The Last Hundred Years' Dendroecology of Scots Pine (*Pinus sylvestris* L.) on a Baltic Bog in Northern Poland: Human Impact and Hydrological Changes

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Abstract

The study was aimed at determining age of the trees growing on the cupola of the Stążki raised bog, at elucidating anthropogenic influences on the water level in the bog, and at exploring effects of climatic factors on the Scots pine tree-ring growth. Samples were collected, with Pressler's bores, from 22 Scots pines and from a single downy birch. Tree-ring widths, measured to 0.01 mm, were used to compile – based on the classic dating methods – 143-year-long (1862-2004) ST chronologies. The mean annual ring growth was found to amount to 0.87 mm. The chronologies obtained served as a basis with which to analyse signature years and response functions. Dendroclimatological analyses produced no unequivocal and statistically significant results: the signature years and response function analyses failed to identify a dominant factor and to indicate unambiguously a period during which the weather components studied exerted a decisive effect. Because of that, no climatic reconstructions were carried out. The ring growth of the trees examined was found to be primarily affected by changes in the water level, related mainly to anthropogenic activities. The bog evolution (drying-out and Scots pine invasion) was reconstructed with this assumption in mind. A mass appearance of trees on the bog was dated in the last decade of the 19th century. It was assumed to be triggered by draining operations carried out to lower the water level so that peat could be cut. As a result, conditions amenable for the bog surface to be colonised by Scots pine seedlings were created. The data obtained are important from the standpoint of raised bog conservation; they demonstrate that pine forests growing on raised bogs are not always the final stage of succession, but provide evidence of disturbed bog hydrology and serve as an indicator of a perturbed bog ecosystem.

Key words: peatland, Baltic bog, dendrochronology, tree-ring width, *Pinus sylvestris* L., environmental reconstructions

Introduction

Ombrotrophic, dome-bearing raised bogs in Pomerania are remarkable objects of interest for the peatland science. They are located in the continental climate, on the southernmost boundary of cupola-bearing raised bog range in Europe (Jasnowski *et al.* 1968; Kulczyński 1949). The contemporary form of the Baltic bogs is a result of anthropogenic effects (Herbichowa 1998). Most of these bogs have been dehydrated; although some of them have been subjected to peat cutting, the operation was seldom carried out on a large commercial scale. Some of the bogs have retained their natural state, as determined by the process of peat mass accumulation (Tobolski 2003, 2004).

Tree growth on peat bogs depends on the climate and on anthropogenic activities. Peatland forestation may be a final stage of a bog evolution or may be caused by anthropogenic transformation of bog surface by, *e.g.,* peat cutting or surface drainage. Such activities result in lowering of the water level in the peat profile, whereby peat-forming species disappear and disintegration of the peat mass prevails over its accumulation. The oxygenated, top peat layer (actothelm) increases in thickness, thereby rendering the bog surface amenable for colonisation by tree seedlings. Because of the high tolerance to acidity and moisture exhibited by the Scots pine, it is a most frequent dominant of tree stands growing on raised bogs.

Most of the raised bogs in Poland are overgrown by Scots pine stands that show an admixture of birch. It is not clear to what extent dehydration has influenced the succession; mechanisms of tree response to climatic changes have not been elucidated, either. These questions have not been addressed in Poland yet. Tree expansion onto peatland surfaces has been observed also in Canada (Pellerin and Lavoie 2003) and in the Jura Mountains in Europe (Freléchoux *et al.* 2003).

Knowledge on the origin of Scots pine woods is of a key importance for active protection of Baltic bogs. In this context, dendroecological research provides information on causes of hydrological perturbations and makes it possible to date the onset of tree expansion. Knowledge of past events in ecosystems is indispensable for understanding their functioning and should be utilised whenever peatland conservation plans are developed and relevant methods selected (Willis *et al.* 2007; Willis and Birks 2006).

Dendrochronological analysis provides information on tree age and tree-ring width. That information serves as a groundwork for concluding, within a period covered by a chronology analysed, on climatic and other (*e.g.,* changes in hydrology or habitat fertility, increased air pollution, insect gradation) effects on tree-ring width.

