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The influence of climatic conditions on the tree-ring width of wild service trees (*Sorbus torminalis* L.) in Wielkopolska

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Abstract. The wild service tree (*Sorbus torminalis* L.) is a very rare tree species in Poland, where it reaches the north-eastern border of its natural range. The majority of this species' stands is found in Wielkopolska. This study was aimed at examining the relationships between the growth and climate for trees of the species *Sorbus torminalis* L. growing in the Wielkopolska National Park and the Pniewy forest district (Wielkopolska). The samples for the analysis were taken from 63 trees. However, taking into account the missing growth rings and the difficult identification of the tree ring borders in sapwood, only ca. 30% of the samples could be synchronised and dated accurately. Applying the classic methods of dendrochronological dating, a 94-year STW chronology was constructed, spanning the years of 1920–2013. The chronology, in turn, was used as a basis for dendroclimatological analyses, including correlation, response function, and pointer years. The climatic data used in the analyses came from the meteorological station in Poznań; providing air temperature and precipitation for a period of 66 years (1948–2013) and 48 years of insolation data (1966–2013). Insolation had the highest negative impact and precipitation had the highest positive impact on the annual growth in May and June. Positive pointer years could be linked to humid months with low insolation during the growing season, while negative pointer years are characterised by deficient precipitation, a large number of sunny hours, and high air temperatures in the summer months.

Keywords: dendroclimatology, *Sorbus torminalis* L., Poland

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1. Introduction

The wild service tree (*Sorbus torminalis* L.) is a widespread species in Europe, from North Africa through Spain, England to southern Sweden, and from the European shores of the Atlantic to northern Iran (Roper, 1993; Mitchell, 1996; Paganova 2007). The wild service tree usually occurs singly or in small isolated groups (Demesure–Musch, Oddou–Muratorio 2004; Pyttel et al. 2013; Rasmussen, Kollmann 2004).

The wild service tree is one of the rarest deciduous trees in Poland, growing in only 84 natural sites, with its numbers estimated at about 3,500 specimens, with no saplings or seedlings (Bednorz 2004, 2010). The species reaches the north-eastern border of its range here, occurring mainly in the western part of Poland, with the greatest number of sites found in the Wielkopolska region (Zając M., Zając A. 1997, 2001; Bednorz 2000; Bednorz, Jarosz 2000; Handkiewicz 2002; Szeszycki 2008). It is known as a thermophilic and drought-resistant tree (Bednorz 2007, 2010; Szeszycki 2008). The aim of this study was to investigate the relationship between growth–climate of the *Sorbus torminalis* L. trees occurring in Wielkopolska.

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Table 1. List and basic information on study areas

No.	Lab. code	Forest District	Reserve / Forest Subdistrict	Geographic coordinates		Habitat	Altitude a.s.l. [m]	No. of trees	No. of samples	No. of tree-rings
				φ (N)	**λ (E)**					
1	PN1	Pniewy	Rez. Jakubowo, Rez. Bytyńskie Brzęki	52°27’	16°31’	Lśw	100	24	45	2 789
2	PN2	Pniewy	Rez. Brzęki przy Starej Gajówce, Gmina Kaźmierz	52°^{0}28’	16°28’	Lśw	100	15	18	1 941
3	WPN	Wielkopolski Park Narodowy	Jeziory, Osowa Góra	52°17’	16°47’	Lśw	90	24	46	3 398
							Total	63	109	8 128

