Electronic Journal of Polish Agricultural Universities is the very first Polish scientific journal published exclusively on the Internet, founded on January 1, 1998 by the following agricultural universities and higher schools of agriculture: University of Technology and Agriculture of Bydgoszcz, Agricultural University of Cracow, Agricultural University of Lublin, Agricultural University of Poznan, Higher School of Agriculture and Teacher Training Siedlce, Agricultural University of Szczecin, and Agricultural University of Wroclaw.

ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

2003
Volume 6
Issue 2
Series FORESTRY

FELIKSIK E., WILCZYŃSKI S. 2003. TREE RINGS AS INDICATORS OF ENVIRONMENTAL CHANGE **Electronic Journal of Polish Agricultural Universities**, Forestry, Volume 6, Issue 2.
Available Online http://www.ejpau.media.pl

TREE RINGS AS INDICATORS OF ENVIRONMENTAL CHANGE

Edward Feliksik, Sławomir Wilczyński
Department of Forest Climatology, Cracow University of Agriculture, Cracow, Poland

ABSTRACT

The aim of the research was to establish the reasons for the deep, long-term depression in tree ring formation, which took place in the period from 1950-1980 in Douglas firs (*Pseudotsuga menziesii* Franco) growing in southern Poland. 340 tree rings from 17 trees from the Sudety Mts., the Western Beskidy Mts., Eastern Beskidy Mts. and Roztocze underwent dendrochronological analyses. Results indicate Douglas fir's high sensitivity to air pollution. Long-term drop in tree-ring widths in the years 1950-1980 was probably caused by industrial emissions. Climatic conditions influenced mainly short-term changes in tree-ring sizes and could not have been the cause of long-term depression. The long-term drop in tree-ring widths varied in terms of intensity depending on particular region. It occurred first and with greatest intensity in western Poland, in the Sudety. In the Bieszczady and Roztocze, it took place later and was less intense. Apart from being smaller, the tree-rings were also characterized by high variability of width. After the emissions decreased, the favorable meteorological conditions allowed the trees to regain vitality and homogeneity in their tree-ring reactions.

Key words: *Pseudotsuga menziesii*, dendrochronology, tree ring, radial increment.

INTRODUCTION

Dendroclimatological research conducted so far indicates that Douglas fir, which was introduced to Poland at the turn of the 19th and 20th centuries, is sensitive to climatic factors in a similar way as the native silver fir [9, 10, 11, 13]. Moreover, populations of Douglas firs in south - western Poland indicate a drop in tree-ring sizes from 1950s to 1980s [12]. This phenomenon was also common in silver firs growing in Poland [9] and western Europe [2, 5, 16, 21]. The causes of this phenomenon were attributed to negative climatic condition [6] as well as to the increasing environmental contamination due to industrial emissions [3, 7, 8, 9, 15, 20, 22].

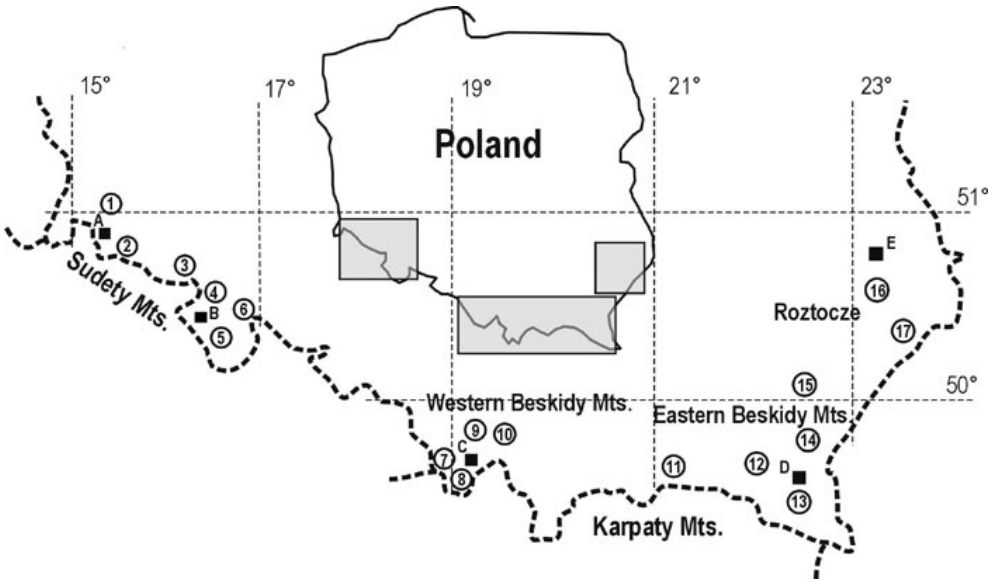
The aim of the research was to determine the causes of long-term decrease in radial increments in Douglas firs and the spatial diversification of this phenomenon in southern Poland.

