VERSITA

GEOCHRONOMETRIA 35 (2010), pp 91-94
DOI 10.2478/v10003-010-0001-9

Available online at
versita.metapress.com and www.geochronometria.pl

TREE-RING CHRONOLOGY OF SILVER FIR AND ITS DEPENDENCE ON CLIMATE OF THE KASZUBSKIE LAKELAND (NORTHERN POLAND)

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Received 15 September 2009 Accepted 7 January 2010

Abstract: The current paper presents investigation of the response of silver firs growing near Kartuzy in the Kaszubskie Lakeland (northern Poland) to climate conditions. Tree-ring width series covering the period of 1914-2006 were built and correlated with mean monthly temperature and precipitation. Dependence of the growth of analysed firs on winter, early spring and summer temperature was observed. Significant relation to moisture availability was detected only for January. Analysis of pointer years revealed similar driving forces that were obtained by correlation and response function investigation. Reaction of firs from the Kaszubskie Lakeland to the extreme climate conditions is analogous to the exhibited at other sites of this species localised outside distribution range. Investigated silver firs seem to have found favourable growth conditions in the studied area and further cultivation of that species in northern Poland may turn to be successful.

Keywords: *Abies abla*, dendroclimatology, temperature, precipitation, Kaszubskie Lakeland, Poland

1. INTRODUCTION

Silver fir (*Abies alba* Mill.) plays an important role in Polish forestry because of its high productivity and wood quality. It is a typical mountain species and constitutes, as the main component, forests growing in southern part of Poland (Raport..., 2008). However, forest utilisation caused that nowadays this species grows all over the country, even outside its natural range. Even though silver fir very often forms pure, single-species stands, it is rather considered, together with oak and beech, as a valuable addition in Scots pine-dominated stands.

Climate conditions are considered as one of the most influential factors that shape tree-growth (Fritts, 1976). Knowledge about effect of the climate on the cambium activity and, as a result, on the growth of trees is of a great importance for silviculture. Such knowledge is especially crucial in terms of silver fir decline observed within natural range of that species in the 1960s and 1970s (Jaworski, 1982; Eckstein *et al*., 1983; Dobrowolska, 1998) and slight improvement reported in the following decades (Zawada, 2001). Analysis of the adaptation of a given species to the environmental conditions outside its natural distribution range may also serve as an assessment tool for validation of its possible introduction or further exploitation in such areas. Tree-ring studies with their year-to-year resolution prove to be a very efficient method of such analysis as the width of the annual radial increment is the direct effect of the tree-environment interactions (Schweingruber, 1996).

The aim of the study was (i) to establish tree-ring chronology of silver fir from the Kaszubskie Lakeland and (ii) to analyse the influence of the climate conditions on tree-ring widths.

2. STUDY SITE

The study was performed in the Kaszubskie Lakeland (northern Poland). The site was located outside the natural distribution range of silver fir in Poland (**Fig. 1**). The Kaszubskie Lakeland characterises with variable landscape and environmental conditions. Significantly higher elevation (Wieżyca – 329 m a.s.l.) and relative heights constitute abounding relief, which, in addition, is full of lakes and wetlands connected to the impermeable bedrock. Glacial and fluvioglacial origin of the bedrock results in poor, often acidulated soils whose scattered distribution influences the vegetation in a great measure (Kondracki, 2000). Mean annual temperature calculated

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ISSN 1897-1695 (online), 1733-8387 (print)

Fig. 1. *Localisation of the study site (dot) and natural distribution range of silver fir in Poland (grey area).*

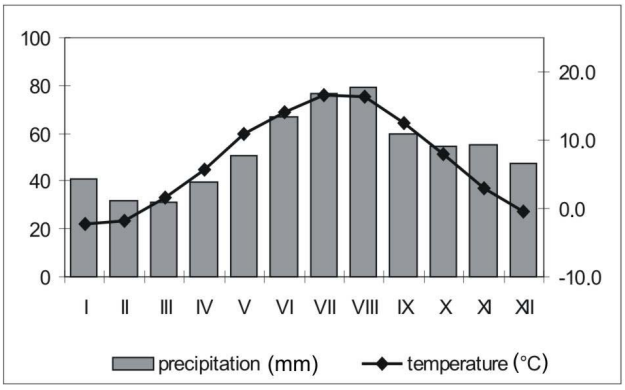

Fig. 2. *Mean monthly temperature and precipitation in the Kaszubskie Lakeland (1901-2002).*

for the period 1901-2002 comes to about 7°C. In July temperature exceeds 16°C, while in January drops slightly below –2°C. Average annual sum of precipitation reaches 630 mm, of which 273 mm falls in the growing season (**Fig. 2**). Scots pine accompanied by Norway spruce and common beech dominates in the species structure of local forests.