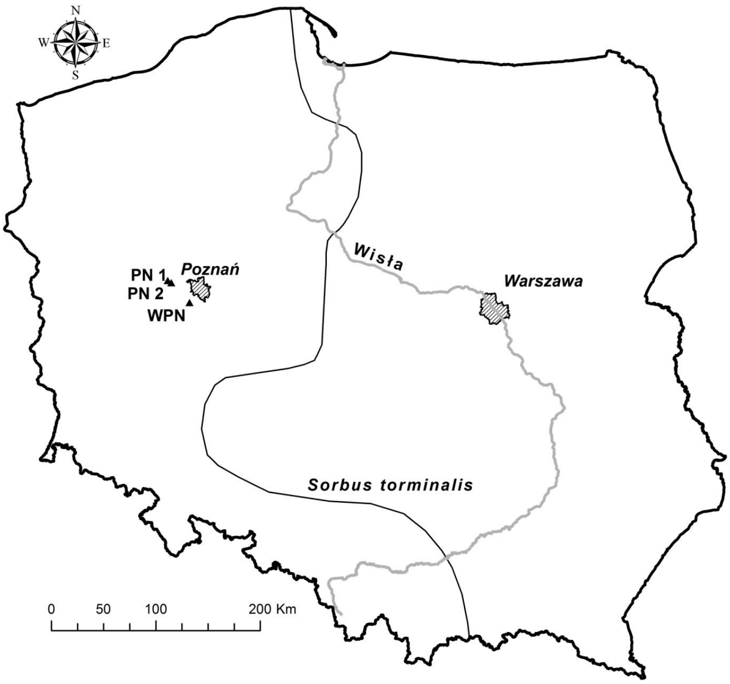

Figure 1. Location of study plots

2. Materials and methods

The study subjects were 63 *Sorbus torminalis* L. trees growing in the reserves of Jakubowo, Bytyńskie Brzęki, and Brzęki near Stara Gajówka, in Kaźmierz Township, the Pniewy Forest District and the Wielkopolska National Park (Fig. 1, Table 1). All study plots are located in the Poznań Lakeland, at a height of 90–100 m above the sea level, in fresh forest habitat (Protection Plan ... 1998, 1998, 2008). The samples were taken at 1.3 m above the ground level, if possible, drilling through the tree and obtaining two samples per tree.[1] The drilled sites were secured with Lac Balsam and wooden pegs of the same diameter as the

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[1] Permission was required from the following institutions to collect the samples: The State Forests National Forest Holding, Regional Directorate for Environmental Protection in Poznań, Chairperson of the Township Council of Kaźmierz, Director of the Wielkopolska National Park and Minister of the Environment.

drill bit. After transporting the samples to the laboratory, they were glued to wooden core mounts, dried and sliced with a knife in order to obtain a clear picture of the annual growth from the tree rings. Many difficulties were encountered while measuring the width of the rings, such as, for example, identifying the boundaries of the annual growth (especially in the very light sapwood layer) and having a very large number of rings falling off. In order to better delineate the ring boundaries, the sample was rubbed with writing chalk and the measurements were taken under a 'water filter' (i.e., a layer of water was placed on the sample). Most of the samples where the rings had fallen off (more than four rings) were eliminated from further analysis. The large number of samples with missing rings was the reason for the inability to date about 70% of the measurement sequences, despite knowing the date of sampling. The width of the annual growth of trees was measured with an accuracy of 0.01 mm using a stereo microscope, a moveable measuring table connected to a meter and Dendrometer software (Mindur 2000).

A total of 8,128 rings of annual growth were measured (Table 1). Next, the chronology was established using the classic methods of dating (cross-dating method), the coefficients of correlation *r*, and the value of the Student's t-test. The correctness of this chronology was tested with the Cofecha program (Holmes 1983, 1994). Indexing and eliminating the age trend were performed according to the standard procedures in the Arstan program (Cook, Holmes 1986 Cook, Kairiukstis 1990). We also calculated the Expressed Population Signal (EPS), describing the representativeness of the studied measurement sequences given the characteristic variability of the response of the study population (Wigley et al. 1984). The juxtaposed chronology was the basis of the dendroclimatological analyses: the analyses of the correlation and response function, as well as analyses of pointer years, for which data was used from the nearest meteorological station in Poznań, located about 15 to 30 km from the study plots (66 years of data, i.e., 1948–2013, were used for air temperature and precipitation, 48 years of data, i.e., 1966–2013, were used for insolation). The correlation analysis and response function were conducted using the RESPO program in the DPL package (Holmes 1983, 1994) within 16 months from June of the year preceding growth (pJUN) to September of the actual year of growth (SEP). Pointer years (+ positive, characterised by an increase in the width of annual growth and – negative, characterised by a decrease in the width of the tree ring) (Meyer 1997–1998) were calculated using the TCS program (Walanus 2002) with a minimum of 10 trees, with a minimum threshold of 90% compliance.

