



Stand characteristics and dynamics of sub-spontaneous European yew (*Taxus baccata* L.) in a Central European urban forest (Potsdam-Telegrafenberg)

Knut Kaiser¹ · Luisa Kluth² · Ingo Heinrich³ · Thilo Heinken²

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Abstract

In northern Central Europe, larger sub-spontaneous occurrences of the European yew developed in the 20th/twenty-first century in the vicinity of settlements. Using the example of such an occurrence on the Telegrafenberg hill at Potsdam, the population characteristics and dynamics of the yew as well as the local forest vegetation and site characteristics were investigated. For this purpose methods from population ecology, geobotany, dendrochronology, and soil science were applied. Starting from yews planted as ornamental trees at the end of the nineteenth century, a population of 2341 specimens has developed over an area of 27 ha, largely characterised by sub-spontaneous individuals. Trees with a height up to 1 m predominate. The maximum tree height is 11 m. Whereas the oldest specimen is 116 years old (AD 1909), most yews are only a few decades old, as the root collar diameters demonstrate. The tree-ring site chronology developed for 14 yew trees indicates a strong common growth signal. Local tree growth seems to profit to some extent from high temperatures in late winter to spring, but mainly from precipitation in late spring to summer and suffers, but not lethally, from high temperatures in summer. The sub-spontaneous yews are part of older sessile oak stands, which previously also included Scots pine disappearing recently due to drought-related dieback. These stands are characterised by a dense shrub layer, consisting of yews and mainly Norway and sycamore maple, black cherry and others. The soils are sandy podzolised Cambisols (Dystric Arenosols) with moder humus. Both forest vegetation and soil properties indicate a poor to medium nutrient supply and a medium dry soil water regime at Telegrafenberg. This local example underlines the potential of yew as a relatively drought-resistant species, offering a forest tree that is well adapted to an increasingly warm and dry regional climate. In general, sub-spontaneous yew occurrences complement well autochthonous stands of this endangered and protected tree species in the wider region.

Keywords Yew · North-east Germany · Sub-spontaneous spread · Site conditions · Drought tolerance

Introduction

In northern Central Europe, the European yew (*Taxus baccata* L.) has largely disappeared from its natural forest habitats caused by centuries of human impact in the form of wood exploitation, intensive forest use and targeted eradication of this poisonous tree (Conwentz 1892; Brande 1994; Hageneder 2007). In recent decades, however, there has been a remarkable stabilisation of the relict and planted populations and a slight spread. Most forest occurrences have been placed under nature protection and in some cases planting measures have been initiated to increase the local populations (Falencka-Jabłońska 2004; Cedro 2023; Kaiser et al. 2024). Although still rare in forests, this conifer has

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✉ Knut Kaiser
knut.kaiser@gfz.de

¹ GFZ Helmholtz Centre for Geosciences, Telegrafenberg, 14473 Potsdam, Germany

² General Botany, Institute for Biology and Biochemistry, University of Potsdam, Maulbeerallee 3, 14469 Potsdam, Germany

³ Department of Natural Sciences, German Archaeology Institute DAI, Podbielskiallee 69-71, 14195 Berlin, Germany

probably now escaped the danger of extinction in that area. In contrast, this positive development of yew differs from the partial dynamics elsewhere in Europe and beyond (e.g. Schirone et al. 2010; Linares 2013; Thomas and Garcia-Martí 2015; Saulnier et al. 2026).

A parallel development concerns the strong increase in sub-spontaneous yew populations on the edge of urban settlements, where it is growing spontaneously after first being introduced as an ornamental tree species in gardens, parks, cemeteries, and other green spaces. The extent of this population growth may even exceed that of relict and planted forest occurrences (Fig. 1A). This process was first systematically observed in the 1980s/1990s in northern and eastern Germany (Brandes 1987; Kowarik 1992; Seidling 1995; Reimers 2000; Pietzarka 2005). Later, results of such observations were also published from other parts in Central Europe such as western Poland, western Germany, Austria, and Hungary (Bartha et al. 2005; Iszkuło and Boratyński 2005; Hetzel 2010; Stöhr 2019). Although already cultivated locally as an ornamental tree in Renaissance and Baroque gardens (Turner 2005), the widespread use of yew as a garden tree in Central Europe did not occur until the end of the nineteenth century. Especially around prestigious buildings, in parks and in villa districts of many cities, yew has been planted as a fashionable tree among others for many decades (Forrest and Konijnendijk 2005). Trees, which functioned as potent seed sources after a certain time, establishing sub-spontaneous yew stands in their partly forested neighbourhood.

In addition to the general rarity of its forest occurrences and its symbolic value as a witness to the forest history in northern Central Europe, yew has also recently received increased attention in the course of forest ecological and climate adaptation research. On the one hand, this conifer represents an element of the natural, but currently strongly depleted tree species spectrum in the region. Its regeneration is one general goal of ongoing large-scale forest conversion measures (e.g. Zerbe 2002; Bolte et al. 2009; Leuschner et al. 2022). On the other hand, there are initial indications that sub-spontaneous yew stands have so far survived the current climate change in the region exceptionally well, i.e. extended periods of drought and heat of the last decades (Gribbe et al. 2024; Holtmann et al. 2024; Knocke et al. 2024; Pohle et al. 2024). These observations complement the existing knowledge on this tree species, which has a remarkably wide ecological amplitude (Schretzenmayr 1987; Thomas and Polwart 2003; Pietzarka 2005). Although the empirical data base for this assumption is still small, yew may have the potential to be a drought-tolerant tree species in Central Europe (Roloff and Grundmann 2008; Schill 2019; Camarero et al. 2024).

One way to estimate the resilience of yew to climate change is to apply dendroclimatology (e.g. Fritts 1976; Schweingruber 1983; Cook and Kairiukstis 1990; Speer 2010). So far, tree rings of yew have been explored for their dendrochronological potential in Germany (Schill 2019; Kaiser et al. 2024), Ireland (Galvin et al. 2014), United Kingdom (Moir 1999; Bebhuk et al. 2025, 2026; Hindson and Moir 2026), Bulgaria (Lyubenova et al. 2001), Slovakia (Sedmáková et al. 2017), Ukraine (Iszkuło et al. 2011), Georgia (Kvaratskhelia and Gavashelishvili 2025), Azerbaijan (Seyfullayev et al. 2021), Pakistan (Tayyab et al. 2023), and India (Yadav and Singh 2002). However, most studies have been conducted in Poland (Cedro 2004, 2005, 2012, 2023; Cedro and Iszkuło 2011; Cedro and Cedro 2015).

This paper is a case study on the dynamics of urban forests and, in particular, on the regeneration ecology of a rare tree species that is not yet well understood in terms of its site requirements and dynamics. We present a sub-spontaneous yew population which shows a structure and dynamics typical for urban forests in north-eastern Germany. However, the location of this stand on a glacial hill with sandy soil and great distance from groundwater is extreme in certain respects. The spread of yew that has taken place here over a century illustrates very well the potential of this tree species to establish new forest occurrences even under dry and nutrient-poor conditions. According to current supra-regional knowledge, the dense colonisation of such locations by the yew may initially seem rather unusual, as this tree species is partly associated with sites having a moderate water and good nutrient supply (e.g. Thomas and Polwart 2003).

The aim of our study is to describe a sub-spontaneous yew stand in a complex way and to understand its long-term dynamics. We use a multidisciplinary approach that includes data from vegetation ecology, geobotany, dendrochronology, and soil science. The following specific research questions are addressed:

- (1) What are the fundamental characteristics of the local yew population in terms of population biology?
- (2) What conclusions can be drawn about the dynamics of the local yew population?
- (3) What are the characteristics of the site in terms of relief, soil and water balance?

Methods

Study area

The yew population studied is located on the Telegrafenberg hill about 1.5 km south of the city centre of Potsdam, north-eastern Germany (Fig. 1B). This toponym comes from the former station of a ca. 600 km long optical telegraph line

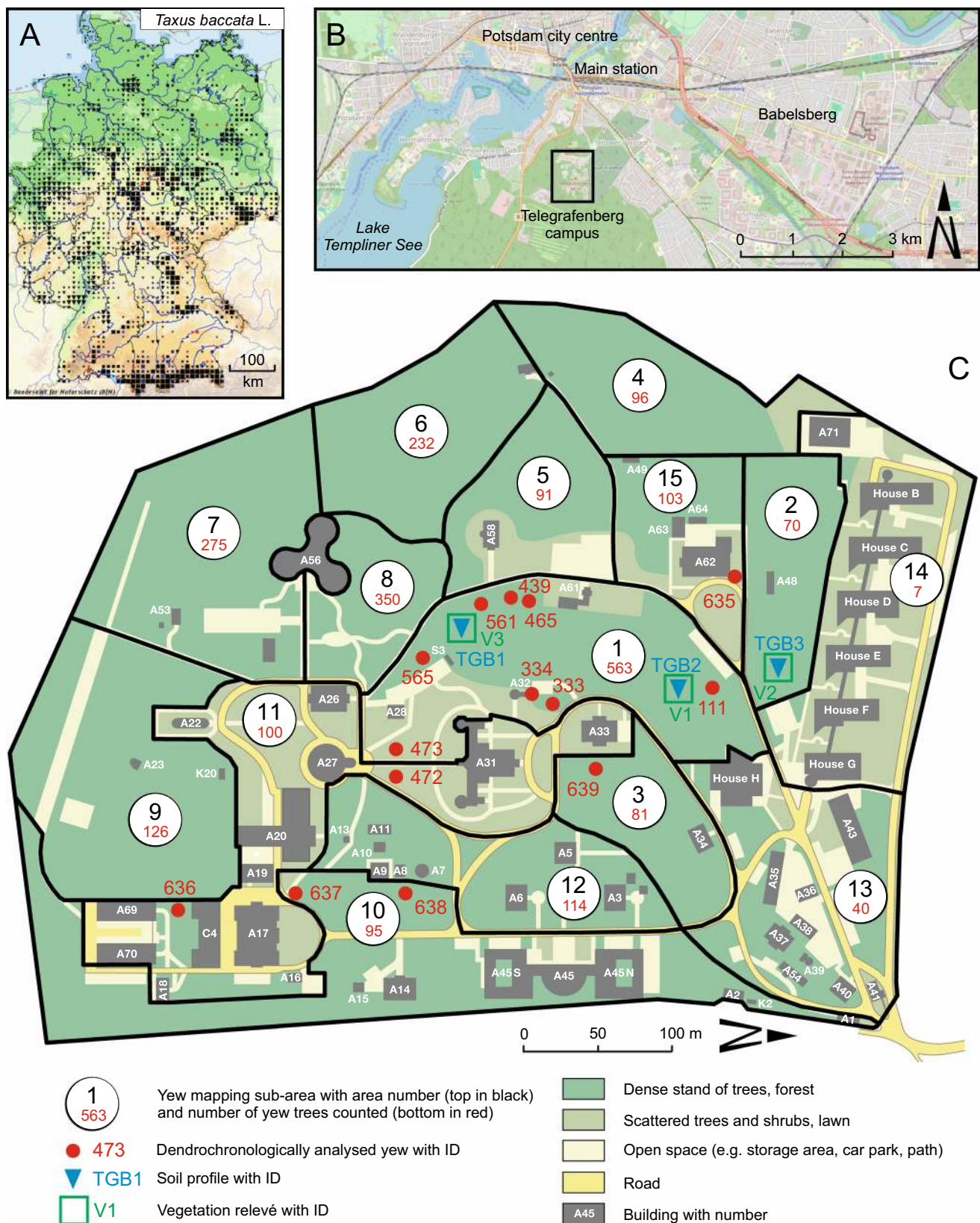


Fig. 1 Study area. **A** Distribution of *Taxus baccata* L. according to grid mapping in Germany (data: Federal Agency for Nature Conservation, <https://www.floraweb.de/>). **B** Map of Potsdam city centre with location