RESEARCH MATERIAL AND METHODS

Seventeen populations of Douglas firs were selected in the area of the Sudety Mountains, the Karpaty Mountains and Roztocze (Fig. 1). In each tree stand, we cored 20 100-year-old trees on both sides at the height of 1.3 meters above the ground. The trees were cored by means of Pressler bore. The samples were then measured to obtain tree-ring widths, the values of which were put in chronological sequences.

For each group of trees, we calculated the average tree-ring size for every year. In this manner, 17 site tree-ring chronologies were formed for the period 1910-1999. Based on site tree-ring chronologies, we created regional tree-ring chronologies. They represented mean tree-ring widths of trees from the Sudety, the Western Beskidy, the Eaestern Beskidy and Roztocze.

Fig. 1. Study area. Douglas fir sites (circles), climatic stations (black squares)



The level of tree-ring width variability in particular years was calculated by means of the coefficient of variation. In order to eliminate natural trends of tree-ring width, chronologies underwent standardization [4].

In order to determine climatic conditions and their possible influence on long-term decrease in radial increments in the years 1950-1980 as well as their increase after 1985. Climatic diagrams were created which show deviation of mean monthly temperatures and rainfall totals of both periods from mean values from the period from1920-1950. This period has been considered as stable in terms of wood increments.

Using response function [14], we calculated theoretical values of tree-rings widths for the years 1920-1999, which were estimated on the basis of the values of monthly temperatures and rainfall totals. Estimated chronologies are the theoretical illustration of tree-ring widths based on the influence of only the climatic factor. The course of these chronologies was then compared with the chronologies of actual values of wood increments.

The meteorological data used in the research came from the Institute of Meteorology and Water Management meteorological stations in Szklarska Poręba (A), Kłodzko (B), Żywiec (C), Lesko (D) and Zamość (E) (Fig. 1).

RESULTS AND DISCUSSION

The course of site tree-ring chronologies indicates that already in the 1930s the values of wood increments began to gradually decrease (Fig. 2, 3) and tree-ring reactions intensified (Fig. 4). In the 1960s and 1970s there was a severe depression in terms of tree-ring sizes accompanied by an increased diversification of tree-rings. This phenomenon first occurred in Douglas firs in the Sudety Mts. In trees growing in the eastern part of the Karpaty Mts. and Roztocze, tree-ring diversification culminated as late as in the late 1980s (Fig. 4).

Fig. 2. Site tree-ring chronologies of Douglas firs from Sudety Mts. (A), Western Beskidy Mts. (B), Eastern Beskidy Mts. and Roztocze (C)

