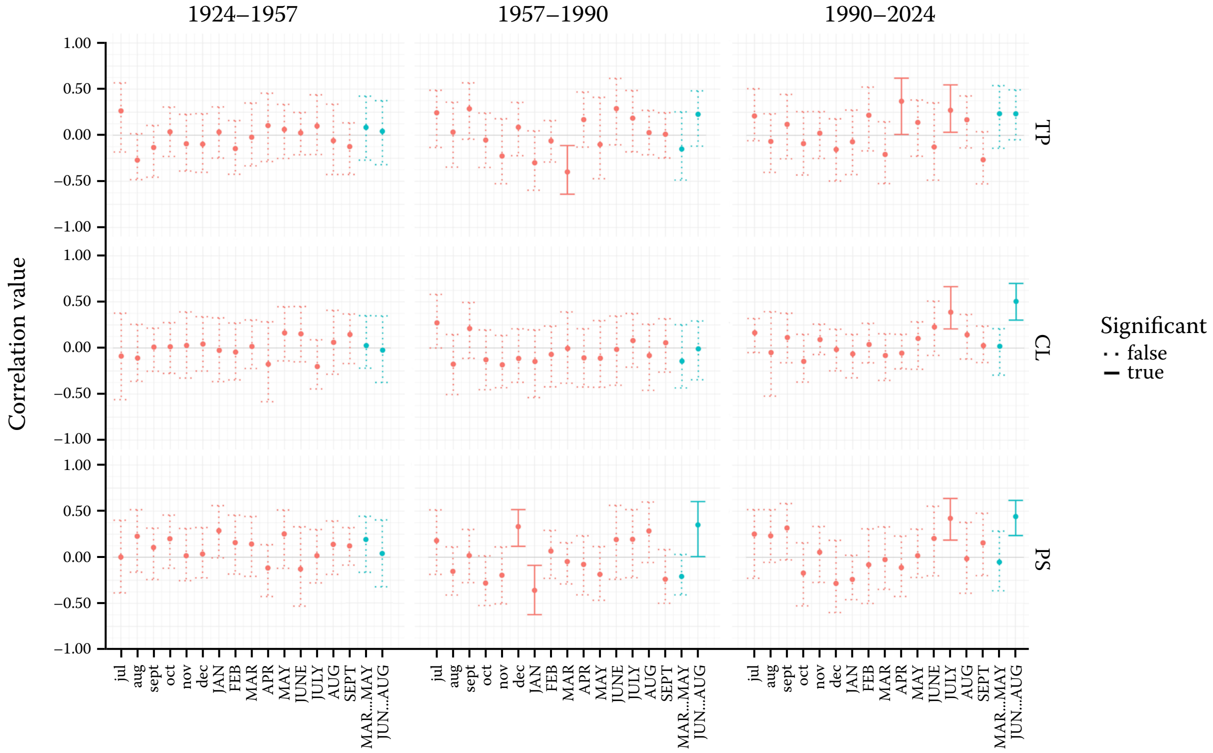

Figure 7. Pearson's correlation coefficients between tree ring indices and monthly precipitation

Lowercase letters – months of the year preceding tree ring formation; uppercase letters – months of tree ring formation; red – values of single months; blue – values of averages; solid line – significant correlations with $P < 0.05$; TP – western redcedar (*Thuja plicata*); CL – Lawson cypress (*Chamaecyparis lawsoniana*); PS – Scots pine (*Pinus sylvestris*)

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Figure 8. Pearson's correlation coefficients between tree ring indices and mean monthly temperature

Lowercase letters – months of the year preceding tree ring formation; uppercase letters – months of tree ring formation; red – values of single months; blue – values of averages; solid line – significant correlations with $P < 0.05$; TP – western redcedar (*Thuja plicata*); CL – Lawson cypress (*Chamaecyparis lawsoniana*); PS – Scots pine (*Pinus sylvestris*)

riod, all species were positively affected by rainfall in July. In addition, TP was positively affected by rainfall in April. Temperature was significant for growth mainly in spring months for all three species, while in the case of CL, a negative influence in summer months can be observed in the last period. The influence of *SPEI* can be considered as generally insignificant in the first and second periods. However, in the most recent period, all species showed positive correlations in summer months. In addition, prespring *SPEI* values were significant for CL and PS (February and January, respectively).