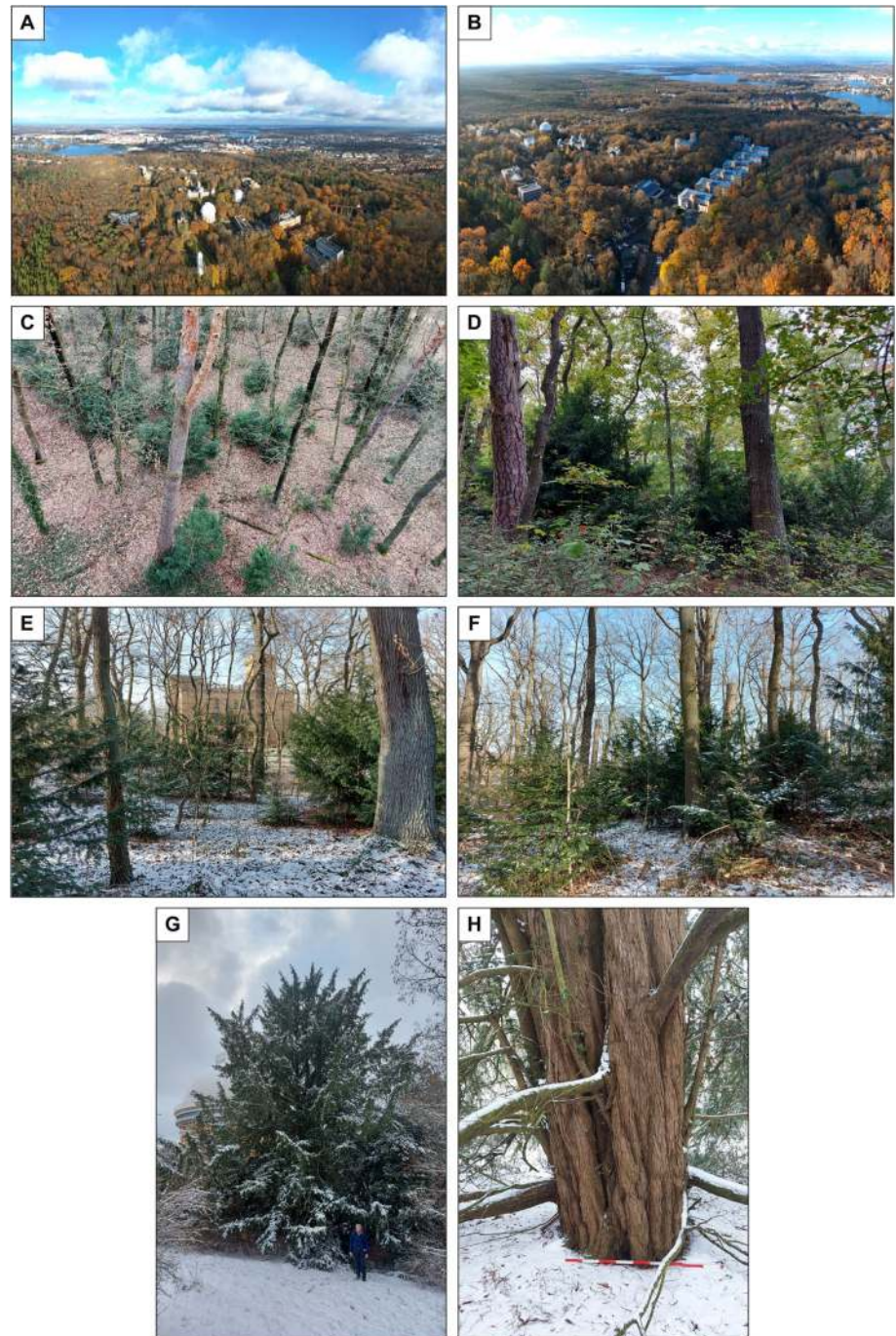
of the Telegrafenberg campus (map background: www.openstreetmap.de). **C** Map of the Telegrafenberg campus with mapping sub-areas of the yew

(semaphore system), which connected the royal palace in Berlin with the Prussian provinces on the Rhine River from 1832 to 1849. Today the area is a largely forested science campus named after Albert Einstein with 65 scattered buildings of varying age and function on an area of 27 ha (Fig. 1C). A number of buildings were constructed here from 1874–1899, forming once a globally significant observatory complex for research in astrophysics, geodesy, meteorology, and geomagnetics (Helmert et al. 1890; Spieker 1894; Eggers 2001). Further buildings followed in the twentieth

century, including the Einstein Tower. A massive expansion, including the founding of a number of institutions for earth research, continued after 1990. The campus, including its forested areas, is fenced and surrounded partly by forest and partly by a cemetery established in 1867.

With 94 m a.s.l., the Telegrafenberg is a prominent glacial hill that rises about 60 m above the neighbouring valley bottom of the Havel River (Fig. 2A, B). Geologically, it represents a terminal push moraine of the Weichselian Brandenburg Advance dating to ca. 34–30 ka (thousand years

Fig. 2 Oblique aerial views and photographs of selected yew stands on the Telegrafenberg campus (photographs: A, B M. Ludwig, C–H: K. Kaiser). **A** Oblique aerial view looking north over the campus forest, in the background the chain of Havel lakes and the city centre of Potsdam. The autumn aspect shows that deciduous trees predominate on the Telegrafenberg. **B** Oblique aerial view looking south-west over the campus forest in autumn, the chain of Havel lakes in the background. **C** Western part of sub-mapping area 8 with view to the north, winter aspect. The view from the roof of building A56 is diagonal to the ground. The upper tree layer consists of pines and oaks. The lower tree and shrub layer consists of yews. **D** Northern part of sub-mapping area 1 with view to the west, summer aspect. The taller trees are oaks, beeches, pines (dead) and maples, with yews below as the lower tree layer. Abundant natural regeneration in the foreground with dominating maples. **E** Northern part of sub-mapping area 1 with view to the west, winter aspect. The „Süring House” (A62 built in 1893) is visible in the background. **F** Northern part of sub-mapping area 1 with view to the east, winter aspect. **G** Old yew specimen ID 473 (1920), 11 m high, in the southern part of sub-mapping area 1 with view to the south. The “Great Refractor” (A27 built in 1899) is visible in the background on the left. **H** Lower part of the old yew specimen ID 473. The root collar diameter of this multi-stemmed tree is 95 cm



before present) (Lüthgens et al. 2020). The micro-relief is quite varied in places and includes slopes with different exposures, some dunes and embankments at path cuttings and near buildings. The hill is mainly composed of sands, supplemented by gravels and silts, which are glacio-tectonically deformed (Weiße 2012). The terrain surface is dominated by sands that have a periglacial and aeolian genesis over a large area. Groundwater is only found at a depth of several decametres. Cambisols (Dystric Arenosols), Regosols and Anthrosols are mapped as the predominant soils on the campus, which indicate dry to moderately dry and widely nutrient-poor to moderate conditions (LGRB 1997; LFE 2024). The local climate is characterised by a mean annual temperature of 8.7 °C (1961–1990)/9.8 °C (1991–2020) and a total annual precipitation of 590 mm (1961–1990)/592 mm (1991–2020) according to public data from the German Weather Service (www.dwd.de).

The local potential natural vegetation (pnV) is a mixed deciduous forest on acidic soils dominated by sessile oak (*Quercus petraea* (Matt.) Liebl.) and pedunculate oak (*Quercus robur* L.) (Hofmann and Pommer 2005). Small near-natural forest stands of this type can be found directly on the campus and in the immediate vicinity. A generation of old-growth Scots pines (*Pinus sylvestris* L.) on the campus that has died off massively in recent years indicates a further local change to mixed deciduous forest. Scots pine monocultures dominate in the wider surroundings. The Telegrafenberg has been forested for at least 350 years, with the exception of the lines of sight for the former optical telegraph and the immediate vicinity of the scientific buildings (Paech 2012). The starting point for the development of the local yew population was the planting of solitary trees in the late 19th to early twentieth century when the science campus was established. Subsequently, local extensive forest management and fencing promoted the spread of yew (for details see chapter 4.1.).

Soil analyses

Three soil profiles (TGB1, TGB2, TGB3) were recorded and sampled in mapping sub-areas 1 and 2 (Fig. 1C, Supplement 1). The intention behind their positioning was to reflect different relief situations (lower and middle slopes with varying exposures) and, in general, to provide a certain coverage of the mapping area with soil profiles. The pedological properties were determined according to the German soil science “KA6” standard (AG Boden 2024). Terminology for soil horizons and soil types follows both this standard and the World Reference Base for Soil Resources (IUSS Working Group WRB 2015).

Soil analyses were performed on a total of 19 samples on the matrix matter < 2 mm to assist in the designation of

sedimentary facies and diagnostic soil horizons as well to derive pedological site characteristics. The analyses were carried out in the Geography Department of the Humboldt-Universität zu Berlin and in the LKS Agricultural laboratory Niederwiesa. Laser diffraction (Beckman-Coulter particle analyser) was used to determine grain-size distribution. Soil pH was analysed potentiometrically in 0.01 M CaCl₂ (soil: solution ratio = 1:2.5). Both total organic carbon (TOC) and total nitrogen (Nt) were analysed by dry combustion (Duma-therm N Pro, multiEA 4000). Phosphorus (P), potassium (K) and manganese (Mg) were determined by continuous flow analysis (CFA) using a C.F.A. Analysator and further devices (Flame Photometer 410, pH Meter Mettler Toledo).