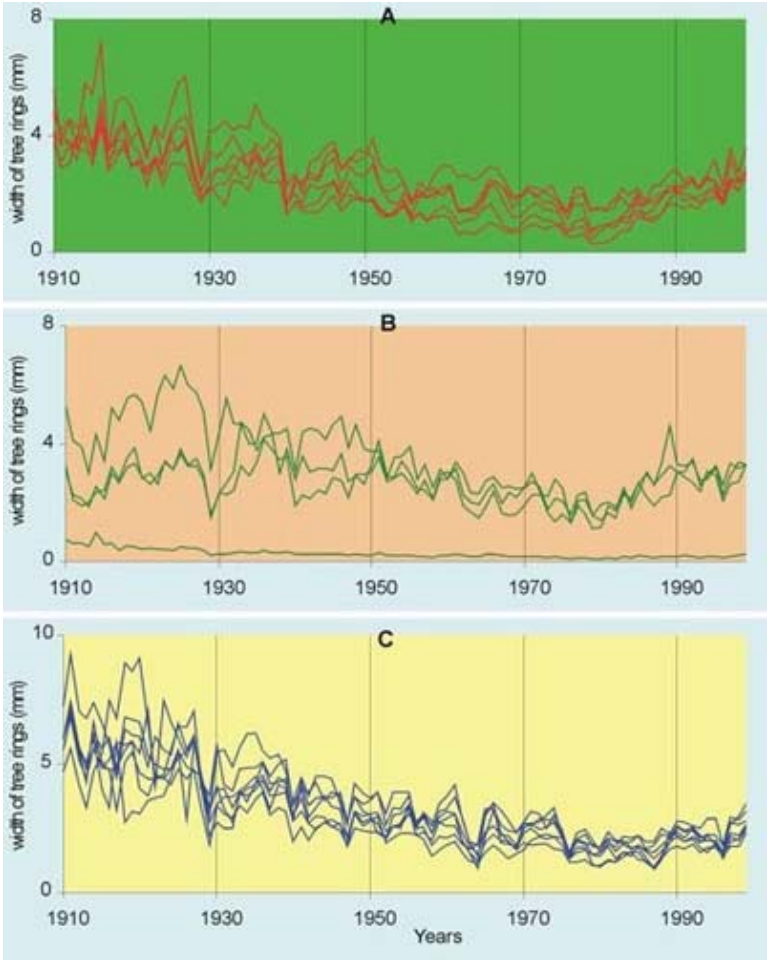


Fig. 3. Regional tree-ring chronologies of Douglas firs from the Sudety Mts. (thick line), the Western Beskidy Mts. (dotted line), the Eastern Beskidy Mts. and Roztocze (thin line)

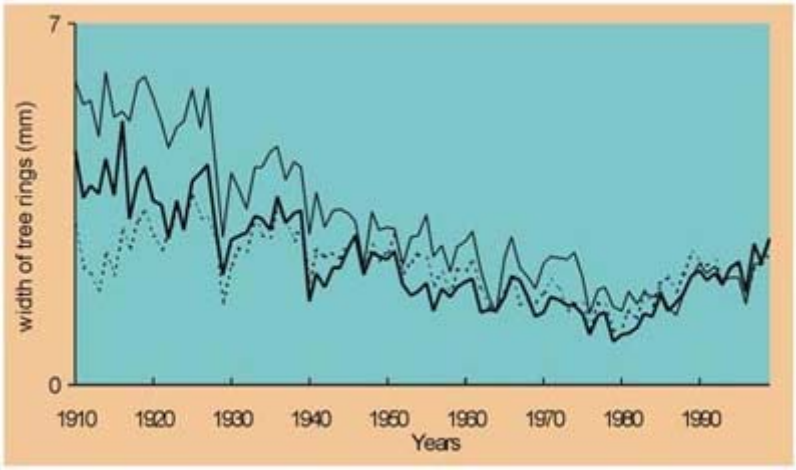
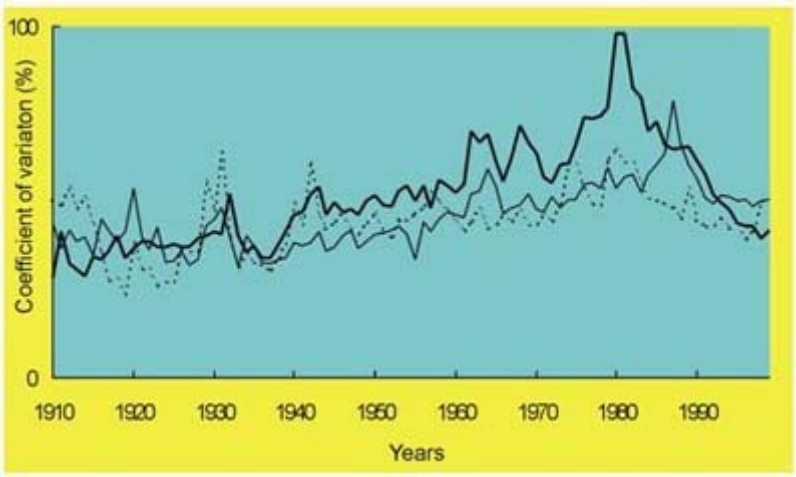