Table 2. Statistics for regional chronology STW (measured and indexed)

Lab. code	No. of years	Time span	No. of samples	Mean width tree-ring [mm]	Measured chronology			Residual chronology		
					STD	***AC1***	***MS***	***STD***	***AC1***	***MS***
STW	94	1920–2013	32	0.77	0.461	0.649	0.357	0.200	-0.028	0.245

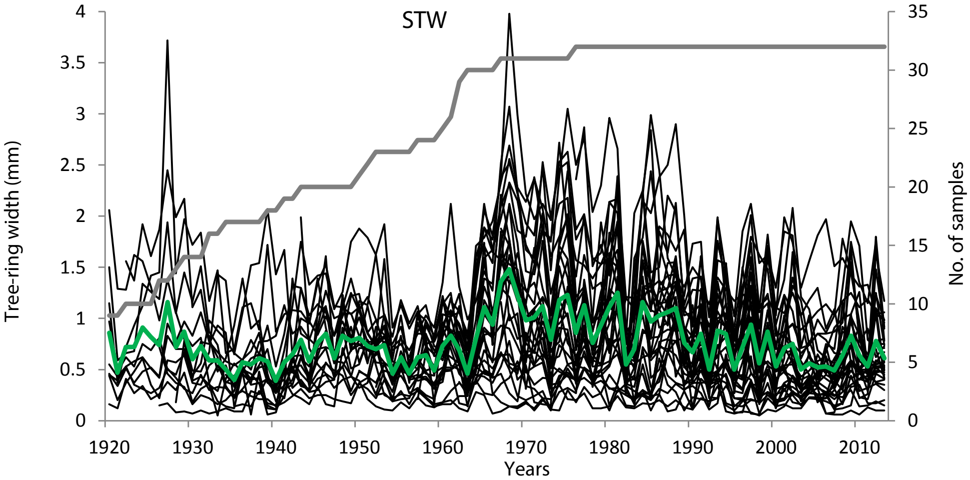

Figure 2. Dendrochronological curves (thin, black lines) making up regional wild service tree chronology for Wielkopolska – STW (green line); number of samples in regional chronology (grey line)

3. Results

3.1. Chronology

The chronology for the STW (*Sorbus torminalis* Wielkopolska) signature was established by averaging 32 individual growth curves, for 94 years from 1920–2013 (Fig. 2, Table 2). The mean width of the tree rings of the studied trees was 0.77 mm, ranging from 0.05 to 3.98 mm. An EPS indicator of 0.90 was the value determined to be above the minimum threshold as indicated by Wigley et al. (1984).

3.2. Dendroclimatological analyses

The correlation analysis and response function indicated that the changes in the air temperature played only a small role in affecting the annual growth (Fig. 3). Negative values dominated among the calculated indicators, which reached