3. MATERIAL AND METHODS

In summer 2007 we selected four sampling plots in the Kartuzy Forest District. Silver fir participation in the species structure of chosen stands varied from 10 to 40%. No fir seedlings or understorey was observed. On each plot we sampled 15 dominant and healthy trees from the upper canopy layer. One increment core per tree was taken with Pressler borer from the breast height. The cores were sanded with finer grade until the tree-ring boundaries became easily distinguishable and then scanned. CooRecorder image analysing program was used for ring width measurements.

Individual series were cross-dated visually with the CDendro software and statistically basing on Gleichlaeufigkeit coefficient (Kaennel and Schweingruber, 1995) and t-value (Baillie and Pilcher, 1973). Synchronisation was also checked with COFECHA program (Holmes, 1999). Series that showed dissimilarity were excluded from the further analysis as they might limit the common signal exhibited by the chronology. In total, 57 individual tree-ring width series were used in the chronology formation.

To pronounce climate-related high-frequency signal and to minimise long-term age-dependent trend, each tree-ring width series was standardised in the two-staged detrending using the negative exponential curve and the linear regression function (Cook and Kairiukstis, 1990). Then the indices were prewhitened using an autoregressive model and averaged across all series using bi-weight robust mean estimation (Cook, 1985). Standard and residual chronologies were computed with CRONOL software (Holmes, 1999).

Response function concept (Fritts, 1976) was used to investigate the influence of climate on the growth of silver firs in the Kaszubskie Lakeland. Residual chronology was correlated with climate descriptors. The analysis included thermal and pluvial conditions spanning from June of the previous growth year to September of the current growth year. DendroClim2002 (Biondi and Waikul, 2004) software was used for correlation and response coefficient calculations. Climate data used in the study originates from the CRUTS 2.1 set and spans 1901-2002 period (Mitchell and Jones, 2005). Mean monthly temperature and precipitation values were obtained for the grid with the centre at 18.25°E, 54.25°N.

Extreme environmental factors are supposed to cause the formation of exceptionally wider or narrower ring as the response to unusually favourable or unfavourable conditions (Schweingruber *et al.*, 1990). Pointer year analysis was carried out to determine situations where conspicuously smaller or larger increment occurred. A given year was considered as a pointer one when it was shown by more than 80% of at least 10 trees. Calculations of the pointer years were performed on raw data in WEISER program (Gonzales, 2001).

4. RESULTS

Chronologies

Chronologies covering the period of 1914-2006 were built for silver fir from the Kaszubskie Lakeland (**Fig. 3**). Mean tree-ring width of the individual series constituting the regional chronology was quite similar ranging from 2.43 to 3.07 mm. Mean sensitivity within the entire data set equals 0.282 and running Expressed Population Signal (EPS; cf. Cook and Kairiukstis, 1990) index value exceeded 0.95 over the whole analysed period. This confirms the confidence that further growth-climate analyses for the developed chronologies represent the population signal quite well.

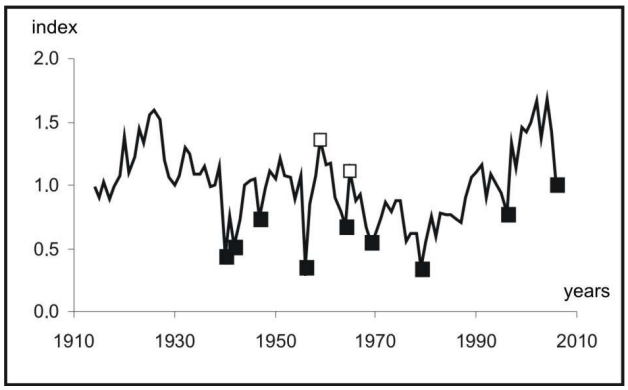

Fig. 3. *Standard chronology and pointer years of silver fir from the Kaszubskie Lakeland. Black boxes indicate negative and white – positive pointer years.*

Response to climate

Growth of silver firs in the Kaszubskie Lakeland turned to depend on the thermal conditions in winter-early spring period and in summer (**Fig. 4a**). Positive significant correlation between tree-ring widths and temperature was found for the period from January to March and for July of the current growth year. In turn, negative relationship with temperature was observed for July and August of the previous growth year as well as for June of the current growth year. Pluvial conditions were important only in winter and the water surplus in that time seemed to be unfavourable factor for silver fir growth. Significant negative correlation was observed for precipitation only in January (**Fig. 4b**).