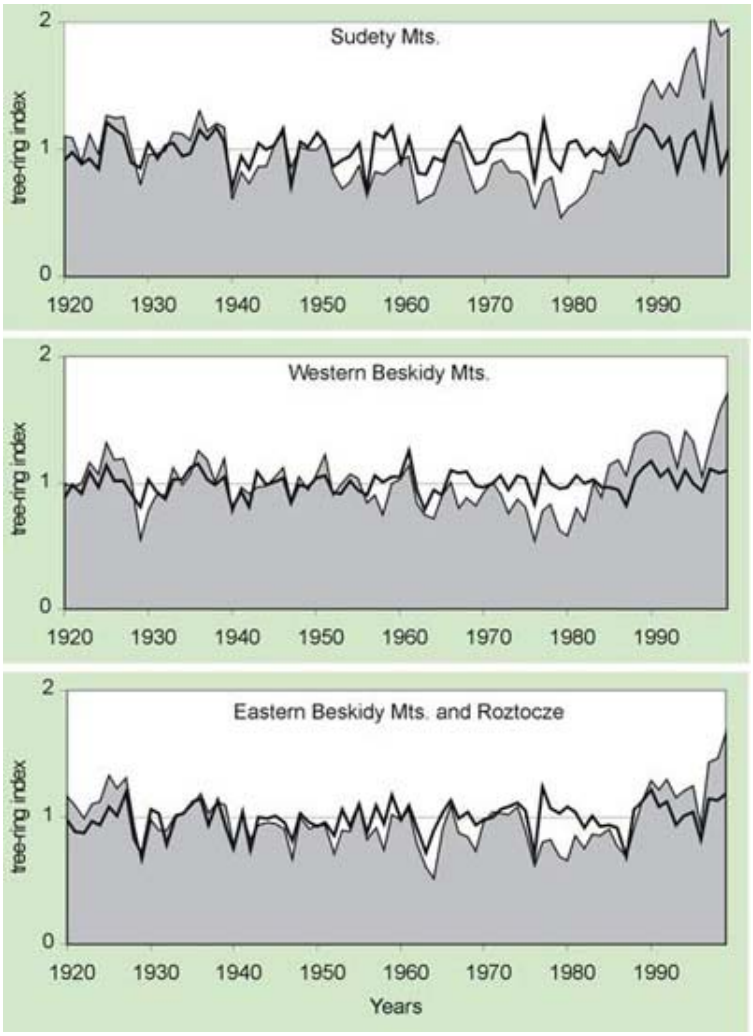
Fig. 4. Annual coefficient of variation of the tree-ring width of Douglas fir trees from the Sudety Mts. (thick line), the Western Beskidy Mts. (dotted line), the Eastern Beskidy Mts. and Roztocze (thin line)



The increase in the variability of tree-ring reactions correlated with the decrease in tree-ring widths (Fig. 3, 4). During the period from 1970 – 1980, Douglas firs in the Sudety and Western Beskidy experienced the biggest drop in tree-ring widths and subsequently very intensive wood increments. These increments were larger than those of Douglas firs from the Eastern Beskidy and Roztocze (Fig. 2, 3).

Standard chronologies from which the natural "aging trend" was eliminated allowed us to determine the precise beginning of tree-ring regression. In the Sudety and Western Beskidy, it occurred in the mid 1950s. Douglas firs from the Sudety displayed the greatest drop, while the smallest one took place in trees growing in the Eastern Beskidy and Roztocze (Fig. 5). In the early 1980s, in the Sudety and Western Beskidy the downward trend in tree-ring widths underwent a radical change: trees began to form larger and larger tree-rings. The same process occurred a few years later in firs in the Eastern Beskidy and Roztocze (Fig. 5). This testifies to a significant reduction of the stress factor and revitalization of trees in the whole area under research. The annual variability of estimated chronologies is almost identical with that of tree-ring chronologies. They differ, however, in long-term variability in the period of 1955-1999 (Fig. 5). If the trees were only influenced by the climatic conditions, then the long-term drops or rises would not take place.