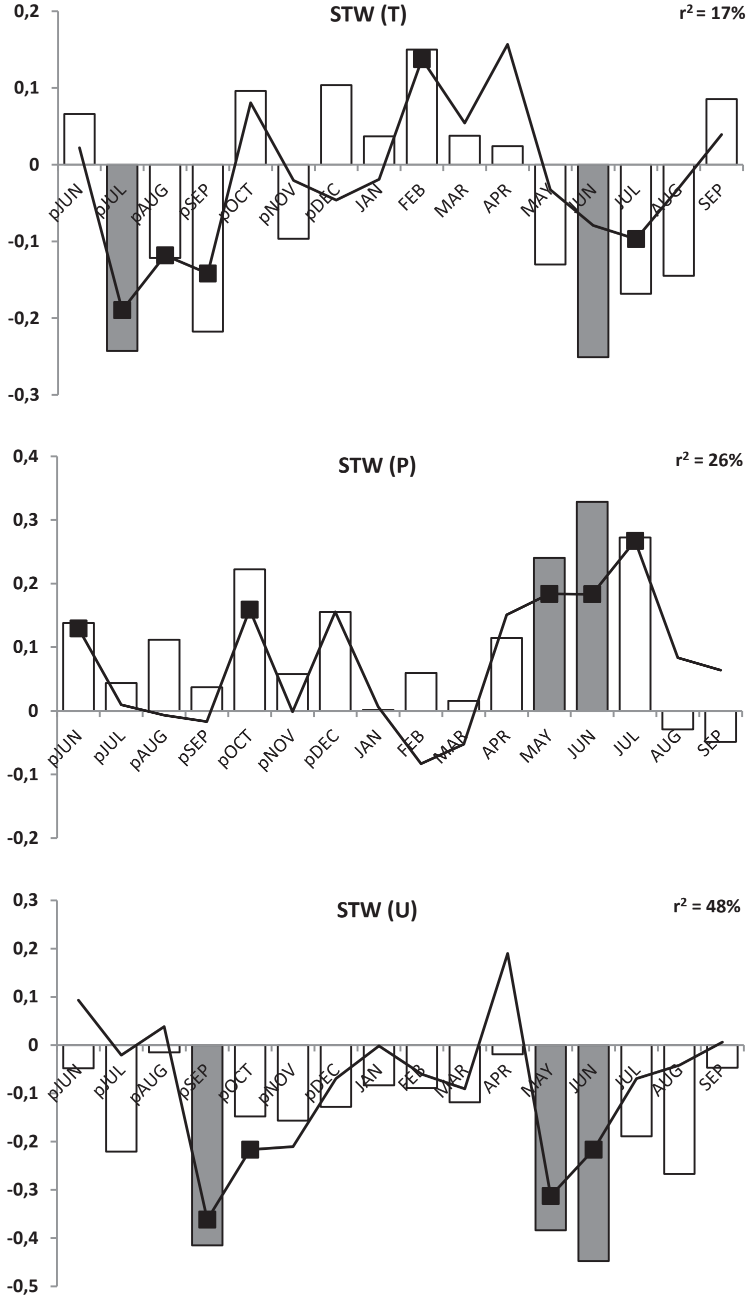

Figure. 3. Results of correlation and response function analyses for STW chronology and air temperature (*T*) and precipitation (*P*) and insolation (*U*); bars denote correlation coefficients; line represents response function; significant values (α = 0.05) marked as black squares and gray bars; *p* – previous year

statistical significance in July, August, and September of the year preceding the increase, and in June and July of the actual year of growth. A positive value for the regression coefficient was reported only for February. Stronger statistical relationships were found in the analysis of 'growth–precipitation'. The positive values of the calculated indicators dominated, and statistically significant values occurred in June and October of the previous year, as well as in May, June, and July of the actual year of growth. The highest values of correlation and regression were obtained for insolation (number of hours of sunshine). As in the case of temperature, the negative values occurred for September and October of the previous year, as well as for May and June of the actual year of growth. The highest coefficient of determination was calculated for insolation (48%); it was lower for precipitation (26%), and lowest, at 17%, for air temperature (Fig. 3). In summarising the results of the correlation and regression analyses, it is clear that the increment of the annual growth of wild service trees in Wielkopolska was mainly influenced by the weather conditions during the period of May–July, with the strongest relationships in June, that is, a small number of hours of insolation during this period, high rainfall, and lower than the mean air temperature are conducive to the formation of wide annual growth increments.