The interpretation of the pedological data in terms of water and nutrient supply of the sites follows the German soil classification standards “KA6” and “SEA95” (Landesforst Mecklenburg-Vorpommern 2009; AG Boden 2024).

Yew mapping and tree properties

In 2023 and 2024, a complete mapping of the yew individuals on the Telegrafenberg campus was carried out mainly outside the vegetation period (Kluth 2024). For this purpose, the campus was divided into 15 mapping sub-areas based on topographical and vegetation structure criteria (Fig. 1). In sub-areas 1–2 a full GPS-based inventory was carried out, using a R10 Trimble device. The measurement accuracy reaches a few decimetres. As this procedure was very time consuming, yews were only counted in mapping sub-areas 3–15 mostly along ca. 10 to 20 m wide transects. Unlike in other areas, it was not possible to reliably detect yew trees by remote sensing (Oreti et al. 2020), as they do not form a single-layered understorey population on the Telegrafenberg. Furthermore, the dominant young trees are normally not resolved in the image, which leads to a serious underestimation of the number of yew individuals.

In mapping sub-areas 1 and 2, the tree height per tree individual was measured with a laser distance meter (TruPulse360°R) and the root collar diameter near ground-line with a tree caliper. The reason for measuring the root collar diameter instead of the common diameter at breast height (130 cm above ground) is the very high number of young trees of less than 200 cm height (cf. Schüle and Heinken 2025). Moreover, the root collar diameter is often used for strongly branching tree species, including various conifers such as yew (Chojnacky and Rogers 1999). The size class distributions within sub-areas 1 and 2 were presented using histograms. The relationship root collar diameter (RCD) and tree height was calculated using a Nonlinear Least Squares (NLS) model in R (equation used: $\text{Height} = a \cdot \text{RCD}^b$). The Root Mean Squared Error (RMSE) for estimating the accuracy of the regression model

was determined using the package *qpcR* (Spiess 2025). In mapping sub-areas 3–15, only the height was determined as a tree property.

Vegetation relevés

In order to characterise the vegetation of the yew stands, three vegetation surveys (relevés) were taken on 17 June 2024 using the Braun-Blanquet method (Dierschke 1994). The plots were selected in forest stands with a certain density of yews and with as little disturbance from forest paths as possible. The plot sizes were 20 × 20 m, and the vegetation layers with all plant species and their cover (according to a cover-abundance scale, see Supplement 2) were recorded separately. The relevés were compared with 12 relevés at comparable sites in the immediate vicinity (Telegrafenberg outside the science campus) and further surroundings (Potsdam urban area). These date from the years 1996 (Seidling 1996) and 1997–1999 (T. Heinken, unpublished) and were recorded using exactly the same method, with the exception of a slightly different plot size. The nomenclature of vascular plants and bryophytes follows German SL 1.5. (Jansen and Dengler 2008).

To gain a general overview of the species composition of yew-rich forest stands and those without yew, we used a non-metric multidimensional scaling (NMDS) with the function *metaMDS* from the package *vegan* (Oksanen et al. 2020). We used Bray–Curtis as a distance measure and maximum random starts was set at 500 to search for a stable solution. Mean weighted Ellenberg indicator values (mL, mF, mR, mN; see below) and the cover values of vegetation layers were included as environmental variables (function: *envit*; package: *vegan*; Oksanen et al. 2020). Results were graphically displayed using *ggplot2* (Wickham 2016) and *ggord* (Beck 2024).

Weighted mean indicator values for light, moisture, reaction (pH), and nitrogen according to Ellenberg et al. (2001) were calculated from the vegetation relevés. Nitrogen indicator values for bryophytes were taken from Simmel et al. (2021). For this purpose, the cover values were ordinally transformed according to van der Maarel (1979) in order to downweight strongly covering species. The mean indicator values were compared between the vegetation types using an ANOVA and pairwise post-hoc Tukey tests. The statistical analyses were performed with R version 4.0.2 (R Core Team 2020).

Additionally, we determined for all species whether they are (regionally) classified as neophytes or synanthropic in Brandenburg (according to Ristow et al. 2006) or in nearby Berlin (according to Seitz et al. 2018). According to Hofmann and Pommer (2005), we also determined which species are considered to be typical components of the pnV of acidic

sandy sites that are far from groundwater in the immediate vicinity. These are the vegetation units "Waldreitgras-Winterlinden-Eichen-Hainbuchenwald" (reed grass-linden-oak-hornbeam forest), "Straußgras-Eichenwald" (bentgrass-oak forest), "Drahtschmielen-Eichenwald" (wavy hair-grass-oak forest), and "Straußgras-Traubeneichen-Buchenwald" (bentgrass-sessile oak-beech forest). In order to determine the naturalness of the 15 forest stands studied, the coverage ratios of the resulting three species groups (neophytic/synanthropic species, components of the pnV and other native species) were compared.

Dendrochronology

In January and September 2024, 46 increment cores from 14 dominant yews, i.e. larger individuals in terms of trunk diameter and tree height, were collected. Sampling focused on these relatively few larger individuals on Telegrafenberg, representing 0.5 sampled trees per ha (with regard to the overall size of the campus). One of the yews sampled could be identified as female based on the arils visible in autumn, while the rest are males. A minimum of two cores were taken from each tree, and in some instances three to four cores were extracted, in order to produce consistent average growth curves. The increment cores were first glued on wooden sample holders and then surfaced carefully with increasingly fine sandpaper, to increase the contrast of the ring boundaries. Samples were scanned in 2400 dpi using the Epson Expression 12000XL flatbed scanner. Finally, tree-ring width was measured using the WinDENDRO software (WinDENDRO 2009) and the software COFECHA was employed to verify the dating and accuracy of measurements (Holmes 1983). Subsequently, the chronology statistics Rbar (mean correlation between series) and EPS (expressed population signal) were calculated for windows of 30 years with an overlap of 15 years with the software ARSTAN. The descriptive metrics, commonly used in dendrochronology, are measures of the strength of the observed common signal among the trees in a chronology (Cook 2002). In ARSTAN, the raw data series were standardised by first power transforming individual series to homogenise the variance of the series and then detrended applying a negative exponential function to remove non-climatic trends such as age trends. Since standardisation reduced the autocorrelation below the limit of significance, no additional autoregressive modelling was necessary, and thus the ARSTAN standard chronology was used for the comparison with the climate data. Climatic data obtained from the E-OBS Temperature and Precipitation Data set (Cornes et al. 2018) for the years 1970 to 2023 were used for climate-growth correlation analysis. In addition, the three-month version of the Standardised Precipitation-Evapotranspiration Index (SPEI-3) was selected for the

years 1920 to 2023 as an indicator for drought conditions (Vicente-Serrano et al. 2010). All data were downloaded from the KNMI Climate Explorer website (<http://www.knmi.nl>; van Oldenborgh and Burgers 2005). The influence of climate on the yew tree-ring index series was investigated by computing simple linear Pearson correlations (r) with monthly and seasonal climate variables in a period from October of the previous year to October of the current year.

Results

Soil properties

Despite their location in different positions of the local relief (middle and lower slopes; Fig. 1C, Supplement 1), the three soil profiles investigated in mapping sub-areas 1 and 2 are typologically identical. They represent “Podsol-Braunerden” (Cambisol, Dystric Arenosol) with a generalised Ah-Ee/Bv-Khs/Bv/IC (Ah/Bwsh/Bw/C) horizon sequence (Supplements 1, 3). The morphological characteristics of the overlying humus horizons (O) with a range in thickness of 6–7 cm indicate the moder humus form. Since all three profiles have largely the same characteristics, further structural/spatial analysis was not considered meaningful.

With regard to the soil substrates, field record and grain size analyses indicate layers of “solimixtive cover sand” (including Bv/Bw horizons) overlying layers of “glacio-fluviolacustrine sand”. In general, the grain-size analyses reveal a dominance of sand (58.1–82.1%), followed by silt (15.8–38.7%) and clay (1.5–3.2%; Supplement 1). The upper layers consist of moderately silty sands (sandy loams), the lower layers of weakly silty sands (loamy sands). Coarser particles than sand grains are completely absent in the soil horizons, with the exception of the lower boundary zone of the Bv/Bw horizons. Here, a narrow enrichment of gravels and cobbles (stones) is formed, which have a maximum axial length of 15 cm. A large number of these gravels and cobbles are formed as very well-developed ventifacts, i.e. late Pleistocene wind-faceted clasts (Supplement 3).

The local soils are extremely remote from groundwater with several decametres. In general, hydromorphic features are absent with one exception. The weak relict gleyic features in the subsoil of TGB1 (IIrGo-IC) may date from the late Pleistocene period. Overall, the sandy soils are very well porous. According to field findings on the Telegrafenberg, they dry out shortly in summerly drought periods. Thus, according to FAO (2006) the local soil moisture regime type can be classified as “udic” (from Latin *udus*, humid).

The pH value of all soil horizons is very low, ranging from a minimum of 3.2 in the topsoils to a maximum of

4.4 in the subsoils, corresponding to extremely strongly to strongly acidic, respectively. Together with the sandy soil type, this indicates a medium to low base saturation, i.e. medium to poor nutrient supply of the local sites. The C:N ratio of 18–19 in the humus layers and 16–18 in the minerogenic humic topsoil horizons indicates the moder humus form, confirming the morphological characteristics. All soil chemical parameters taken together result in an intermediate nutrient level (SEA95: “M” site) corresponding to a mesotrophic nutrient supply.

Spatial distribution of yew

A total of 2341 yew specimens were counted on the campus. Of these, 2336 were identified as *Taxus baccata* and five as *Taxus x media* (a hybrid of *T. baccata* L. and *T. cuspidata* Sieb. & Zucc.). A number of 174 specimens (7%) can be defined as planted specimens based on structural and spatial characteristics (e.g. old specimens near buildings, occurrence as age-identical specimens in a hedge or obviously arranged in a border). However, the majority with 2167 specimens represents a sub-spontaneous population, i.e. developed by natural seed dispersal.

Yew is generally very irregularly distributed. In addition to old single specimens, mostly near buildings, larger groups of yew occur in the forested areas, especially in the mapping sub-areas 1–10 (Figs. 1C, 2C–F). These form a second tree layer and a shrub layer of varying heights (up to a maximum of 11 m; Fig. 3). The sub-areas 1, 6, 7, and 8 with the highest number of individuals (232–563 specimens) are located near the female old specimen ID 473 (Fig. 2G, H), which can be regarded as the most prominent “mother tree” for the yew population on the Telegrafenberg (see chapter 4.1.). However, there is a larger number of younger and fruiting trees. Within the yew groups, there are individuals of different heights and diameters. In some cases, several yews grew in close proximity to each other. In general, the tallest and thickest and therefore likely older individuals are distributed in the centre of the campus in or close to sub-area 1, while low and thin and therefore likely younger individuals are mainly found on the western edge of the campus. Nevertheless, yew seedlings occur in all sub-areas except 14 and 15.