In Figure 10, daily so-called heatmap graphs are presented. TP was generally less influenced than other species by daily precipitation; the key period was after DOY (day of the year) 200 (end of July) in both current and preceding years, with positive correlations. TP was also negatively influenced by rainfall after DOY 300 (beginning of November) when considering at least 50 previous days. CL also showed a positive influence of rainfall after DOY 200 of the current year. However, with increasing DOY and window length, the correlation shifted gradually up to DOY 365. PS showed a positive correlation of growth with both the preceding year and the year of tree ring formation. In terms of daily temperature, all three species exhibited a similar pattern, with correlation starting in prespring and lasting up to the end of April in case of short window, in case of longer windows up to DOY 300 (end of October). Species varied in the start of growth-temperature correlation, with CL at DOY 20, followed by TP and PS at DOY 50. The CL and TP were also negatively influenced by temperature at the end of June. In the case of correlation between growth and *SPEI*, PS and TP were positively influenced in the second half of the year preceding. In the year of tree ring formation, PS and CL were negatively influenced by increasing *SPEI* in the first half of the year, up to DOY 150. Generally, all three species were positively influenced by *SPEI* in the second half of the summer (after DOY 200). In this case, the highest correlation was observed at PS, followed by CL and TP.

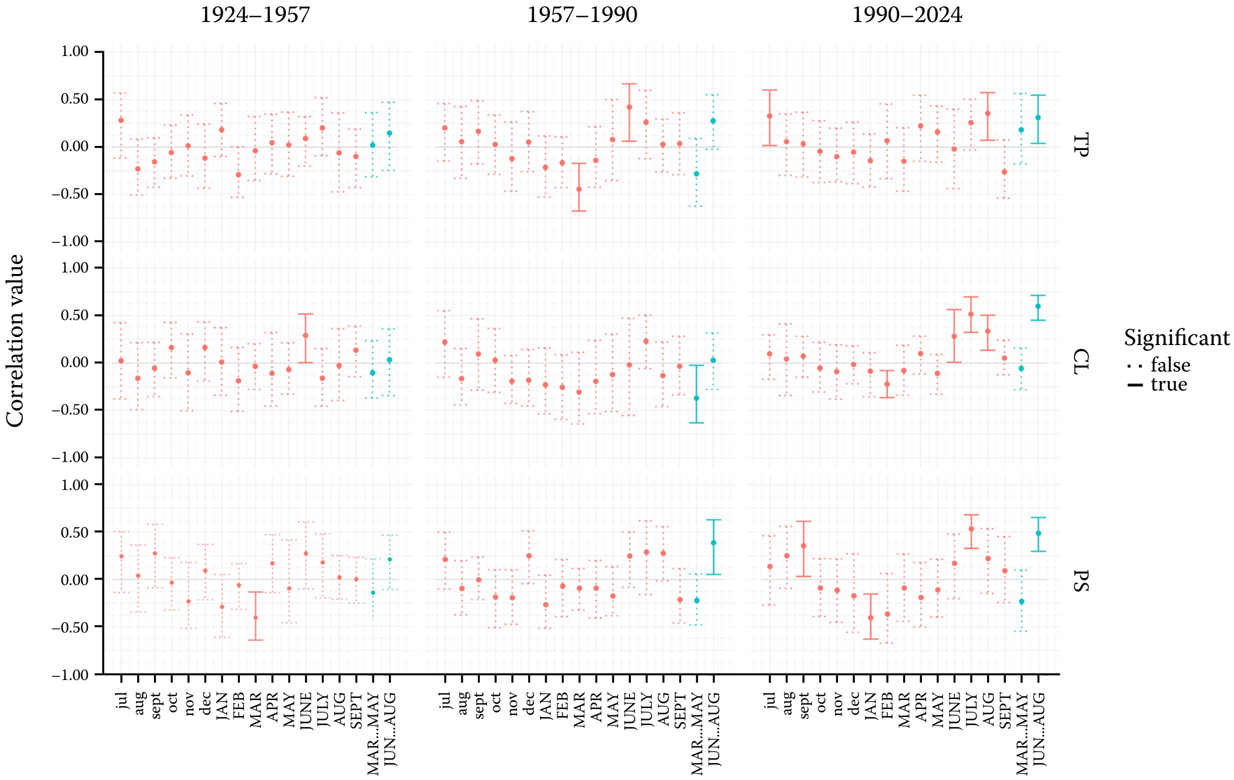

Figure 9. Pearson's correlation coefficients between tree ring indices and the three-month standardised precipitation evapotranspiration index (*SPEI*)