27 pointer years were calculated for the STW chronology, including 11 positive years (1955, 1957, 1960, 1964, 1967, 1974, 1977, 1984, 1993, 1999, and 2001) and 16 negative years (1928, 1930, 1944, 1947, 1954, 1956, 1959, 1966, 1973, 1976, 1978, 1992, 1995, 1998, 2000, and 2003). The analysis of the weather conditions for the designated pointer years allowed us to associate the positive pointer years with periods/years of higher than normal precipitation, especially with heavy rainfall during summer and a small number of insolation hours in the summer months. The negative pointer years were those with deficient rainfall in summer, often with high temperatures and insolation during these months. Examples of pointer years could be 1967 (a positive year) and 1992 (a negative year) (Fig. 4). The annual rainfall in 1967 in Poznan was 773 mm, the highest on record for the period of 1948–2013. The total precipitation in almost all months was above normal; however, the summer months had particularly high amounts of rainfall. The total annual hours of insolation that year was 1,477, which was well below the mean multi-year value, and the number of insolation hours in summer was also below average. In 1992, the annual amount of precipitation in Poznań was only 355 mm (which had a multi-year mean of 532 mm), with rainfall continuing to be below normal during all of the months of the growing season (June was especially dry, with only 3 mm of

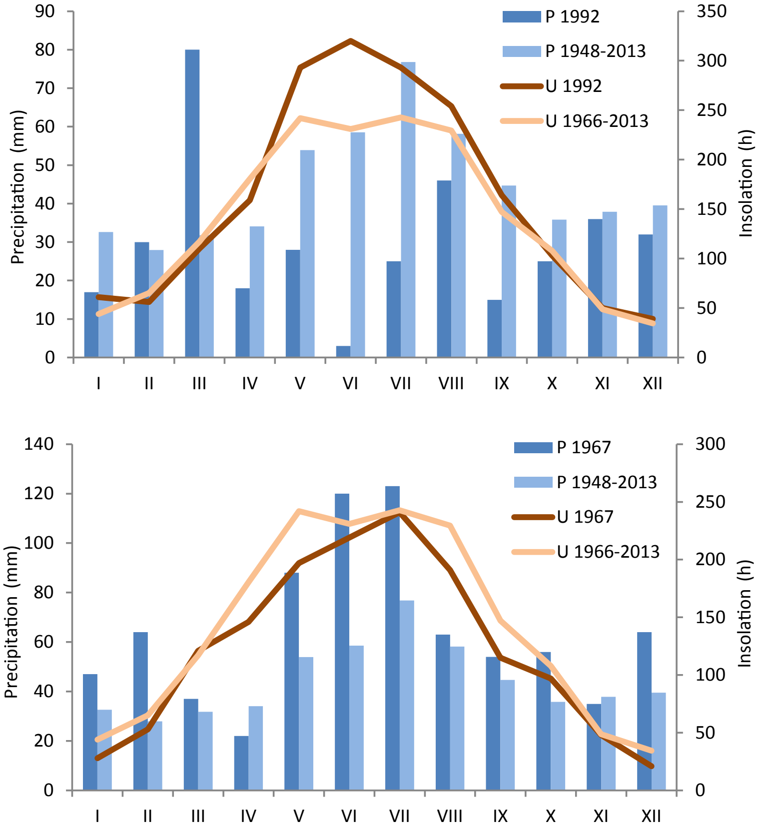

Figure 4. Monthly sum of precipitation (*P*) and monthly insolation (*U*) in positive pointer year (1967), compared with mean values for 1966–2013 in Poznań