Fig. 5. Reconstruction of the growth of Douglas fir, estimated from the climate-growth relationship during the calibration period from 1920 to 1950 (thick lines), compared with the indexed tree-ring width (grey fields)

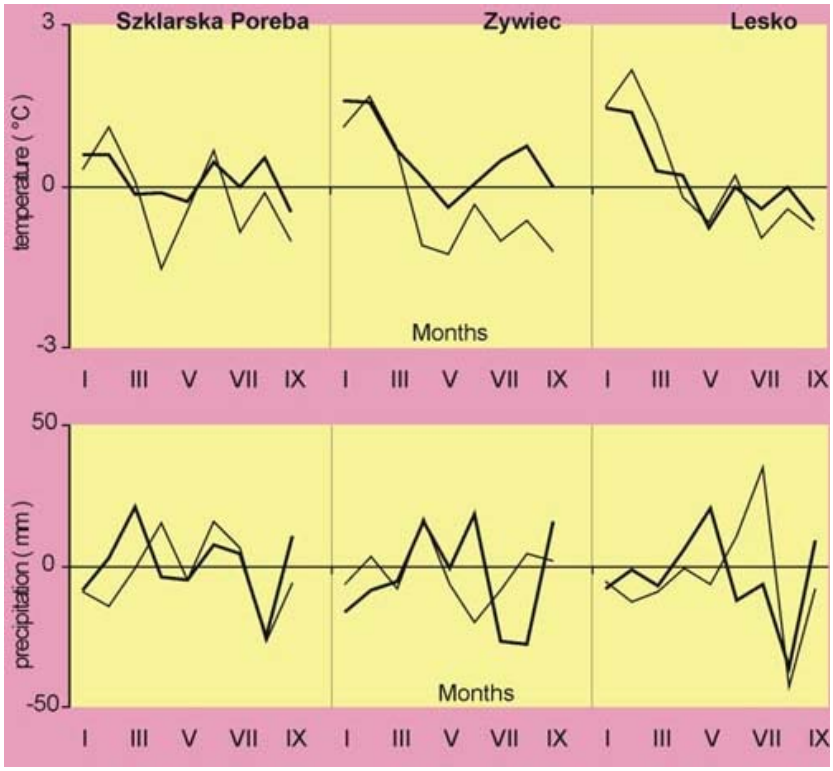


Numerous short-term drops in tree-ring sizes can be observed in the chronologies, for example in the following years: 1929, 1940, 1947, 1962, 1963, 1976, 1979 and 1996 (Fig. 2, 3). These were years with particularly negative climatic conditions for Douglas firs (Feliksik and Wilczyński 1997, 2000, 2002, 2003): they were characterized by very frosty winters or dry summers. These conditions negatively influenced the cambial activity of trees. However, even a slight improvement of the climatic conditions caused that the trees regained good form and created wide tree-rings (Fig. 2, 3).

Results presented above allowed us to determine that the climatic factor was probably not the cause of long-term drops in tree-ring widths in the second half of the 20th century. Therefore, there had to be another factor that had a negative influence on the trees' physiology. Once this factor was eliminated in mid 1980s, the trees entered a phase of regeneration and their tree-rings widths increased. At the same time, the tree-ring width variability decreased significantly. The trees began to react more homogenous to the external factors, which determined their growth.

In order to verify the above thesis, we compared the climatic conditions of the following periods: 1920-1950, 1970-1980, and 1985-1999. It turned out that during the period of tree-ring depression (1970-1980) and during that of tree-ring width (1985-1999), the climatic conditions were similar (Fig. 6). The thermal conditions of winters, which have the greatest influence on Douglas firs' tree-rings [10, 11, 12, 13] improved in comparison to those of the 1920-1950 period. This confirms the thesis that the climate was not the cause of long-term tree-ring depression. It could have had, on the other hand, a positive impact on the improvement of the trees' condition during the last 15 years.