This study was aimed at determining age of the trees growing on the dome of a raised bog and at exploring effects of man-made water level changes and climate on the Scots pine tree-ring width.

Area of study

The study was carried out in the Stążki Baltic bog, located in northern Poland ($54^{o}25'$ 27.7"N; $18^{o}05'$ 00.2"E) ca 35 km south of the Baltic Sea coast (Figure 1). The site is located on a morainic plateau (214.6 m highest elevation), in the Kashubian Lakeland, 13 km NW of Kartuzy. The plateau is bordered from the south and from the west by River Łeba, River Dębica discharging into the Łeba near Staniszewo and bordering the pleateau from the east. The north-western ribbon depression is filled with waters of the lakes Miłoszewskie and Lewinko; the lakes give rise to Stream Młynówka that discharges, near the village of Bolszewo, into Stream Gościna that empties into River Reda west of Wejherowo. The morainic plateau is an important watershed. It is slightly undulating and features numerous drainless depressions filled with *Sphagnum* mires. Many of them have been destroyed due to unregulated peat cutting, and transformed into meadows or heathlands (Szafrański 1961).

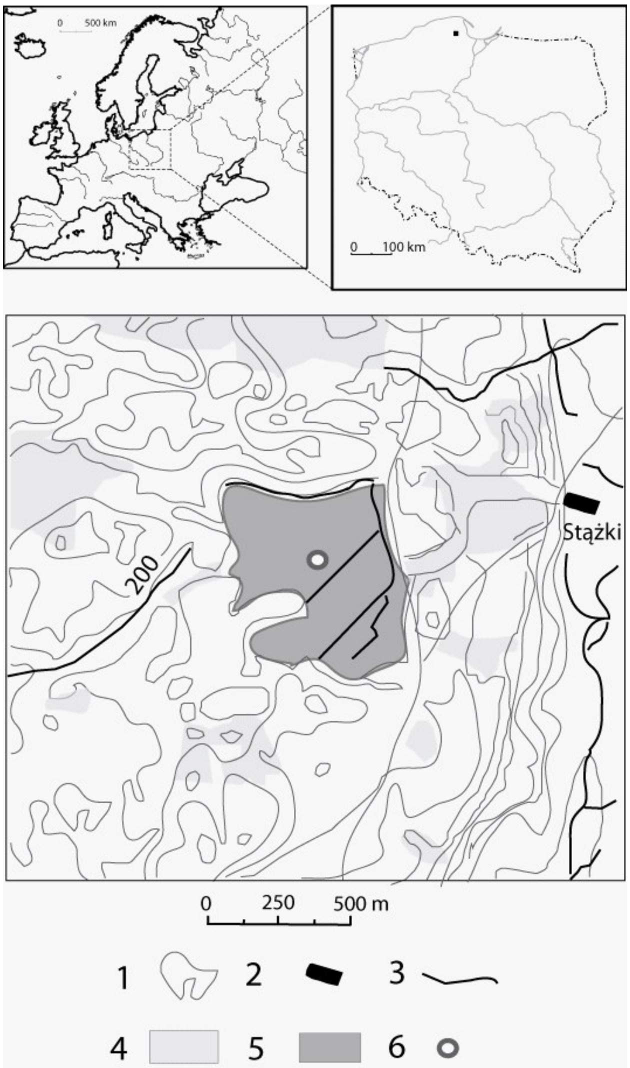

Figure 1. The setting of the study site. Legend: 1, contour lines; 2, village; 3, ditch and stream; forest; 4, Stążki bog; 6, coring site