Lowercase letters – months of the year preceding tree ring formation; uppercase letters – months of tree ring formation; red – values of single months; blue – values of averages; solid line – significant correlations with $P < 0.05$; TP – western redcedar (*Thuja plicata*); CL – Lawson cypress (*Chamaecyparis lawsoniana*); PS – Scots pine (*Pinus sylvestris*)

In Figure 11, Pearson's correlation coefficients are presented in 20-year moving windows, showing time variability and evolution of climate-growth relationships over time. In case of precipitation, increasing correlation within summer months can be observed for all three species, with PS being the first and most correlated. Spring correlations are generally shifting from negative to positive values over time; however, this shift lacks statistical significance. Winter precipitation had a significant negative influence on TP growth from 1973 to 2003. An increase in the negative impact on PS has also been observed since the 1990s. From the point of view of mean summer temperatures, TP was negatively influenced; however, the correlations were not significant. CL has, over time, shifted from positive to negative correlations, which have been statistically substantial in the last decades. Native PS exhibited fluctuations in summer correlations, whereas spring and winter correlations were generally statistically significant throughout the year. In the case of *SPEI*, it can be observed that its increasing correlation during the last decades in the summer months is the case for all three species. PS also showed a strong negative correlation in the previous decades with winter *SPEI*.

Resistance, resilience, recovery and average relative growth reduction. Values of resilience indices are presented in the graph in Figure 12. For the *Rs* index, only in the year 2013 was a difference observed between species. In this specific year, the best values were achieved by TP, followed by PS. For the *Rc* index, statistically significant differences were observed in the years 1976 and 2013. In both years, CL was the worst among observed species. In terms of *Rt*, statistically significant differences were observed in the years 1956 and 1976, with the best values achieved by PS and CL, respectively. *ARGR* significantly differed between species only in the year 1976. This year, CL experienced the least reduction, whereas PS experienced the most significant reduction.

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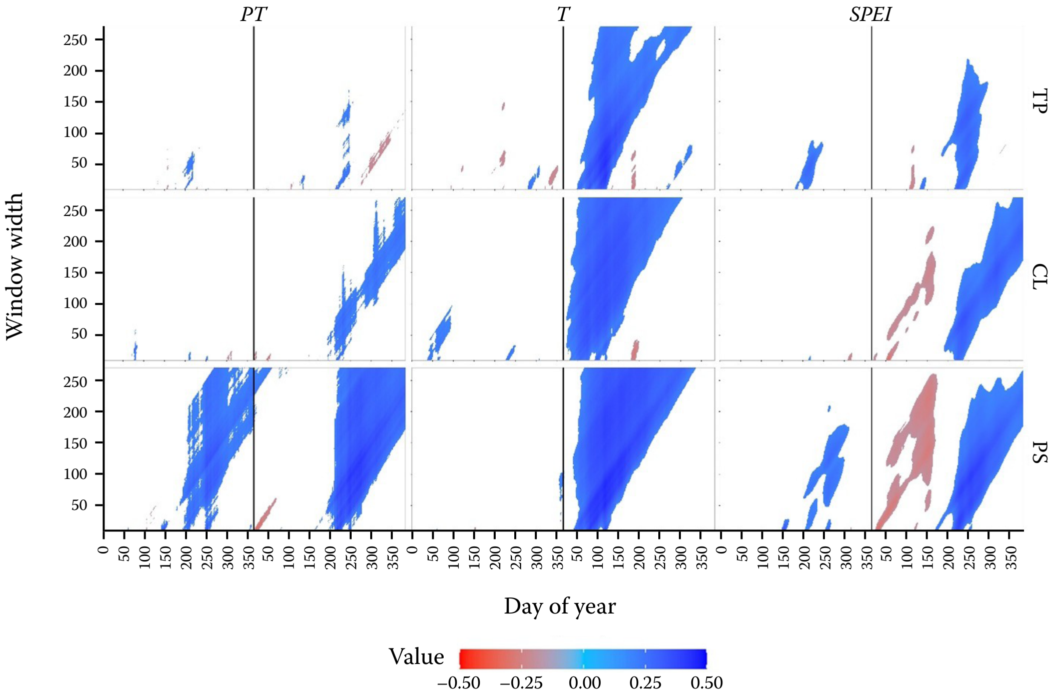

Figure 10. Heatmap of daily Pearson correlation coefficients between tree-ring indices and daily climate characteristics of precipitation (*PT*), air temperature (*T*) and standardised precipitation evapotranspiration index (*SPEI*)