Fig. 6. Climatic diagrams for periods 1970-1980 (thin lines) and 1985-1999 (thick lines). Deviation from norm counted for period 1920-1950



There had to be another strong factor that weakened the trees until mid 1980s. This thesis corresponds with the research on the concentration of air pollution in Europe and Poland [1, 17, 18, 19], which indicates that there has been a steady increase in industrial emissions especially in Western Poland, since the post-war years. The emissions culminated in the 1970s and 80s. In the following years, however, the level of industrial emissions clearly began to drop. It seems then, that it was the industrial pollution that weakened the trees. This point of view is also confirmed by the spatial distribution of emissions: the greatest concentration was recorded in western Poland and it decreased in the eastern direction [17]. The distribution and concentration of pollution correspond, with the time span and depth of long-term drops in Douglas firs' tree-rings in the area under research.

CONCLUSIONS

Dendrochronological research is an effective tool in detecting causes of the variability of incremental reaction of trees brought about by climatic and non-climatic factors. The analysis of tree-rings allows detecting negative phenomena occurring in tree's lives sooner than observations of other external symptoms.

1. Douglas fir displays a relatively high sensitivity to air pollution. It manifested itself in high variability of tree-ring reaction and in long-term drop in wood increments.
2. The phenomenon of annual increment depression had different intensity, depending on the region. It occurred first and most intensely in the Sudety and the Western Beskidy, while in the eastern regions of Poland it took place later and with less intensity.
3. The climatic factor determined only short-term variability in radial increments and did not have an impact on their long-term decrease.
4. Decrease in industrial emissions in the 1980s and favorable meteorological conditions facilitated an increase in the formation of wood increments and homogeneity of tree-ring reactions.

ACKNOWLEDGEMENTS

The investigation was supported by the Polish State Committee for Scientific Research (KBN) under grant No 6 PO6H 096 20.