Population biological characteristics of yew

If all 2341 yew specimens that were recorded on the campus in terms of their tree height are considered, the size class 0 to 1 m tall dominates and there is a marked drop towards the higher size classes (Fig. 4). The size class 0 to 50 cm tall is only the third largest, as very small tree individuals (saplings) were sometimes very difficult to identify.

Fig. 3 Spatial distribution of individual yew trees differentiated by tree height in mapping sub-areas 1 and 2 on the Telegrafenberg campus

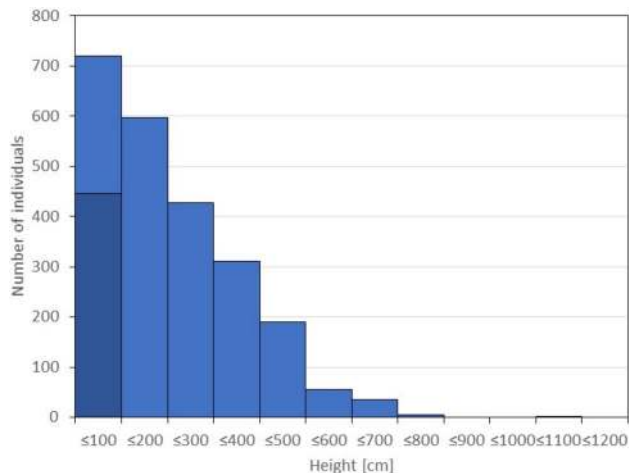
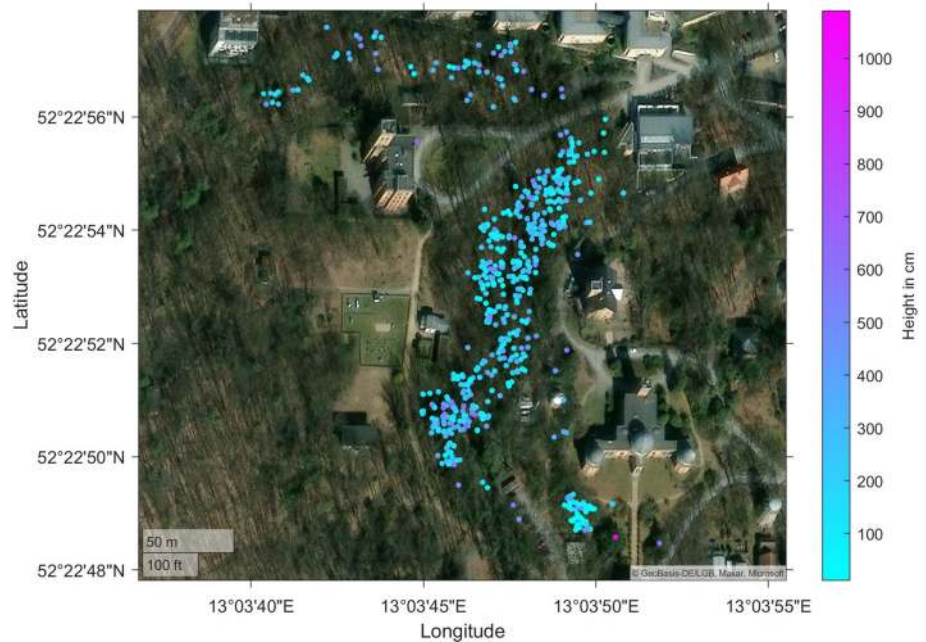


Fig. 4 Histogram of the tree height of all 2341 yew specimens recorded on the Telegrafenberg campus. The darker colour in the column for individuals ≤ 100 cm indicates the specimens of maximum 50 cm in height, which were mapped separately

A total of 633 *Taxus baccata* L. individuals (and two *Taxus x media* individuals) were mapped in the mapping sub-areas 1 and 2. Most common were small trees with a maximum height of 1.5 m (Fig. 5), with 279 individuals (44%) belonging to this group. Trees in the size classes 1.5 to 3.5 m tall had slightly lower numbers of individuals (a total of 239 individuals, 37%). Beyond that, there was a continuous decline in the number of individuals with tree height, and apart from the 10.9 m tall mother tree, there were no specimens more than 7 m tall (Fig. 5, left). The decline in the number of individuals with tree height can be described by a negative linear function ($r^2=0.8871$, $p<0.001$). Accordingly, yew individuals with a root collar

diameter of a maximum of 5 cm predominated (391 individuals, 62%). The frequency distribution of root collar diameters (Fig. 5, right) follows a negative exponential function ($r^2=0.9784$, $p<0.001$) if the multi-stemmed individuals are left out of the analysis. The tree height increases steadily with the root collar diameter, but as the diameter grows, the model's representation of the curve becomes flatter (Fig. 6) and the scatter of the values also enlarges.

Forest vegetation characteristics

The yew stands in the study area (Supplement 2, no. 1–3) are old sessile oak stands, which previously also included Scots pine, as shown by some dead individuals. They are characterised by a relatively open upper tree layer and a dense shrub layer (Figs. 7, 8), consisting of yews and mainly Norway maple (*Acer platanoides* L.), sycamore maple (*A. pseudoplatanus* L.), black cherry (*Prunus serotina* Ehrh.), mountain current (*Ribes alpinum* L.), and partly snowberry (*Symphoricarpos albus* (L.) S.F.Blake). In the herb layer, young woody growth predominates alongside ivy (*Hedera helix* L.), mostly of the species mentioned, while there are hardly any herbs or grasses (Fig. 7). This makes them relatively similar to maple-rich oak stands on the lower, settlement-near north-western slope of the Telegrafenberg (Fig. 8, Supplement 2, no. 4–8), though these stands have lower shares of tree and shrub species in the understorey (Fig. 7). Sessile oak forests on the upper slopes of the Telegrafenberg, further away from settlements and outside the fenced science campus, as well as on comparable sites in the urban area of Potsdam, have a significantly different structure and species composition (Supplement 2, no. 9–15, Figs.

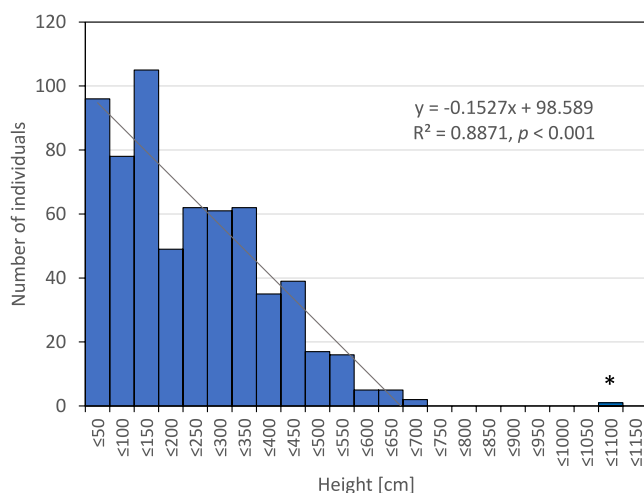
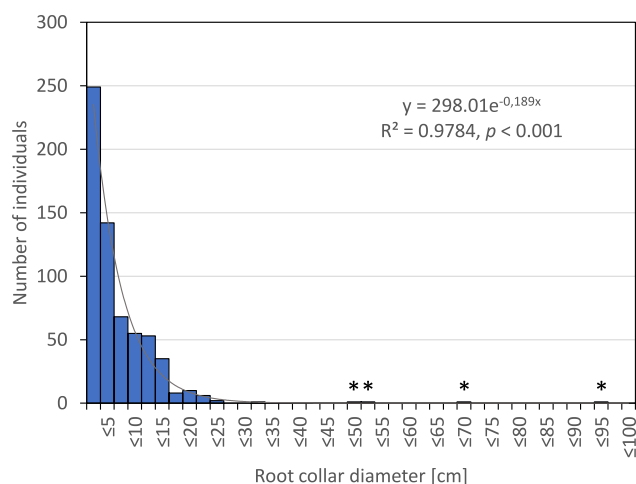


Fig. 5 Statistical characteristics of the yew population ($n=633$) in the mapping sub-areas 1 and 2 on the Telegrafenberg campus. Left: Height distribution of yew individuals in the study area. The mother tree ID 473 is marked with “*” and was not included in the calculation of the



correlation. Right: Distribution of the root collar diameter of yew individuals in the study area. Multi-stemmed individuals are marked with “**” and were not included in the calculation of the correlation

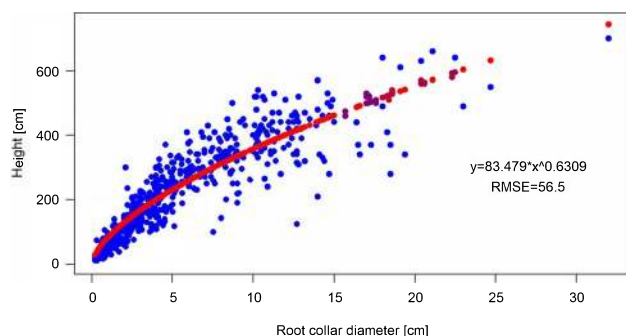


Fig. 6 Relationship between the root collar diameter (RCD) and the height of yew individuals in the mapping sub-areas 1 and 2 area on the Telegrafenberg campus. The parameters of a Nonlinear Least Squares (NLS) model are given (equation: $\text{height} = a * \text{RCD}^b$). The multi-stemmed individuals were not shown