TP – western redcedar (*Thuja plicata*); CL – Lawson cypress (*Chamaecyparis lawsoniana*); PS – Scots pine (*Pinus sylvestris*); vertical lines separate the previous and current years; only significant correlations with $P < 0.05$ are depicted

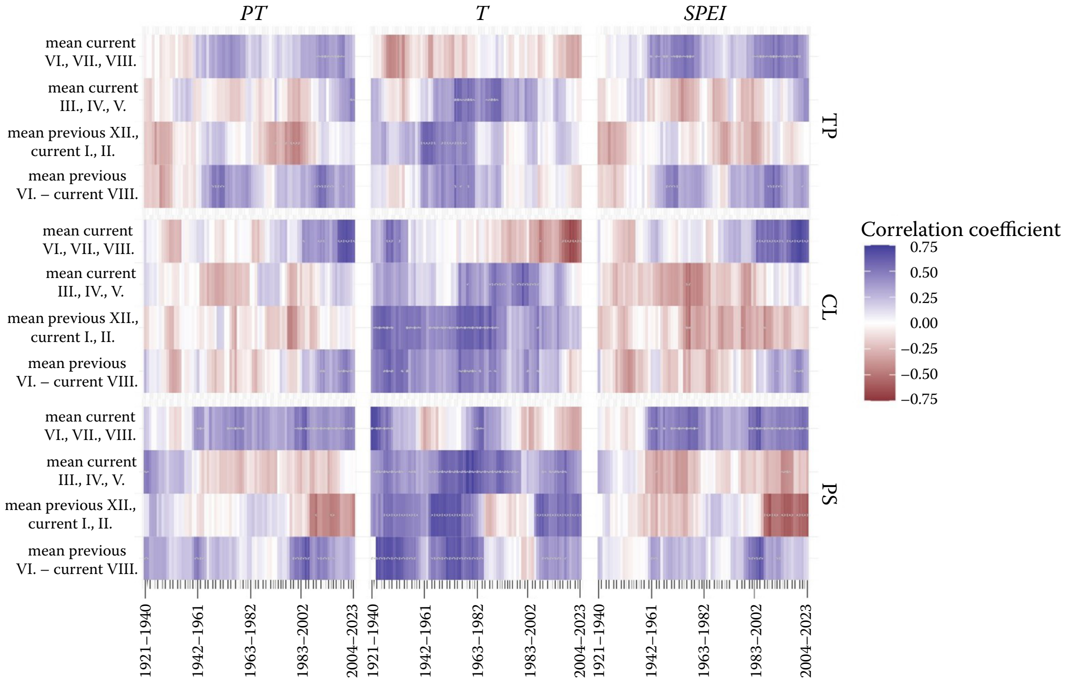

Figure 11. Moving Pearson correlation coefficients between tree-ring and monthly climate characteristics of precipitation (*PT*), temperature (*T*) and standardised precipitation evapotranspiration index (*SPEI*)

*significant correlations with $P < 0.05$; TP – western redcedar (*Thuja plicata*); CL – Lawson cypress (*Chamaecyparis lawsoniana*); PS – Scots pine (*Pinus sylvestris*)