Methods of study

In July 2005, Pressler's bore samples were collected from 22 Scots pines and from a single downy birch growing on the dome of the Stążki raised bog. The bore was applied at the height of 1.3 m from the bog surface. Tree-ring width was measured at the University of Szczecin's Laboratory of Climatology and Marine Meteorology. The measurements were performed with dendrochronological research equipment using the DendroMeter software (Mindur 2000). Each measurement, taken to 0.01 mm, was performed twice, from the part closest to the heart wood towards the bark. A total of 2,856 tree-ring width measurements were performed. In addition, the presence of very narrow rings and those with very wide or diverse late wood was recorded. Once high values of statistical indicators (linear correlation coefficient k, values of t, and coefficient of Gl) were obtained, and following the analysis of dendrochronological curves, effected with the TRRAD module of the TREE RINGS package (Krawczyk 1995, Krawczyk and Krąpiec 1995 and DendroGragh, Walanus 2001), results of the two measurements were averaged to obtain a growth sequence for the tree examined. Subsequently, classical dendrochronological techniques were used to compile a local chronology which was tested with the COFECHA software (DPL package; Holmes 1983, 1994). The chronology was indexed (ARSTAN module of the DPL package; Holmes 1983, 1994) to highlight annual variability in tree-ring width and to eliminate long-term trends (*e.g.,* a centennial trend). The compiled chronology served as a basis with which to carry out dendroclimatological analyses of signature years and response functions.

A signature year is a year in which the tree-ring width of most trees in a population is clearly different (wider or narrower) than that found for neighbouring years (Huber and Giertz-Siebenlist 1969, cf. Kaennel and Schweingruber 1995, Meyer 1997-1998). Signature years are an important component of dendrochronological dating and play a significant part in identifying and eliminating errors in dating of individual samples. Anomalies in ring growth curves emerge during years with favourable or unfavourable external factors, meteorological conditions being most important and variable among them. The signature year analysis was conducted with the aid of the TCS software (Walanus 2002); signature years were determined from a minimum of 10 trees, the minimum concordance threshold being set at 90%.

The climate vs. tree-ring width relationship was explored also with the response function analysis (Fritts 1976, Fritts and Xiangding 1986, Blasing *et al.* 1984, Cook and Kairiukstis 1992, Zielski and Krąpiec 2004). The response function can be calculated with the DPL software package (RESPO module; Holmes 1983, 1994). The procedure involved multiple regression analysis with mean monthly air temperature and monthly sum of precipitation as independent variables. RESPO calculated the linear coefficient of correlation (k), the coefficient of multiple correlations (r), and the multiple regression coefficient of determination (r^2). Effects of climatic factors on tree-ring width sequence were studied with the response function analysis for 16-month-long periods (from June of the previous year to September of the current year). Positive coefficients of linear (k) and multiple (r) correlations correspond to a simultaneous increase in the tree-ring width and the meteorological factor analysed. Negative values of k and r evidence a decrease in the values of meteorological components in parallel with increasing tree-ring width. Value of r^2 determines the strength of the relationship between the climatic factors and the tree-ring width.

Climatic data

Dendroclimatological analyses involved meteorological data collected over 1948-2002 (55 years) by the Institute of Meteorology and Water Management (IMWM) station in Lębork, 26 km NW of the Stążki bog. According to division of Poland into climatic regions carried out by Gumiński in 1948, the area of study is located in the Pomeranian climatic region (IV) (Kondracki 1988), with the mean annual temperature of +7.7^{0}C (range: +6.0 to +9.1^{0}C), January as the coldest month with the mean temperature of –1.2^{0}C (range: -9.4 to +4.3^{0}C), and July as the warmest month with the mean temperature of +16.8^{0}C (from +14.2 to +20.4^{0}C). The growing period is shorter than 200 days. The multi-annual mean sum of precipitation for Lębork is 690 mm; it drops to 422 mm in extremely dry years (*e.g.*, 1964) and increases to 956 mm in extremely wet years (*e.g.*, 1998). February and March are the driest months (36 mm precipitation), July being the wettest one (with an average precipitation of 86 mm). The snow cover persists for up to 75 days, but due to the advection of polar-marine air masses, the temporal and spatial distributions of the snow cover are very variable.