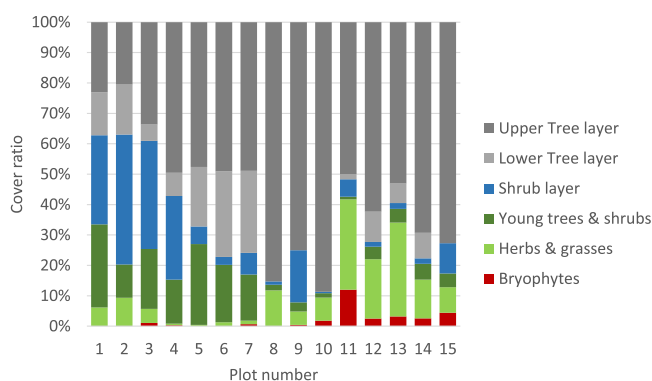
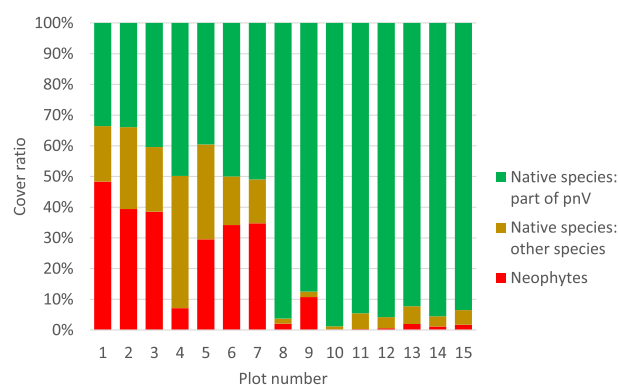


Fig. 7 Vegetation structure and native to neophytic/synanthropic species relation in the forest on the Telegrafenberg and surroundings after analysing the relevés. Left: Vegetation structure of the 15 oak forest stands depicted in Supplement 2. Plot numbers 1 to 3 belong to the yew stands in this study on Telegrafenberg. The others belong to forest stands in the surroundings. Right: Shares of indicators of different levels of naturalness of the 15 oak forest stands depicted in Supplement

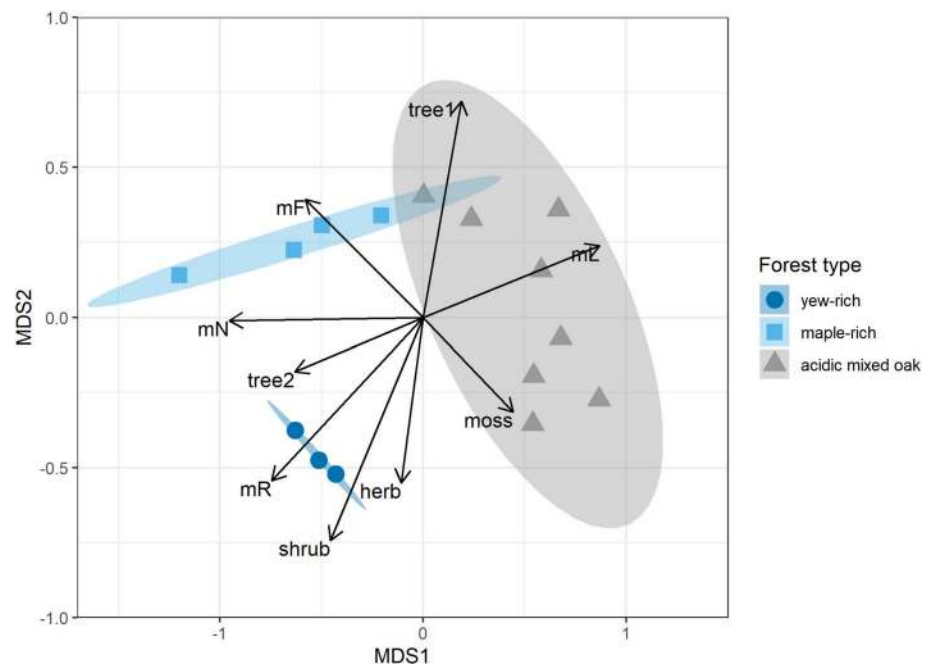
7, 8). These largely lack maple species, ivy and the aforementioned woody plants, while the understorey vegetation is sparse or dominated by acid-tolerant grasses (wavy hair grass *Deschampsia flexuosa* L., pill sedge *Carex pilulifera* L., sheep’s fescue *Festuca ovina* L.) and acidophytic mosses (*Dicranella heteromalla* (Hedw.) Schimp., *Pohlia nutans* (Hedw.) Lindb., etc.).

The yew-rich forest stands in the study area are characterised by a large proportion of neophytic or synanthropic species (Fig. 7), most of them woody plants in the undergrowth (see Supplement 2). In addition to North American species such as black cherry, snowberry and mahonia (*Mahonia aquifolium* Pursh), these also included species native to Central Europe such as yew, mountain currant and



2. Species that are considered as typical part of the potential natural vegetation according to Hofmann and Pommer (2005), other native species and regional neophytes according to Ristow et al. (2006) and Seitz et al. (2018). Both graphs are based on cover values of the plant species in the relevés (5: 87.5%, 4: 62.5%, 3: 37.4%, 2b: 20%, 2a: 10%, 1m: 3.5%, 1: 1.5%, +: 0.5%, r: 0.1%)

Fig. 8 Non-metric multidimensional scaling (NMDS) of vegetation composition of mixed oak forests in the urban area of Potsdam. Two dimensions, stress=0.0847351. Legend for forest type: yew-rich stands in the study area on the Telegrafenberg; maple-rich oak stands on the Telegrafenberg (transect from the built-up area at the foot of the slope to its upper part); acidic mixed oak forests on the hilltop outside the Telegrafenberg campus and comparable sites in the urban area of Potsdam. Mean Ellenberg indicator values and the cover values of vegetation layers are plotted as vectors



sycamore maple, which were only introduced into the wider study region by humans. In contrast, species of the potential natural vegetation play hardly any role, with the exception of the sessile oak (Fig. 7). The maple-rich oak stands at the foothill of the Telegrafenberg mostly have a similar range of species. In contrast, there are hardly any neophytes in the acidic oak mixed forests in Potsdam, while characteristic species of potential natural vegetation, even in the herbaceous layer, absolutely dominate.

Yew-rich and maple-rich oak stands are characterised by moderately, but significantly lower mean indicator values for light than the acidic mixed oak forests (ANOVA, $p < 0.0001$) (Figs. 8, 9). Though mean moisture values are on a similar level, they differ significantly ($p = 0.0058$), with lower values in the yew-rich oak forests compared with the maple-rich oak forests (Figs. 8, 9). There are pronounced and significant differences in the reaction indicator values ($p = 0.0001$) and nitrogen indicator values ($p < 0.0001$), the yew-rich stands having higher indicator values than the acidic mixed oak forests (Figs. 8, 9). The maple-rich stands were similar to the yew-rich stands (N-indicator value) or had a middle position between the yew-rich stands and acidic mixed oak forests (R indicator value).

Dendrochronological characteristics of yew

The 14 yew series exhibit tree-ring widths of 1.04 mm in average. The minimum and maximum values have a wide range extending from 0.26 to 3.92 mm with a standard deviation of 0.458 mm (Fig. 10, Supplement 4). The standardisation and detrending process resulted in a site chronology

of 116 years covering the period 1909 to 2024, with some negative and positive radial growth deviations. Low increment values are exhibited for the years 1915, 1954, 1963, 1970, 1976, 1992, 2003, 2018 and 2022 and large values for 1932, 1980 and 2007. Since 2007 until 2024 tree growth showed an overall declining trend with two extremely negative years 2018 and 2022. The ages of the trees range from 23 to 116 years with an average of 63 years, suggesting that the first yews were probably planted around the turn of the 19th to the twentieth century (Fig. 10). The Rbar and EPS values for the 30-year periods of analysis with 15-year overlaps (2000: 0.47/0.91; 1985: 0.40/0.86; 1970: 0.41/0.84; 1955: 0.05/0.22; 1940: 0.34/0.71) indicate that the yew chronology is a robust estimate of annual growth changes and that it is suitable for dendroclimatic research for the years 1970 to 2023.

In order to identify the main limiting climate growth conditions, correlations were calculated between the tree-ring index chronology and monthly and seasonal mean temperature, precipitation sums, and the drought index SPEI-3 for the so-called “hydrological year”, starting from October of the prior year to October of the current year (Supplement 5). Correlation patterns for mean temperature show positive values for the months February and March and significant negative values for June to August (Supplement 5A). Monthly correlations with precipitation are mainly positive but only significant in June and July, while seasonal values are highly significant for the period April to July (Supplement 5B). In comparison to correlations with precipitation and temperature, those for SPEI-3 were higher (Supplement 5C). For the months June to October correlations were all

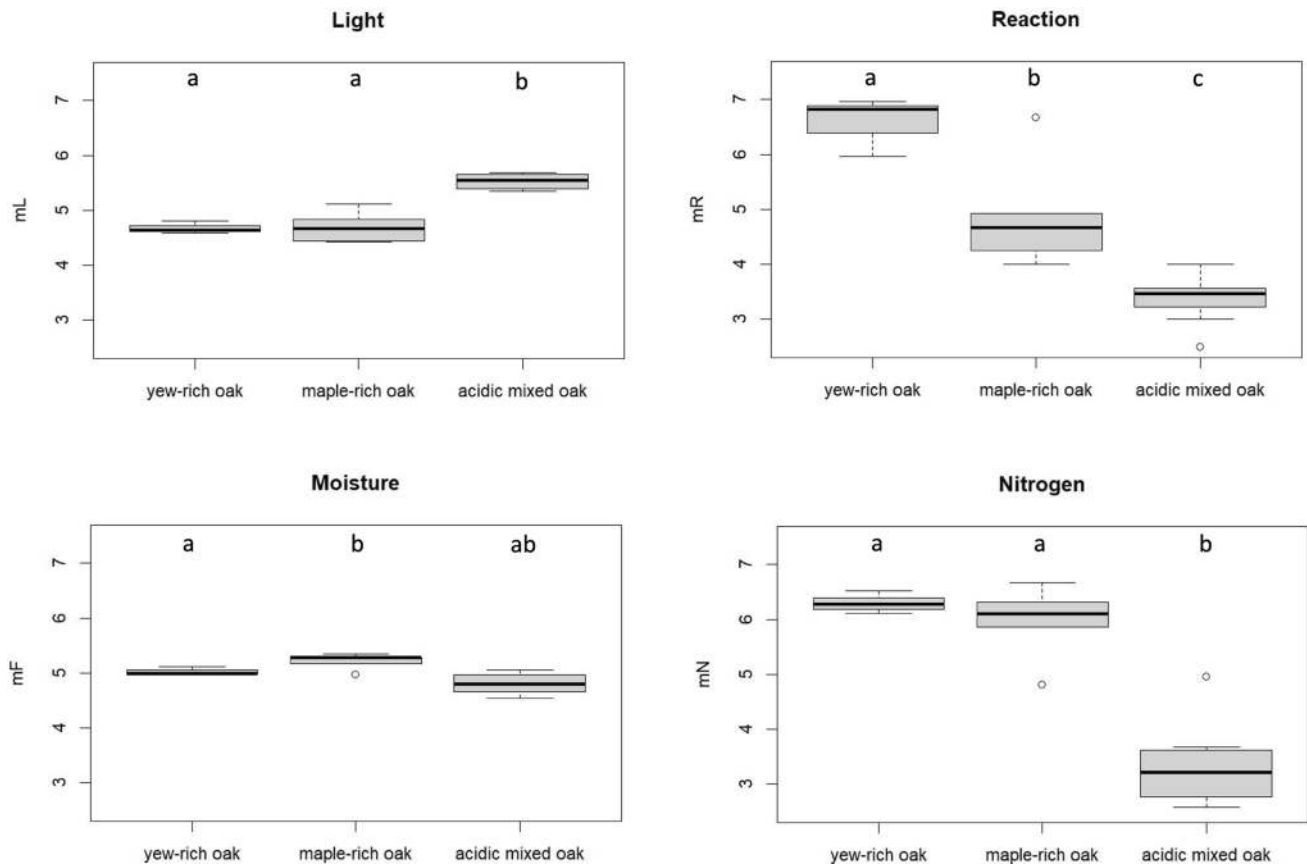


Fig. 9 Mean weighted Ellenberg indicator values for light (L), moisture (F), soil reaction (R), and nitrogen (N) of the vegetation relevés depicted in Supplement 2. Yew-rich oak stands ($n=3$), maple-rich oak stands ($n=5$) and acidic mixed oak forests ($n=8$) on sandy sites far

from groundwater in the Potsdam urban area are compared. Boxplots are shown in the graphs. Vegetation types with significantly different indicator values (ANOVA with Tukey post-hoc test) are marked by different letters

significant and the average of June to August showed the highest value ($r=0.3370$).