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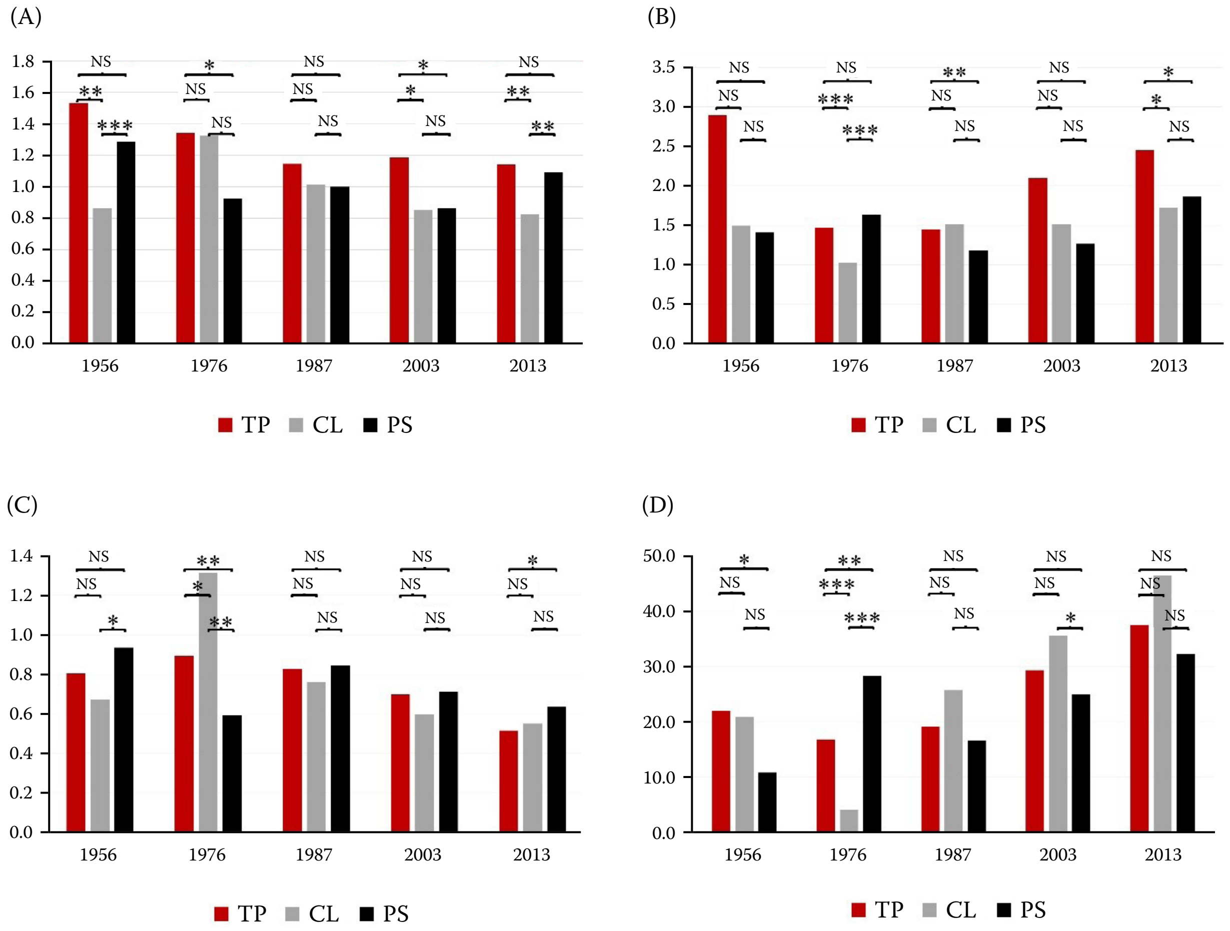

Figure 12. Graph of resilience indices: (A) resilience, (B) recovery, (C) resistance and (D) average relative growth reduction

$^{*}P < 0.05$; $^{**}P < 0.01$; $^{***}P < 0.001$; NS – non-significant; TP – western redcedar (*Thuja plicata*); CL – Lawson cypress (*Chamaecyparis lawsoniana*); PS – Scots pine (*Pinus sylvestris*)

DISCUSSION

The use of non-native tree species is a common practice in forestry across the globe (FAO 2020). In the Czech Republic, non-native tree species are not commonly used (Beran 2018) in commercial forestry due to various reasons. However, exotic species should not be entirely rejected and should be used with caution to mitigate potential risks. Therefore, before wider use, it is appropriate to perform long-term experiments. Two tree species (TP and CL) from the north-western America origin were evaluated in this study from the point of view of production potential and growth response to climatic factors in the conditions of the Czech Republic.

In the case of productivity (*BAI*), the best values were achieved by TP, followed by PS and CL. The results demonstrate the immense production potential of TP compared to native species. Similar results were obtained by Schlüter et al. (2015) in southern Germany when comparing TP and *Picea abies*, or by Cedro and Nowak (2024) in north-west Poland, even if both studies were performed in locations with more abundant rainfall and higher mean annual temperature. TP surpassed CL in terms of increment also in oceanic conditions of Western Europe (Dendoncker et al. 2025).

Since the productivity of a forest stand does not necessarily correspond with its ecological stability and sustainability (Vose et al. 2016), other points of view were also evaluated.

First, linear growth trends were evaluated for individual parts of the chronology. Native PS exhibited a positive growth trend in all parts. On the other hand, the growth trend of CL was negative most of the time. Further worsening of its growth trend can be expected, facing alternation of natu-

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ral conditions driven by global climatic change, since great demands on stable soil and air moisture (Zobel et al. 1982). The growth trend of TP turned from negative to positive, probably as a result of GCC. In the last period, the growth was even more positive than the trend of PS. Further improvement of the TP growth trend can be expected since it has a relatively wide ecological range (Antos et al. 2016).