Pointer years

In total, 11 relatively narrow or wide rings were found in chronologies of silver fir growing in the Kaszubskie Lakeland (**Fig. 3**). Only two of them (1959, 1965) were found to be the positive pointer years. Profound decrease in growth was observed especially in the 1940s when three pointer years (1940, 1942 and 1947) were determined. Also in the 1960s analysed trees experienced greater impact of limiting environmental conditions. Two negative pointer years (1964, 1969) were found out in that period. Year 1956 has a specific character as all of 57 analysed trees reacted in the same way producing very narrow ring.

5. DISCUSSION

Presented values of the mean annual diameter increment of silver firs from the Kaszubskie Lakeland are slightly lower than those obtained for trees growing in north-eastern Poland (Koprowski and Gławenda, 2007). In turn, they are similar or merely higher than values reported for stands growing within the natural distribution range of that species in southern Poland (Feliksik, 1993; Szychowska-Krąpiec, 1999). Analysed stands seem to fully recover from the decline phenomenon occurring in the 1960s, which is indicated by the increasing growth in last 20 years (**Fig. 3**). Analogous trend observed for Norway spruce (Koprowski, 2008) and Sitka spruce (Feliksik and Wilczyński, 2008) may indicate that northern Poland is characterised by favourable vegetation conditions for species that are outside their natural range there.

Feliksik (1990) and Feliksik *et al.* (2000) reported the role of winter temperature in the process of silver fir wood formation. Koprowski and Gławenda (2007) showed the importance of the thermal conditions in February and March on the growth of silver fir outside its natural distribution range as well. Also negative character of 1940, 1942, 1947 and 1956 pointer years indicates the unfavourable influence of coldness on growth of analysed silver firs. Winters in these years were very severe. In the studied region mean monthly temperature reached –9.7°C (January 1942) and –10.1°C (February 1947), while average values of this parameter for the period 1901-2002 are –2.2°C and –1.7°C respectively.

Many papers report drought vulnerability of silver firs and this fact results very often in precipitation reconstruction (Buentgen *et al.,* 2009; Hoffmann *et al.*, 2009). Presented results do not show any significant response of analysed trees on water deficit. Koprowski and Gławenda (2007) observed similar relationship for firs in north-eastern Poland and explained this fact with enough amount of moisture in the habitat and optimal distribution of water delivery during the year. Gaussen-Walter climate diagram (**Fig. 2**) for the Kaszubskie Lakeland does not show any possible lack of moisture over the year and especially growing season. However, what does not occur in wider temporal scale, may sometimes appear in case of