Discussion

Establishment and dynamics of the local yew population

The oldest yew (ID 637), next to the former Geodetic Institute/A17 built in 1892, dates dendrochronologically to the year 1909. Two trees (ID 473 from 1920 and ID 472 from 1925) form an intentional symmetrical structure in the path and visual axis to the former Astrophysical Observatory/A31 built in 1879 (Fig. 1C). Yew ID 473, a female specimen with a height of 10.9 m and a root collar diameter of 95 cm, represents the tallest and most prominent, albeit not the only "mother tree" on the campus. Other old yews are also directly related to buildings (e.g. ID 635/1931 with A62 and ID 334/1911 with A32). This generally reflects the planting of yew as ornamental greenery as part of the garden

design of the observatory. Photographic and other evidence of the intensive historical use of this tree species as individual trees, groups of trees and hedges, whether pruned or not, can be found in various publications and studies on the observatory (Braatz and Wey 1996; Eggers 2001; Seichter and Otto 2002).

A younger age cohort seems to exist in trees from the 1950s, which also occur near buildings (IDs 333, 636). But a significantly younger age cohort of adult yews concerns specimens with an age of 1973–2001 (IDs 111, 439, 465, 561, 565, 638, 639). Although the dendrochronological sampling was not aimed at statistical representativeness and therefore not all older yew specimens found were dated, the minimum age of the sub-spontaneous yew spread in the campus forest becomes visible here.

With its negatively exponential or "reverse J-shaped" distribution of root collar diameters, highly skewed towards small / young individuals, the yew population structure on the Telegrafenberg shows clear characteristics of a rapidly expanding population (cf. Svenning and Magård 1999). This distinguishes it from most remnant populations in European

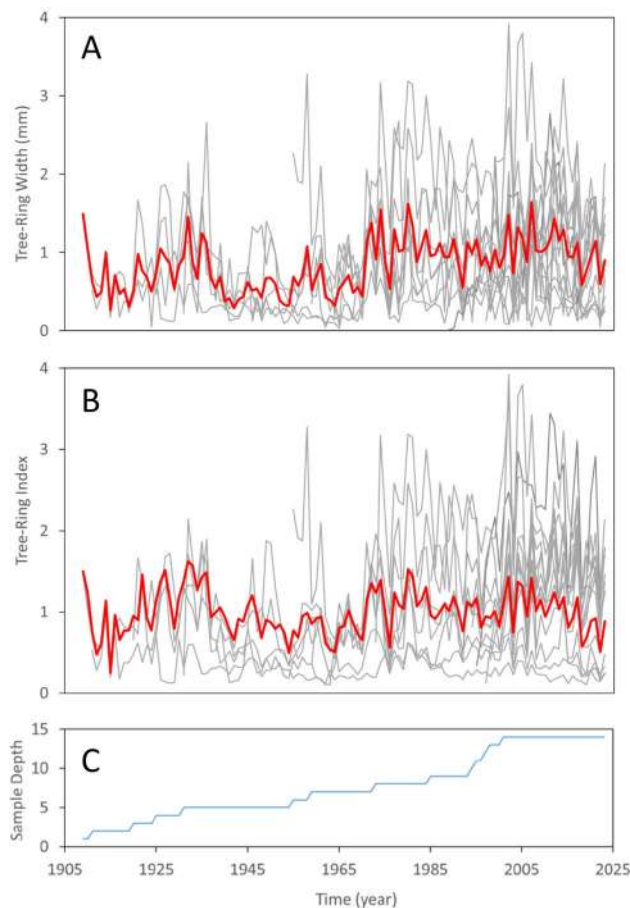


Fig. 10 Tree-ring width **A**, tree-ring index **B** and sample depth **C** for 14 analysed yew individuals on the Telegrafenberg campus. The mean chronologies are plotted in red

protected areas with generally larger mean diameters and thus older individuals and different proportions of young plants (e.g. Dhar et al. 2007; Piovesan et al. 2009; Ruprecht et al. 2010; Devaney et al. 2014; Sedmáková et al. 2017; Bujoczek and Bujoczek 2018; Ahmadi et al. 2020).

The flattened curve of the height of the yew individuals with the stem diameter is generally typical for forest stand structures (for yew see: Piovesan et al. 2009; Ahmadi et al. 2020). It indicates that the yew trees in the study area grow to a maximum height of about 11 m (like the free-standing mother tree ID 473), possibly under a canopy only 7 m. This places them at the lower end of the height range of European yew stands, with mean heights of older individuals in the range of 11–12 m (Piovesan et al. 2009) and maximum recorded tree heights from 15 m (Dhar et al. 2007; Sedmáková et al. 2017; Kaiser et al. 2024) to 22 m (Insinna and Ammer 2000). Only in the Near East Hyrcanian forests in northern Iran, heights up to 30 m seem to occur regularly (Ahmadi et al. 2020). This is not surprising given the relatively dry climate and poor soils and shows that, though the yew is vital on Telegrafenberg, it will not grow into the

upper tree layer. In general, it is typical for yews to form a second or third tree layer in the undergrowth in beech and other mixed deciduous forests (Dhar et al. 2006; Piovesan et al. 2009; Sedmáková et al. 2018) due to its limited (height) growth.

Long-time lags between introduction and spread are typical for non-native species (Kowarik 1995). Here, it can be partially, but not entirely, explained by the time until first seed set of yew (maturity of yew according to different sources between 30 and 50 years; Thomas and Polwart 2003; Cedro and Iszkuło 2011; Iszkuło et al. 2011). The many young individuals (Fig. 4) then indicate a renewed surge in the spread of yew during the last 25 years. We can assume that the main reason for this was a gradually increasing availability of seeds due to the growing number of trees at maturity. However, it could be also partially linked to an extensification of local park/forest management, as trees have not been regularly felled for some time (exceptions include dying trees near roads and paths) and tree regeneration has not been removed from the forest. The latter was sometimes done in the past as part of local park maintenance activities, but is no longer practised. The condition of the soil may also play a role, as the forest topsoils in the region has become significantly enriched with nutrients, especially nitrogen, in recent decades (Fleck et al. 2019). A better nutrient supply could have a favourable influence on the natural regeneration of yew (Thomas and Polwart 2003).

The yew spread generally took place in a fairly closed forest, as evidenced by topographic maps, aerial photographs and terrain photos and, most importantly, the many older trees in the canopy layer above the yew stand. Dendrochronological research has been conducted for *Quercus petraea* (Matt.) Liebl. and *Pinus sylvestris* L. from this forest, with a maximum of 224 and 130 tree rings, respectively, demonstrating the long forest history of this site (Babian 2011; Liang et al. 2013; Schneider et al. 2022). The oldest *Quercus* specimen dates back to 1786, the oldest *Pinus* specimen to 1833.

The general mechanism of seed dispersal of wind-pollinated and bird-dispersed yew is well known from a number of studies. The seeds are mainly transported by birds (especially thrushes/*Turdidae* and starlings/*Sturnidae*) via intestinal passage (e.g. Snow and Snow 1988; Hulme 1996; Thomas and Polwart 2003; Iszkuło and Boratyński 2005; Chybicki and Oleksa 2018; Schmidt 2024). Small mammals (e.g. Schaumann and Heinken 2002) and, especially in hilly terrain, gravity also play a subordinate role. A phenomenon linked to birds as seed dispersers on the Telegrafenberg and elsewhere is the frequent localisation of yew seedlings and young trees at the base of the trunks of older deciduous trees, which serve as feeding and resting places for the birds.

In addition to the presence of older yew trees as a seed source, the fencing of the site is of particular importance for the establishment of the individual-rich yew population in the forested parts of the campus. There is evidence of a fence since the 1870s (Spieker 1879). It has been renewed several times and slightly extended. To this day, the fence effectively prevents the browsing influence of game, roe deer in particular, on young yew plants and other trees (see also Svenning and Magård 1999; Iszkuło and Boratyński 2005). Currently, this can be observed as a great contrast especially in the west and south of the campus forest. Here yew can be found, sometimes in the midst of lush natural regeneration of other woody taxa (e.g. *Acer*, *Quercus*, *Fagus*, *Robinia*, *Symphoricarpos*), right up to the fence. Beyond the fence there are almost no more specimens except old pines or oaks. In general, the density of natural tree regeneration outside the fence is very low to non-existent (see also relevés 10–12 in Supplement 2). The situation is different in the busier northern and north-western neighbourhoods of the campus. Intensive day-round disturbance from people and traffic almost completely eliminates the influence of game here, promoting intensive regeneration of yew and other woody taxa despite the absence of a fence here.

The size of the yew population on the Telegrafenberg campus with its 2341 individuals on an area of 27 ha can be assessed by comparing it with the results of a Germany-wide yew inventory (Forstbüro Ostbayern 2013). A total of ca. 60,000 naturally growing adult yew trees found is distributed across 342 local populations, with only 13 populations having more than 1000 individuals. Of course, these statistics include only adult specimens, whereas immature individuals predominate on the Telegrafenberg. Although no statistics for sub-spontaneous yew occurrences are available in Germany, this comparison clearly shows that the Telegrafenberg population is a comparatively large one.