Climate-growth relationships were investigated using bootstrapped monthly Pearson's correlation coefficients for specific time periods and in moving 20-year windows. According to them, the growth of native PS was positively influenced by summer rainfall and *SPEI*. Positive influence also had the summer temperature most of the time. Results also confirm sensitivity to the mean temperature of the year preceding, which is mentioned in other studies (Brichta et al. 2024).

In the case of both introduced species, a similar pattern can be observed. In the summer months, correlation with rainfall and *SPEI* is becoming more positive, with mean temperature more negative. Spring positive correlation since the middle of the 20th century indicates benefiting from prolonged vegetation period and mild winters, as evergreen conifers can photosynthesise under mild winter conditions (~ 5 °C) and thus improve carbon storage for the following growing season (Guehl et al. 1985; Larcher 2000). However, these positive correlations have been disappearing in the last decades in the case of both exotic species. The too-early start of growth, caused by mild winters, subsequently damages the new growth due to late frosts (Augspurger 2013; Vitasse et al. 2019).

When comparing TP with CL, the growth of the second-mentioned species was more influenced by the negative impact of GCC. In the area of the Czech Republic, neither species was examined due to its infrequent presence in forest stands. But studies were performed in other close European countries, such as Germany (Schlüter et al. 2015; Hoffmann et al. 2018, 2020) or Poland (Gławenda, Bijak 2014; Cedro, Nowak 2024). These studies mentioned that CL is sensitive to air temperatures of the late winter/early spring period (February–March) and to precipitation sums in the summer months, which does not correspond to the results of our study. In our case, CL was also sensitive to temperatures in late winter and spring, as well as summer precipitation. Moreover, it was negatively sensitive to summer temperatures in the last decades, in our case. This, together with the fact that the influence of the mentioned variables is increasing in the previous decades, suggests that CL is not suitable for use as a production forest species in the Czech Republic facing GCC. The reason is probably the continental character of the climate, where drought periods in summer become a limiting factor. The limitation by the continental nature of the climate is also apparent when results are compared to the study by Dendoncker et al. (2025), which evaluated CL as a promising species in conditions of the Belgian oceanic climate. CL was considered promising also in a study performed by Song et al. (2021) in the Netherlands. In contrast, TP confirmed its nature as a generalist with a high degree of stress tolerance (Antos et al. 2016). A key factor influencing growth can be considered the mean temperature in late winter and spring. In the last decades, summer precipitation has also become a limiting factor. In contrast to the mentioned studies focused on climate-growth relationships of TP, the preceding year did not play a crucial role in growth. This phenomenon can occur in oceanic climate conditions, site-specific, since according to studies by Hoffmann et al. (2018, 2020), the temperature in the previous year had a positive influence. This corresponds with conclusions on the growth of TP old-growth stands in Vancouver made by Dobrý et al. (1996). However, growing TP in future can be negatively influenced by ongoing GCC according to the results of Andrus et al. (2024). This study suggests that the dieback of TP stands in the native area is primarily caused by hot and dry summers, which are also limiting in our case, as indicated by moving correlations.

For the assessment of reaction to exceptionally unfavourable conditions, we calculated so-called resistance indices in specific negative pointer years. Significant differences between species were found only in 30% of cases. The results indicate that the relative loss of production exhibited a gradual increase over time. However, no general pattern was found, suggesting that there was no difference between species in reactions to negative pointer years. This conclusion differs from the results presented by Dendoncker et al. (2025) in the case of Belgium, where CL expressed higher resistance than TP.

CONCLUSION

The study compared productive potential (*BAI*) and climate growth relationships between *Thuja plicata*, *Chamaecyparis lawsoniana* and *Pinus sylvestris*. *Thuja plicata* exceeds the other two species in terms of basal area increment. All species were negatively influenced by summer drought; however, *Thuja plicata* and *Chamaecyparis lawsoniana* were only influenced in the most recent period. Also, all species were positively affected by spring and late winter temperatures, whereas summer had the opposite effect. In terms of reaction to extreme events, no significant results were obtained. Generally, the negative influence of GCC effect is observable in all three species, with the most substantial negative effect on native *Pinus sylvestris* and introduced *Chamaecyparis lawsoniana*, which suffers from a continental type of climate. In times of dynamic GCC, *Thuja plicata* appears promising for future use in conditions of Central Europe. Future use of this species may result in higher wood productivity and higher resilience of forest ecosystems to damaging agents. As the study was restricted to a single stand, the results should not be generalised. Further investigations on a broader site scale with consideration of genetic aspects are necessary.

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