Chronology

The ST chronology was compiled for the Scots pines growing on the St¹æki bog. The chronology is made up of 13 individual dendrograms (selected from a total of 28 tree-ring width curves by the classic dendrochronological dating procedure) representing the period 1862-2004 (143 years). The year 2005 was not included into the chronology because the growing period of that year was in progress during sampling, whereby the entire ring width accretion could not be recorded. The mean tree-ring width was found to amount to 0.87 mm. The shortest growth curve, SS5, was 29 years long, the longest (SS14) being equal in duration to the ST chronology (143 years) (Figures 2 and 3). The number of rings in a tree cannot be equalled with the age of that tree (although the rings were counted from the heart wood), because the samples were collected 1.3 m from the bog surface, so the actual age was assumed to be equal to the number of rings plus 7-10 years. There is a large age difference (38 years) between the oldest tree sampled (SS14), its age estimated at about 150 years, and younger (*e.g.*, SS9) trees. The chronology shows a number of years (1920, 1940, 1954, 1964, 1969, 1976, 1987, 1993, 2000, and 2003) with tree-ring widths lower than the mean; there are also years marked by peaks on the dendrograms (1932, 1939, 1953, 1958, 1967, 1972, 1985, 1991, and 1997) (Fig. 2). The downy birch individual sampled was about 40 years old (the ring count amounted to 30).

The chronology compiled served as a basis for dendroclimatological analyses and environmental reconstructions.

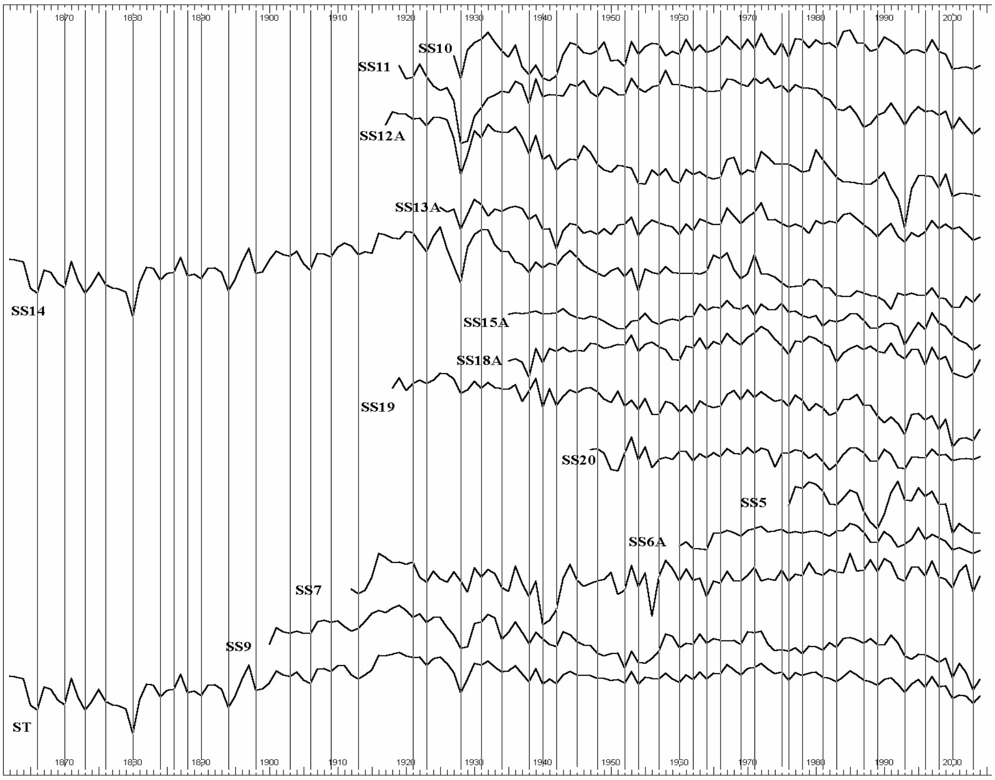

Figure 2. Individual dendrochronological curves forming the Scots pine chronology (ST)