REFERENCES

1. Adema E.H. 1987. Quantification of air pollutants in Europe and its importance to vegetation. (In:) Kairiukstis L., Nilson S., Straszak A. (eds.) Forest decline and reproduction: Regional and global consequences. Proceedings of the workshop held in Krakow, Poland: 19-43.
2. Bauch J., Göttsche-Kühn H., Rademacher P. 1986. Anatomische Untersuchungen am Holz von gesunden und kranken Bäumen aus Waldschadensgebieten. [Anatomical research of healthy and diseased trees from damged tree stands]. Holzforschung 40: 281-288. [in Germany].
3. Bernadzki E. 1983. Zamieranie jodły w granicach naturalnego zasięgu. (W:) Białobok S. (ed.). Nasze drzewa leśne. Jodła pospolita. [Dying of silver fir in its natural territory]. (In:) [Our forest trees. Silver fir]. PWN: 483-501. [in Polish].
4. Cook E.R., Holmes R.L. 1986. Users manual for computer programs ARSTAN. (In:) Holmes R.L., Adams R.K., Fritts H.C. Tree rings chronologies of western North America: California, eastern Oregon and northern Great Basin. Chronology Series 6. Univ. of Arizona, Tucson: 50-56.
5. Eckstein D., Aniol R.W., Bauch J. 1983. Dendroklimatologische Untersuchungen zum Tannensterben. [Dendroclimatological research of dying of silver firs]. Eur. J. For. Path. 13: 279-288. [in Germany].
6. Eckstein D., Sass U. 1988. Dendroecological assessment of decline and recovery of fir and spruce in the Bavarian forest. (In:) Bucher J.B., Bucher-Walin I (eds.). Air Pollution and Forest Decline. IUFRO P2.05, Interlaken, Birmensdorf: 255-260.
7. Eling W. 1993. Immissionen im Ursachenkomplex von Tannenschädigung und Tannensterben. [Emissions as a set of causes of damage to and dying of silver firs]. Allgemeine Forstzeitschrift 48: 87-95. [in Germany].
8. Eling W., Bretschneider M., Schwarzfischer C. 1999. Zuwchsdepression an Tannen durch Schwefel-Emissionen. [The increment reduction of silver firs caused with emissions of sulphur]. Allgemeine Forstzeitschrift 54: 896-898. [in Germany].
9. Feliksik E. 1991. Badania wrażliwości ważniejszych gatunków drzew leśnych na zanieczyszczenia przemysłowe. [Research on the sensitivity of major species of forest trees to industrial pollution]. Zesz. Nauk. AR w Krakowie 254, Leśnictwo 20: 353-374. [in Polish].
10. Feliksik E., Wilczyński S. 1997. Klimatyczne uwarunkowania przyrostów kambialnych jedlicy zielonej (*Pseudotsuga menziesii* Franco) z wybranych stanowisk w Polsce. [Climatological conditions of the Douglas fir (*Pseudotsuga menziesii* Franco) radial increments from selected sites in Poland]. Acta Agr. Silv. ser. Silv. 35: 3-16. [in Polish].
11. Feliksik E., Wilczyński S. 2000. Wpływ warunków klimatycznych na przyrost grubości jedlicy zielonej (*Pseudotsuga menziesii* Franco) z Beskidu Średniego. [The influence of climatic conditions on the increment width of the Douglas fir (*Pseudotsuga menziesii* Franco) from the Beskid Średni Mountains]. Probl. Zagosp. Ziem Gór. 46, PAN: 87-96. [in Polish].
12. Feliksik E., Wilczyński S. 2002. The climatological signal in tree-rings of Douglas fir (*Pseudotsuga menziesii* Franco) from the Sudety Mts. Acta Agr. Silv. Ser. Silv. 40: 14-23.
13. Feliksik E., Wilczyński S. 2003. Dendroclimatological characterization of Douglas fir (*Pseudotsuga menziesii* Franco) from the Wielkopolska region. EJPAU 6, Issue 1.
14. Fritts H.C. 1976. Tree-Rings and Climate. Acad. Press, London.
15. Jaworski A. 1982. Fir regression in Polish Mountain areas. Eur. J. For. Pathol. 12, 3: 143-149.
16. Kenk G., Kremer D.B., Gallus M. 1984. Jahrring- und zuwachsanalytische Untersuchungen in erkrankten Tannenbeständen des Landes Baden-Württemberg. [Studies of tree-rings and increment growth of damaged silver fir stands in Baden-Württemberg]. Mitt. Forstl. Versuchs- und Forschungsanst. Baden-Württemberg 112: 1-38. [in Germany].
17. Molski B. 1987. Fir and pine phloem and wood growth retardation due to air pollution. (In:) Kairiukstis L., Nilson S., Straszak A. (eds.) Forest decline and reproduction: Regional and global consequences. Proceedings of the workshop held in Krakow, Poland: 115-124.
18. Molski B., Głębicki K., Dmuchowski W. 1987. Data management computer system of air pollution impact on forests used in the botanical garden of the Polish Academy of Sciences and its relation to existing systems in Poland. (In:) Kairiukstis L., Nilson S., Straszak A. (eds.) Forest decline and reproduction: Regional and global consequences. Proceedings of the workshop held in Krakow, Poland: 45-52.
19. Nilson S. 1987. State of the art report on the extent of forest decline attributed to air pollutants in Europe – fall 1986. (In:) Kairiukstis L., Nilson S., Straszak A. (eds.) Forest decline and reproduction: Regional and global consequences. Proceedings of the workshop held in Krakow, Poland: 409-418.
20. Pollanschütz J. 1987. Effects of air pollutants on forest growth. (In:) Kairiukstis L., Nilson S., Straszak A. (eds.) Forest decline and reproduction: Regional and global consequences. Proceedings of the workshop held in Krakow, Poland: 125-128.
21. Schweingruber F.H. 1986. Abrupt growth changes in conifers. IAWA-Bull. 7: 277-283.
22. Zawada J. 1980. Zwiększona zawartość siarki w igłach jako przyczyna regresji jodły. (W:) Problem ustępowania jodły w Karpatach. [Increased content of sulphur in needles as a cause of the regression of silver fir. (In:) The problem of fir regression in the Carpathians]. Konf. Nauk., Kraków, PTL. [in Polish].

Edward Feliksik, Sławomir Wilczyński
Department of Forest Climatology
Cracow University of Agriculture
29 Listopada 46, 31-425 Cracow
phone: (48) (0 prefix 12) 6225141, 6225143
e-mail: rlfeliks@cyf-kr.edu.pl; rlwilczy@cyf-kr.edu.pl

Responses to this article, comments are invited and should be submitted within three months of the publication of the article. If accepted for publication, they will be published in the chapter headed 'Discussions' in each series and hyperlinked to the article.