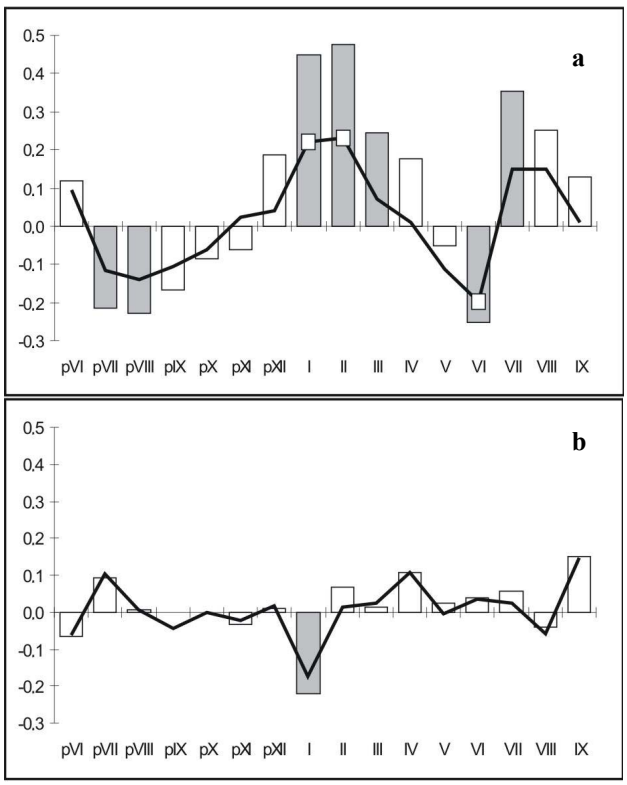

Fig. 4. *Correlation (bars) and response (line) coefficients between tree growth indices and mean monthly temperature (a) and total monthly precipitation (b). Grey bars and squares indicate values significant at P=0.05; p – previous year.*

individual years. In 1956, apart from severe winter, analysed firs also suffered from extremely low precipitation in May (ca. 20% of long-term average). Also 1964 and 1979 negative pointer years seem to be caused by insufficient moisture availability. However the absence of the widely recognised drought years (e.g. 1992 reported by Drobyshev *et al.*, 2008) may support the concept of Koprowski and Gławenda (2007).

6. CONCLUSIONS

Dendroclimatological investigation on silver fir growing in the Kaszubskie Lakeland showed that thermal and pluvial conditions of winter have the most important influence on the radial growth of this species in that region. Analysed trees seem to prefer warm and dry winters and, to some extent, warmth in early spring and the middle part of the growing season. Studied stands seem to have recovered from the growth decline of the 1960s exhibiting constant increase in diameter increment over last 20 years. Similarity in growth rate between trees growing inside and outside the natural distribution range may indicate good adaptation of silver fir to the environmental conditions of the Kaszubskie Lakeland. This, in turn, may support the idea of further attempts of this species cultivation in northern Poland.

ACKNOWLEDGEMENTS

The research was funded within the grant 2 P06L 017 30 supported by Polish Ministry of Science and Higher Education. The author wishes to thank the reviewers whose comments helped to improve the manuscript.

REFERENCES

Baillie MGL and Pilcher JR, 1973. A simple crossdating program for tree-ring research. *Tree-Ring Bulletin* 33: 7-14.

Biondi F and Waikul K, 2004. DendroClim2002: A C++ program for statistical calibration of climate signals in tree-ring chronologies. *Computers & Geoscienciences* 30: 303-311. DOI 10.1016/j.cageo.2003.11.004.

Buentgen U, Brazdil R, Frank D and Esper J, 2009. Three centuries of Slovakian drought dynamics. *Climimate Dynamics* DOI 10.1007/s00382-009-0563-2

Cook ER, 1985. *A time-series analysis approach to tree-ring standardization*. Dissertation, University of Arizona: 171 pp.

Cook ER and Kairiukstis LA, 1990. Methods of Dendrochronology: applications in the environmental sciences. Dordrecht, Kluwer: 395 pp.

Dobrowolska D, 1998 Zjawisko zamierania jodły pospolitej (*Abies alba* Mill.) w naturalnym zasięgu (Phenomenon of silver fir decline within natural distribution range). *Sylwan* 142 (12): 49-55 (in Polish with English abstract and summary).

Drobyshev I, Niklasson M, Eggertsson O, Linderson H and Sonesson K, 2008. Influence of annual weather on growth of pedunculate oak in southern Sweden. *Annals Forest Science* 65: 512 DOI 10.1051/forest:2008033.

Eckstein D, Aniol RW and Bauch J, 1983. Dendroklimatologische Untersuchungen zum Tannensterben (Dendroclimatological investigation on silver fir decline). *European Journal of Forest Pathology* 13: 279−288 (in German).DOI 10.1111/j.1439-0329.1983.tb00128.x

Feliksik E, 1990. Badania dendroklimatologiczne dotyczące jodły (*Abies alba* Mill.) występującej na obszarze Polski. (Dendroclimatological research concerning silver fir occurring in Poland). *Zeszyty Naukowe Akademii Rolniczej w Krakowie* 151: 1-106 (in Polish).

Feliksik E, 1993. Teleconnection of the radial growth of fir (*Abies alba* Mill.) within central Europe. *Dendrochronologia* 11: 171−175.