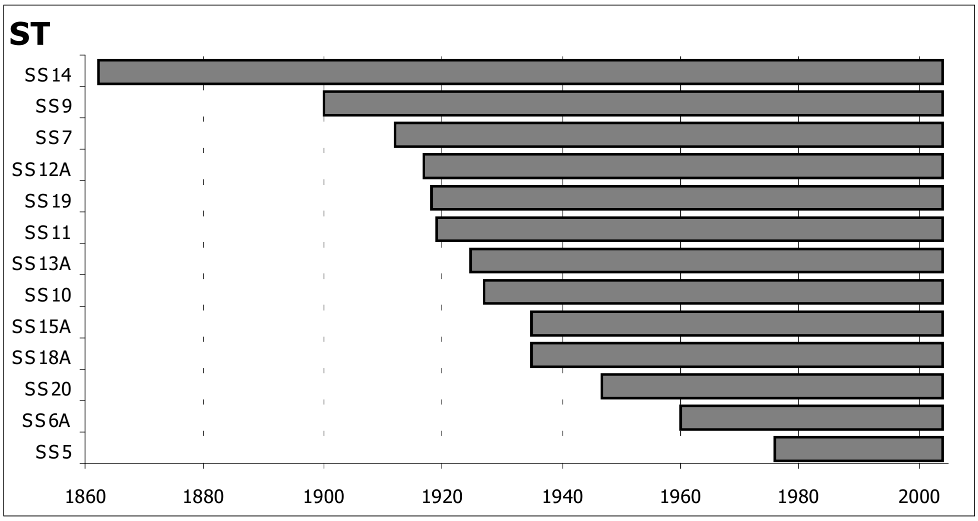

Figure 3. Dendrochronological dating of growth sequences of *Pinus sylvestris* L. samples forming the ST chronology

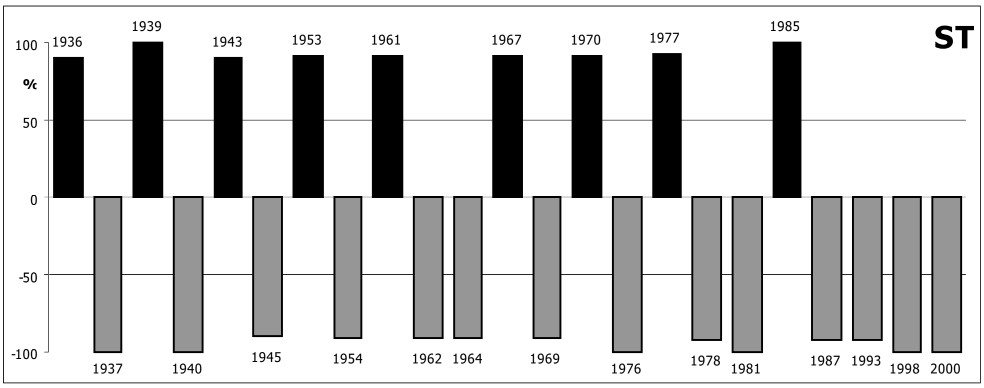

Figure 4. Signature years (positive years marked black; negative years marked grey) in the Scots ST pine chronology

Results

Analysis of signature years

Analysis of signature years revealed 23 years in which more than 90% of the trees showed an identical growth trend (14 years with a negative trend and 9 years with a positive one) (Figure 4). As there are no detailed meteorological data for the period prior to 1948 at the Lębork station, no weather analysis could be carried out for the following signature years: 1936, 1937, 1939, 1940, 1943, and 1945. In the remaining years entered into calculations, analysis of relationships between the tree-ring width on the one hand and the temperature and sum of precipitation on the other produced no unequivocal results. Negative years were present in those periods with a mean annual temperature much lower than the multi-annual mean (*e.g.*, 1987, the coldest year in the period 1948-2002) and in very warm years (*e.g.,* 2000). The temperature history of winter months varied as well: there were years with a very severe and long winter *(e.g.*, 1964) and with a warm winter (*e.g.*, 1993 and 1998). The temperature in spring and summer could be higher or lower than the mean. The annual sum of precipitation in negative years was found to vary from 422 mm (the driest year during the period of observations) to 956 mm (the maximum annual sum of precipitation). Similarly, the sum of precipitation in spring-summer varied from year to year. Similarly, no significant tree-ring width versus climate relationships were detected in the positive signature years.