The current yew stand on the Telegrafenberg has developed in a forest that was dominated by *Pinus* and *Quercus* to a locally varying degree, as evidenced by the old trees in the upper tree layer. There are also some older individuals of mainly *Acer* and *Fagus* as well as other deciduous trees. This forest is currently undergoing considerable dynamics, including the death of nearly the entire old *Pinus* population as well as many older deciduous trees and the development of a species-rich natural regeneration (see above) including yew. The quantity, density and vitality of the yews indicate that they compete extremely well with other tree species.

A “bentgrass-sessile oak-European beech forest” (Hofmann and Pommer 2005) is considered the pnV of the Telegrafenberg and its surroundings. This forest type is characterised by acidic, moderately nutrient-supplied sandy soils with a moderately dry water regime. *Pinus* plays a minor role here and can establish mainly after disturbance

in an early successional stage. Currently, *Pinus* is not present in natural forest regeneration, neither inside nor outside the campus forest. The Telegrafenberg and its southern surroundings are part of a larger relict forest (“Potsdamer Heide”, locally referred to as “Großer Thiergarten” indicating feudal hunting use; von Suchodoletz 1683), which was dominated by *Quercus* until the middle of the eighteenth century. This was followed by an anthropogenic conversion of tree species to *Pinus* (Krausch 2008). Pollen analytical data from a mire (Moosfenn) and a small lake (Teufelssee) 3 km and 3.5 km south of Telegrafenberg, respectively, supplemented by data from a lake 6 km to the north-east (Sacrower See), show the local forest development for the last millennium and beyond (Müller 1969; Landgraf and Notni 2003; de Klerk 2006; Alinezhad et al. 2024). Immediately at the beginning of the regional German colonisation in the High Middle Ages (late 12th/early thirteenth century), however, these pollen diagrams show, with partly very low non-arboreal pollen sums (below 10% to 35%), a very high proportion of *Pinus* (e.g. ca. 50%) and quite low proportions of deciduous trees (e.g. ca. 25% *Quercus*, ca. 10% *Corylus*, well below 10% *Fagus*). This could be attributed to a certain human impact that has promoted *Pinus* as a pioneer tree species. Possible contradictory interpretations of historical vegetation and pnV are also conceivable.

Spread of yew in regional urban, park and regular forests

Yew belongs to the original tree vegetation of the Brandenburg-Berlin region. Various pollen records indicate autochthonous occurrences here since the mid-Holocene and until around the sixteenth century (Brandt 1994; Kaiser et al. 2024). In the nineteenth century at the latest, the autochthonous occurrences disappeared due to human impact, while yew has been locally cultivated in the environs of Berlin since at least 1594 (Kowarik 1992; Brandt 2001; Seidling 2001). In the eighteenth and nineteenth centuries, this tree species was then regularly planted in parks, gardens and cemeteries of the region.

Our vegetation analysis shows that yew is spreading on the Telegrafenberg largely in an urban forest, which has replaced less human-influenced, near-natural stands of acidophilous mixed oak forests. Beyond yew, this forest is characterised by a pronounced undergrowth of maple species and black cherry, which is also typical for urban forests outside the yew population. This vegetation transformation is accompanied by a spread of neophytic woody plants. While black cherry was introduced as a forest tree and has spread throughout northern Germany (Starfinger et al. 2003), the maple species and other neophytic woody plants were initially planted since the nineteenth century

as ornamentals in settlements, parks and along avenues. They mainly spread in urban forests during the last decades (Kowarik et al. 2013; Gregor and Kasperek 2021). The decrease of the Ellenberg light indicator values in such urban forests is due to the spread of shade-casting tree species such as maple and yew in the undergrowth (Leuschner and Ellenberg 2017). The increased nitrogen indicator values indicate an enrichment of nutrients in the soils of the urban yew-rich forest, while the increased reaction indicator values may be explained by the absence of acid indicators in largely herbeaceous-free and moss layer-free stands and the high R-indicator values of some woody plants such as the yew. Here, however, the indicator value approach obviously reaches its limits and does not correctly reflect the actual extremely strongly to strongly acidic pH situation of the forest sites on the Telegrafenberg. In particular, the assignment of a R value of 8 to yew (Ellenberg et al. 2001) is unrealistic considering its wide site amplitude from extremely acidic to basic. In addition to the area-wide nutrient enrichment through atmospheric nitrogen deposition (e.g. Diekmann et al. 2023), this is likely due to a higher frequency of recreational activities, including deposition of faeces and urine mainly from dogs (De Frenne et al. 2022). Fertilisation in turn supports the spread of mesophytic woody plants. Together with the shadier and therefore more humid microclimate (see lower Ellenberg moisture values), this results in a “mesophication” (Perring et al. 2018) of acidic forests, driven by yew, ivy and other woody species, in the course of which the ground vegetation from acid-tolerant indicators of nutrient-poor soils disappears.

In the immediate vicinity of the Telegrafenberg campus, i.e. in the urban area of Potsdam, there are extensive stands of old planted yew trees in several large parks as well (Sanssouci, Babelsberg, Neuer Garten; Supplement 6A, B). For Sanssouci, there is evidence of yew plants being imported from what was formerly Hinterpommern/East Pomerania (today in NW Poland) as early as 1746 (Kühn 2019). The total number of old yew trees in these parks is probably several hundred. Sub-spontaneous stands have also developed within these yew groups and in surrounding groves, but, more detailed information on the number of individuals and other characteristics such as exact age is lacking here. Sub-spontaneous yew populations with an age of some decades have also developed on the outskirts of the city, particularly in the west and north of Potsdam comprising the vicinity of older single house estates, villas and tree-rich gardens (Supplement 6C, D; Buhr et al. 2009; Paulsen 2018). What all these new populations have in common is that intensive public traffic, i.e. permanent disturbance by pedestrians, vehicles and dogs, means that the browsing effect of game on yew seedlings (Mysterud and Østbye 2004; Sedmáková et al. 2018; Moosavi et al. 2024) is significantly reduced.

Large sub-spontaneous yew occurrences, each with several hundred to thousands of individuals, can be found in the southwest (Pfaueninsel, Wannsee, Grunewald; áement 6E, F), northwest (Spandauer Forst, Jungfernheide/Tegel) and southeast (Königsheide/Treptow) of Berlin (Seidling 1995, 1998, 1999, 2001; Seidling and Constien 1998). As in Potsdam, historical yew plantings in parks, gardens and cemeteries were the starting points of the current spread, continuing at an accelerated pace since the 1980s/1990s. Particularly striking here is the proximity of the sub-spontaneous occurrences to areas heavily frequented by people and dogs (Seidling 2001). The range of dry forest vegetation communities colonised by yew extends from reed grass-linden-oak-hornbeam forest at nutrient-rich sites to wavy hair-grass-oak forest sensu Hofmann and Pommer (2005) at nutrient-poor sites. However, moist and nutrient-rich sites along lake shores and mire edges are also colonised (Seidling 1998). Based on the available data on spatial yew densities (Seidling 2001), it seems certain that Berlin, as the largest city, also has the largest sub-spontaneous yew population in Central Europe with several thousands to tens of thousands of individuals. These trees complement the almost 3000 yew specimens that occur here along streets and in other urban greenspaces (von Döhren and Haase 2022).

A larger sub-spontaneous yew occurrence in the rural area of East Brandenburg had a different start setting. On a former vineyard of the former Chorin Monastery, which was reforested in the 18th/nineteenth century, a large yew population has developed with several hundred specimens (Forstbotanischer Garten 2020; Panka and Panka 2023; Supplement 6G). Originating from trees planted along a road around 1889/90, today's yew population has emerged from these trees through natural regeneration. It could be the largest sub-spontaneous population in the region outside of urban agglomerations. The yew stand is single-layered homogeneous and consists of 70–80-year-old specimens. Yew is growing in the understorey of a structured, species-rich forest consisting of *Fagus*, *Acer*, *Quercus* and *Ulmus*.

Another, but significantly smaller sub-spontaneous yew population of 78 trees exists near Crussow in the Uckermark region (Forstbotanischer Garten 2020). This population has developed over an area of 4 ha around a memorial stone erected in 1895. A few specimens near the stone are over 100 years old, most of the trees are around 40 years old. The yew population has developed here in a forest dominated by *Pinus menziesii* (Mirbel) Franco and *P. sylvestris* L. with *Quercus*, *Fagus*, *Tilia* and *Betula* mixed in. Particularly remarkable is the fact that from a well-known original population of only a few decorative trees, a quite considerable yew population has developed in the surroundings

not protected by any fences, which also has a rich natural regeneration.

The examples above clearly show that a number of very vital sub-spontaneous yew populations have grown in the Brandenburg-Berlin region in various forest habitats (urban, park and regular forests) over the last decades to about a hundred years. However, as a systematic inventory of sub-spontaneous yew occurrences, with the exception of Berlin (Seidling 1998), is still lacking, their number and total population size is likely to be considerably larger than published local records suggest. A study on the German Baltic Sea coast north of the area under consideration has shown that even the local forest authorities are often unaware of the numerically large but rather young and therefore inconspicuous sub-spontaneous yew populations (Daute 2023). This becomes obvious when yew colonises rather unusual habitats, such as in this case partly forested coastal dunes (Supplement 6H).

These regional examples from northeast Germany can be added by supra-regional and even transcontinental examples of sub-spontaneous yew populations. A particular focus of attention so far were on occurrences within and in the vicinity of botanical gardens and arboreta (Giertych 2000; Nielsen and Leverenz 2002; Pietzarka 2005; Iszkuło and Boratyński 2005; Li et al. 2021). Obviously, this is caused by the fact that a professional interest in this “rare” species in such settings is apparent. An interest that may still be raised elsewhere complementing the use of yew as a widespread planted urban tree with some health risk (Alós Ortí et al. 2022; von Döhren and Haase 2022) and the frequent use of individual trees as urban bioindicators (Samecka-Cymerman et al. 2011; Rojo et al. 2020; Zarek et al. 2020).

Yew as a potential drought tolerant species for the region?

The yew sites on the Telegrafenberg campus are widely characterised by natural sandy soils with very low clay and moderate silt contents. The genetic characterisation of the soil substrates in profiles TGB1-3 as “solimixtive cover sand” (AG Geologie 2023, alternatively also “Kryoturbatsand”, LGRB 1997, or “cover bed”, Kleber et al. 2024) and “glacio-fluviolacustrine sand” is based on regional experience from soil mapping. Detailed sedimentological findings that could provide alternative explanatory models, e.g. by sandy aeolian dynamics, are generally rare on the Telegrafenberg (Weiße 2012).