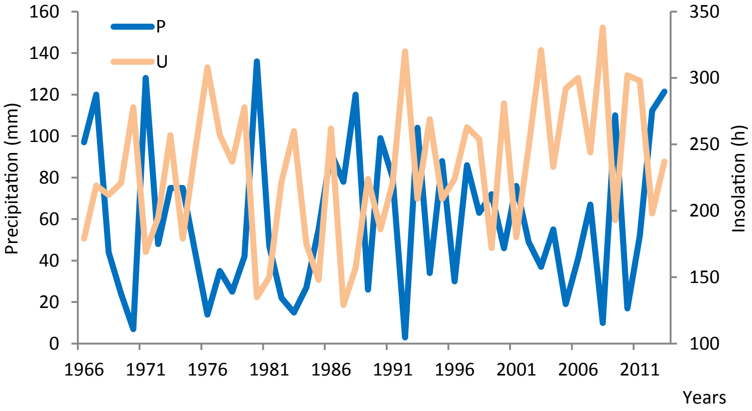

Figure 5. Monthly sum of precipitation (*P*) and monthly insolation (*U*) in time interval 1966–2013 from Poznań for June

precipitation). Insolation that year amounted to 1,902 hours, with the mean for the period of 1966–2013 at 1,690 hours. The number of insolation hours was particularly high in the months of May–August, with one of the highest recorded values over a period of many years occurring in June (320 hours). In addition, the summer months were characterised by high air temperatures (with means exceeding 20 °C in July and August).

4. Discussion and summary

Insolation, that is, the number of hours during which the solar disk is not obscured by clouds, strongly affects all the environmental processes, including physical, chemical, and biological processes. Among others, it determines the course of the growing season, the efficiency of photosynthesis, and the generative reproduction of plants. In our climate zone, insolation depends primarily on the season, cloud cover, and air pollution. It is considered the most comprehensive factor of climate, reflecting thermal and precipitation conditions, as well as being a derivative of cloud cover (Koźmiński, Michalska 2005). However, this climatic factor is rarely used in dendroclimatological studies, although it is one of the dominant factors determining the formation of the annual growth rings of trees. In particular, the number of insolation hours in May and June strongly influences the width of the tree ring of the wild service tree. Insolation is a derivative of cloud cover, which is inseparably linked to the most important hydrometeor — precipitation. The higher the cloud cover, the greater the probability of precipitation, thus reducing insolation. Negative correlations are noted for precipitation and sunshine (Poznań meteorological station for the period of 196–2013), the lowest for the sum of the years (-0.20), higher for the sum of the individual months, including May at -0.38 and for June at -0.59 (Fig. 5). The results of these relationships are contradictory indicators of correlation and regression for precipitation and insolation in May and June. A greater number of insolation hours also means increased air temperature, resulting in the negative values of correlation and regression for this climatic factor, which were observed in a similar period.

Sorbus torminalis trees are rarely the subject of dendrochronological analyses (Rasmussen 2007; Pyttel et al. 2011, 2013; Cedro 2014, 2015). In Germany and Denmark, analyses carried out in 15 locations on the basis of 75 trees indicate the dominant role of the previous summer's temperature, as well as the summer month thermals of the actual year of growth at some sites (negative correlation values dominate) in the process of shaping the annual growth increments (Rasmussen 2007). An analysis of diameter at breast height, height, and age of the wild service trees of south-western Germany (80 trees) showed extremely small height and thickness increments of these trees. According to the authors, this is the response of the trees to strong competition and their survival strategy in unfavourable conditions (Pyttel et al. 2011, 2013). At the same time, it was found that this species is highly shade-tolerant, able to survive, regenerate, and reproduce in the understory of a compact stand. Cedro (2014, 2015) confirms a growth–climate relationship for the sites in Poland, primarily for the year preceding the actual growing season (simple correlations for precipitation, negative indicator values for temperature) and also simple relationships for precipitation in the actual year of growth.

Currently, the wild service tree is very rare in Poland, has no economic significance and is not often the subject of dendrochronological studies. But, global warming is changing the living conditions of trees, and unless they manage to adapt to the pace of these changes, the limits of their range may shift in the coming decades. The current niche species will then gain importance, by extending their range and increasing their numbers. Therefore, more knowledge about the ecology of wild service trees, especially at the boundaries of its natural range where these trees have the greatest potential for adaptation, is extremely important in the face of increasing human pressure on natural habitats and climate change.

Conflict of interest

The author declares no potential conflicts of interest.

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