Analysis of response function

The coefficient of determination (r^2), which reflects the strength of association between air temperature and precipitation on the one hand and the tree-ring width on the other, was high (62%). However, the correlation and regression coefficients were rather low. With respect to temperature, most of the coefficients (except those for March) were negative, which means that low temperature in the preceding year of growth (particularly in July and September) as well as in spring of the current growth season produced a positive effect in the tree-ring width (Figure 5). Most important was the temperature of September of the preceding year: the higher the mean temperature of September, the poorer tree-ring width growth in the following season (a relationship discernible also in the signature year analysis). Correlation and regression coefficients of the relationships involving atmospheric precipitation were mostly positive. Two seasons produced particularly distinct relationships: autumn (September and October) of the preceding year and spring (March-May) of the current one (Figure 5). High precipitation in those periods enhanced the formation of wide tree rings.

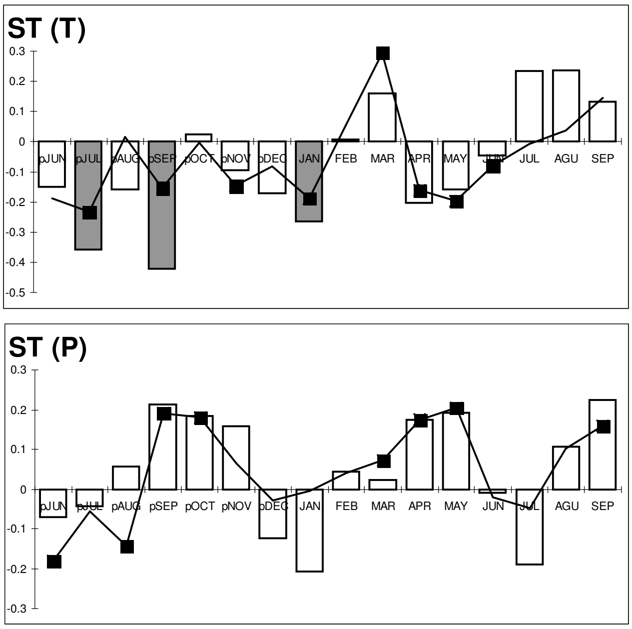

Figure 5. Results of response function analysis for: T, air temperature; P, precipitation. Bars depict correlation coefficients; lines show regression coefficients; significant values are indicated by grey bars and solid black squares. Coefficient of determination: $r^2 = 62\%$

Environmental reconstructions

The tree-ring width vs. climate relationships produced by the dendrochronological analysis of the Scots pine growing on the Stążki bog were not useful in climate reconstructions. The analyses of signature years and response functions failed to identify a dominant factor and to unequivocally determine the period during which the weather components considered were of a key importance for the relationships analysed.

Trees growing on raised bogs with very high ground water levels are less sensitive to weather conditions, compared to trees growing on mineral soils. Due to their shallow root system, the trees of the first group respond to variations in the ground water level which, in drained bogs, is primarily dependent on anthropogenic activities. The lack of ground water level data for the Stążki bog makes it impossible to analyse the water level vs. tree-ring width relationship in detail. It was, however, assumed that a drop in the ground water level (bog drainage) would correspond to a positive phase of the tree stand growth, while a rise in the ground water level would result in inundation of the root system (thus restricting oxygen uptake) and would correspond to a negative growth phase.

The reconstruction was based on the analysis of the chronology obtained as well as on the 9-yr moving average of the chronology, the latter allowing to identify periods of varying growth trends (Figure 6).

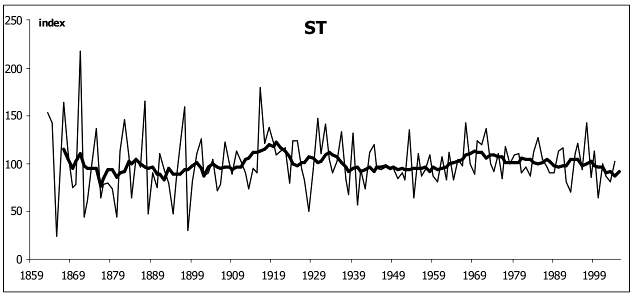

Figure 6. Indexed local chronology for the Scots pine at Stążki (black line) and the 9-year moving average (bold black line)