Podzolic Cambisols (Dystric Arenosols) are present in places with anthropogenically undisturbed soil surfaces, such as the soil profiles investigated. The analysed soil profiles TGB1-3 with their generalised Ah-Ec/Bv-Khs/Bv/IC (Ah/Bwsh/Bw/C) horizon sequence and maximum depths

of the Bv (Bw) horizon with a range of 55–65 cm indicate a soil development that is typical for the region at such sites (Kühn et al. 2015). This suggests locally well-preserved soil surfaces, i.e. not altered by erosion or colluvial deposition. Exceptions to the natural status of the soil cover exist in form of buildings, backfill layers, roads, and rubble accumulations. Regosols and Anthrosols have formed here as a result of anthropogenic truncation and backfilling, respectively. These disturbances in the soil cover are the result of around two hundred years of anthropogenic construction activity. At the beginning of the nineteenth century these were very localised, but from the end of the nineteenth century and up to the present day they have affected more and more areas (Spieker 1894; Paech 2012).

The groundwater on Telegrafenberg is extremely deep with some decametres. Depending on the exposure, moderately dry (north-facing) to dry (south-facing) sites have developed in terms of soil moisture. This natural soil hydrological regime is only locally affected by the punctual release of water from a historically constructed radial drainage system for the observatory (Spieker 1879). Soil types and analytical data indicate moderately nutrient-rich to poor sites with acidic to extremely acidic soil reactions both on the campus and in its immediate surroundings (LGRB 1997; online data from Landeskompetenzentrum Forst Eberswalde LFE 2024).

This local site differentiation according to relief-dependent soil moisture is also reflected in the distribution of natural tree regeneration, including yew. For example, in mapping sub-area 1 with its north-west and north-exposed slopes, both the number of yew trees (563 specimens) is particularly high and the regeneration of *Quercus*, *Fagus*, *Acer*, and *Robinia* is particularly intensive. In mapping sub-area 7, on the other hand, which is exposed to the south-west, the number of yew is significantly lower with 275 specimens and the natural regeneration of deciduous tree species is only just in an initial state. The old cover stand of *Pinus* is currently collapsing here as a result of a regional series of extremely dry years in the last decade. In addition to the exposure, given the predominantly short distances of endozoochorous seed dispersal by passerines (Jordano et al. 2007) as main dispersal vector of yew, the distance of seed trees may also have an effect, such as the “mother tree” ID 473, which is close to mapping sub-area 1.

It is interesting to note that in this drought series since 2018 (Conradt et al. 2023; Holtmann et al. 2024; Pohle et al. 2024), despite the overall good vitality of the tree regeneration, both young and old deciduous trees have died from time to time. However, no significant losses of yew, both old and young specimens, were recorded. Rather, it appears that any gaps in the deciduous tree stands are quickly colonised by yew. Individual stands are even physiognomically

dominated by yew. In general, yew is a shade casting and shade tolerant species (Heinze 2004; Pietzarka 2005; Leuschner and Ellenberg 2017; Binder 2023), but its establishment and growth benefits from increased light availability in shady deciduous forests by gaps (Svenning and Magård 1999; Sedmáková et al. 2017).

The dendroclimatological analysis of yew on Telegrafenberg has revealed that tree growth is limited to some extent by low temperatures in late winter to spring and mainly by dry and hot conditions in summer to early autumn. Similar results were found by Schill (2019) for sites in Chorin and Crussow in northeast Germany while for yew in south-western Poland, Cedro and Cedro (2015) identified a relatively strong late winter to spring correlation but a rather weak summer signal. Similarly, in Azerbaijan yew growth is primarily and positively influenced by winter temperatures and, to a lesser degree, by precipitation during summer and early autumn (Seyfullayev et al. 2021). Slightly different seems to be the situation in Ireland (Galvin et al. 2014) and western Ukraine (Iszkuło et al. 2011) where the strongest correlations were found with dry conditions in summer. The strongest climate-growth correlations with SPEI-3 ($r=0.70$) on Telegrafenberg also point into this direction. According to the principles of dendroclimatology (Fritts 1976; Speer 2010), high correlations indicate a higher sensitivity of trees to climate variations which is usually the case towards the altitudinal and latitudinal limits of the natural distribution of individual species. Accordingly, the climate signals found so far at different locations in Eurasia suggest that yew is either limited by low winter-to-spring temperatures and/or by drought episodes in summer to early autumn. This scenario suggests that yews might still be able to grow during future warming by adjusting growth to more severe conditions. The low-frequency trends in yew on Telegrafenberg indicate only some growth decrease since 2007, while other tree species in Germany, especially spruce, have experienced substantial dieback and significant growth decline (Popkin 2021; Gribbe et al. 2024; Holtmann et al. 2024).

Since the sample numbers in this study were limited and trees were mainly of relatively young age, further material from other sites needs to be collected and analysed to corroborate the results. However, as part of an evaluation of 47 forest tree species in Germany considering the adaptation potential to climate change, yew was also classified as a potential future tree species (Roloff and Grundmann 2008; Roloff 2021). With regard to soil water balance, i.e. tolerance against drought, it is considered "very suitable" for moderately fresh to moderately dry sites and "suitable" for dry to very dry sites. Thus, this meta-study, based on a complex data analysis, places yew in the dry sector of the soil water balance. The dendroclimatological results from this current study on yew are comparable to those of similar studies

on *Quercus petraea* (Matt.) Liebl. (Schneider et al. 2022), *Fagus sylvatica* L. (Scharnweber et al. 2013) and *Pinus sylvestris* L. (Babian 2011; Liang et al. 2013) in northeastern Germany. Climate-growth correlations for all three species, the main tree species on Telegrafenberg, were positive for summer precipitation and drought indices, respectively, and negative for summer temperatures, clearly indicating dry summer conditions as the main limiting factor.

Other studies in the region and beyond list yew, attributing an overall climate resistance (including both heat and drought resistance; Burdová 2024), can only determine limited ecophysiological details (Schill 2019; Binder 2023) or do not assign yew any particular importance or priority with regard to its adaptation potential (Liesebach et al. 2021).

Similar climatic and edaphic conditions as to the Telegrafenberg with its 590 mm annual precipitation and sandy soils also exist in other sub-spontaneously established or even planted yew stands in north-east Germany and north-west Poland, e.g. in Berlin, Chorin, Crussow, Usedom, Darss-Zingst, and around Szczecin, with largely sandy soils and a precipitation range of 530–580 mm (Seidling 2001; Forstbotanischer Garten 2020; Cedro 2023; Daute 2023; Kaiser et al. 2024). All these sites are characterised by vital stands of yew that are expanding through natural regeneration. According to both observations and projection studies, increasing droughts are a major consequence of climate change in the region (Lasch-Born et al. 2016). Yew clearly has the ability to withstand increasing droughts to a certain extent here and, obviously, to expand its occurrence.

Symptomatic of the yew's high drought resistance are extreme occurrences on rocky cliffs with very little to no soil and partly strong insolation. Such yew occurrences can be found in the wider region both on Rügen Island on the Baltic Sea coast (Jeschke 2015) and in the Harz Mountains (Natzke 1998). Also a local sub-spontaneous occurrence in Potsdam should be mentioned here: On the Ruinenberg hill in Sanssouci Park, a small yew grows high up in the rocky wall of the so-called Norman Tower, a mid-nineteenth century scenic architecture built from limestone.

Also based on a broader perspective, i.e. European and beyond, it becomes clear that yew can still survive in rather dry hydroclimatic environments (Saulnier et al. 2026). Although yew performs seemingly best under high humidity, for example particularly well in England, Wales, Scotland, and Ireland with over 1000 mm of precipitation per year (Hageneder 2007), it also thrives at the southern end of its range in some areas in Greece and Spain with a precipitation range of 520–570 mm (Thomas and Garcia-Martí 2015). Here, of course, evapotranspiration is much higher than in northern Central Europe, as well as the resulting water stress for trees. Even at the eastern end of the distribution area, in the Hyrcanian Forest region south of the

Caspian Sea, yew sometimes still occurs with less than 600 mm of precipitation (Ahmadi et al. 2019). However, all this is by no means an all-clear signal regarding the generally endangered status of yew in the entire area of its occurrence. Strict protection of relict occurrences and various measures to re-establish extinct occurrences as well as their sustainable vitalisation are undoubtedly necessary here (Linares 2013; Thomas and Garcia-Martí 2015; Ahmadi et al. 2020; Thakur and Kanwal 2024; Saulnier et al. 2026). This is particularly significant against the backdrop of climate change. From this perspective, however, sub-spontaneous yew occurrences are a particular treasure that cannot be appreciated highly enough.

Conclusions

Long-term ecological processes, such as the establishment/migration, or the climatic promotion/repression of a species, change the tree species structure in a region. Since the second half of the twentieth century, large sub-spontaneous populations of European yew, a regionally rare and protected tree species, have developed in some Central European forests. This mostly took place near urban settlements, starting from planted ornamental trees. Thus, this spread is an anthropogenically initiated process involving a tree species whose natural occurrences in the region have largely disappeared since the Middle Ages due to the over-exploitation of its wood, the general intensification of forest use, and targeted eradication.

Our investigation of a large sub-spontaneous yew population comprising 2341 individuals on the 27-ha large Telegrafenberg campus in Potsdam revealed that it developed in the 20th/21st century from ornamental trees planted at the end of the nineteenth century/beginning of the twentieth century. The yew seeds were probably primarily dispersed by birds. Most of the individuals date from the last few decades. A fence around the campus protects the yews from browsing by game. The local yew population has developed despite somewhat unfavourable site conditions, i.e. a poor to medium nutrient supply and a medium-dry soil water regime at Telegrafenberg.

Data on other sub-spontaneous yew occurrences in the region show that they have mainly been found in the immediate vicinity of settlements since the 1980s/90s. In particular, a very large yew population probably comprising tens of thousands of specimens has developed in the urban forests of Berlin. The colonised sites in the region range from nutrient-rich and moist to nutrient-poor and dry, with dominance of the latter. In addition to the sufficient availability of mother trees, protection from browsing by game through fencing as well as various forms of anthropogenic

disturbance, including pedestrians and dogs, is a general prerequisite for the observed spread of yews.

The yew thus colonises an extremely wide range of sites and thrives even on nutrient-poor, dry soils, which are particularly affected by the consequences of climate change in the region. The yew, a native tree that has been widely underestimated until now, therefore has great potential, particularly in terms of its ecological function of contributing to increasing the diversity, resilience and stability of regional forest ecosystems.

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Data availability The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Code availability Not applicable.

Declarations

Conflict of interest The authors have no conflict of interest to declare that are relevant to the content of this article.

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