Feliksik E and Wilczyński S, 2008. Tree-ring chronology as a source of information on susceptibility of Sitka spruce to climatic conditions of Pomerania (northern Poland). *Geochronometria* 30: 79-82, DOI 10.2478/v10003-008-0002-0.

Feliksik E, Wilczyński S and Podolski R, 2000. Wpływ warunków termiczno−pluwialnych na wielkość przyrostów radialnych sosny (*Pinus sylvestris* L.), jodły (*Abies alba* Mill.) i buka (*Fagus sylvatica* L.) ze Świętokrzyskiego Parku Narodowego (Influence of thermal-pluvial conditions of radial increments of Scots pine, silver fir and common beech in Świętokrzyski National Park). *Sylwan* 144 (9): 53-62 (in Polish with English abstract and summary).

Fritts HC, 1976. *Tree rings and climate*. London-New York-San Francisco, Academic Press: 567pp.

Gonzalez IG, 2001. WEISER: a computer program to identify event and pointer years in dendrochronological series. *Dendrochronologia* 19 (2): 239-244.

Hoffmann K, Buentgen U, Kyncl T, Brazdil R and Esper J, 2009. On the potential of fir ring width data for summer drought reconstruction in southern Moravia, Czech Republic. In: Kaczka RJ *et al*., eds, *TRACE - TreeRings in Archaeology, Climatology and Ecology* 7: 57-63.

Holmes RL, 1999. *Dendrochronology Program Library (DPL) Users Manual*. LTRR University of Arizona, Tuscon.

Jaworski A, 1982. Fir regression in Polish mountain areas. *European Journal of Forest Pathology* 12 (3): 143-159. DOI 10.1111/j.1439-0329.1982.tb01387.x

Kaennel M and Schweingruber FH, 1995. Multilingual Glossary of Dendrochronology. Terms and Definitions in English, German, French, Spanish, Italian, Portugesse and Russian. Berne, Stuttgart, Viena, Swiss Federal Institute for Forest, Snow and Landscape Research: 467 pp.

Kondracki J, 2000. *Geografia Regionalna Polski* (Regional geography of Poland). Wyd. Naukowe PWN: 452 pp (in Polish).

Koprowski M, 2008. Dendrochronologiczna analiza przyrostów rocznych świerka pospolitego (*Picea abies* (L.) Karsten) poza naturalnym zasięgiem a cechy biometryczne szyszek (Dendrochronological analysis of annual increments of Nowray spruce outside its natural range in comparison to biometric features of the cones). *Sylwan* 152 (3): 50-57 (in Polish with English abstract and summary).

Koprowski M and Gławenda M, 2007. Dendrochronologiczna analiza przyrostów rocznych jodły pospolitej (*Abies alba* Mill.) na Pojezierzu Olsztyńskim (Nadleśnictwo Wichrowo) (Dendrochronological analysis of silver fir annual tree-ring growth in the Olsztyńskie Lakeland (Wichrowo Forest District)). *Sylwan* 151 (11): 35-40 (in Polish with English abstract and summary).

Mitchell TD and Jones P, 2005. An improved method of constructing a database of monthly climate observations and associated high-resolution grids. *International Journal of Climatology* 25: 693-712 DOI 10.1002/joc.1181.

Raport o stanie lasów w Polsce (Report on the state of forests in Poland), 2008. CILP. Warszawa.

Schweingruber FH, Eckstein D, Serre-Bachet F and Bräker OU, 1990. Identification, Presentation and Interpretation of Event Years and Pointer Years in Dendrochronology. *Dendrochronologia* 8: 9-38.

Schweingruber FH, 1996. *Tree rings and environment-dendroecology*. Bern, Paul Haupt: 609 pp.

Szychowska-Krąpiec E, 1999. Poźnoholoceński standard dendrochronologiczny dla jodły *Abies alba* Mill. z obszaru południowej Polski (The Late Holocene master chronology of fir from southern Poland*). Zesztyty Naukowe AGH, Geologia* 26 (2): 173-299 (in Polish).

Zawada J, 2001. Przyrostowe objawy rewitalizacji jodły w lasach Karpat i Sudetów oraz wynikające z nich konsekwencje hodowlane (Increment symptoms of fir revitalisation in forests of the Carpathians and the Sudety with silvicultural consequences resulting from them). *Prace IBL Seria A* 3 (922): 79-101.