The first solitary individuals of *Pinus sylvestris* L. appeared on the Stążki bog in the middle of the 19th century (*e.g.*, the tree denoted SS14), which could have resulted from an initial attempt at changing the bog hydrology. A mass appearance of the Scots pine occurred in the last decade of the 19th century as a result of drainage, *i.e.*, lowering of the ground water level in aid of peat digging, which resulted in the conditions amenable for pine seedlings to colonise the bog surface. The 9-yr moving average showed a growing trend of the pine chronology in the years 1910-1920 and 1929-1937, which indicates the presence of a population of young trees with a high growth potential, developing on the bog. In subsequent years, both the chronology and the 9-yr moving average became less variable, evidencing hydrological stability. It was only in the early seventies of the 20th century that a small increasing trend of the growth curves was observed, evidencing bog draining processes to have been resumed. The last 30 years of the chronology show a slight reduction of the tree-ring growth and a negative trend of the 9-yr moving average, indicating that the drainage ditches were being overgrown and the hydrological conditions were reverting to/regenerating the original status as a result of the cessation of anthropogenic activities.

Discussion and summary of the results

The Scots pines growing on raised bogs are very variable, but – as a rule – are smaller, have shorter needles, twisted trunks, and irregularly shaped canopies, compared to the pine growing elsewhere (Roosaluste 1982). The first are the so-called famine tree forms, resulting from the permanently high ground water level, high water acidity, and the lack of minerals in the soil substrate (Freléchoux *et al.* 2003, Freléchoux *et al.* 2000, Läänelaid 1982, Linderholm *et al.* 2002). Those trees pursue an ecological strategy which is different than that adopted by trees growing on minerals soils: their growth is very slow and the life span much longer (Freléchoux *et al.* 2003).

Numerous authors associated the presence of Scots pine under such unfavourable habitat conditions with bog overdrying, caused by natural processes or – particularly frequently during the last 200 years – by anthropogenic effects (Freléchoux *et al.* 2003, Freléchoux *et al.* 2000, Jasnowska and Jasnowski 1981, Jasnowski *et al.* 1968, Sarkkola *et al.* 2004). Drainage, most often associated with peat digging, results in overdrying of the upper layers of the peatland, arrested swamping process and peat accumulation, and marshy soil formation (Jasnowski *et al.* 1968). One to three decades after draining, the habitats transformed that way become colonised by the Scots pine, a pioneering species (Freléchoux *et al.* 2003, Sarkkola *et al.* 2004).

Annual width increments of the Scots pine growing on raised bogs are small; they show strong growth depressions and frequently miss rings (Cedro in press, Obidziński *et al.* in press, Linderholm *et al.* 2002). The tree-ring width vs. climate relationships are weaker and equivocal, compared to those revealed by trees growing on mineral soils (Läänelaid 1982, Linderholm 2001, Linderholm *et al.* 2003, Obidziński *et al.* in press). The major factor affecting the tree-ring width is a change in the ground water level, the change being driven by climate when under normal conditions and by anthropogenic activities when on drained bogs (Freléchoux *et al.* 2003, Linderholm 2001, Linderholm *et al.* 2003, Obidziński *et al.* in press).

Our results cast a new light on the history of Pomeranian raised bogs and show the tree stand on the Stążki bog cupola to be primarily anthropogenic in origin. Even if the Scots pine had been present there in the past, their origins would have been different, primarily related to climate changes. Drainage of and peat digging in the Stążki bog resulted in the Scots pine expansion. Global warming cannot be ruled out as a factor contributing to the lowering of the ground water level in the bog, but anthropogenic activities obliterated a potential signature of the climate.

The data obtained are important for raised bog conservation and demonstrate that pine forests growing on raised bogs are not always the final stage of succession, but may be evidence of a change in hydrological conditions of the bog and of a disturbance in the peat bog ecosystem. Our current research (Lamentowicz *et al.* in prep) is aimed at unravelling, with the aid of stable isotopes and biotic proxies (pollen, plant macroremants, and testate amoebae), relationships between dendroecological record and peat accumulation rate. Stratigraphic data will help us to pinpoint, with a high accuracy, the moment at which the disturbance of the bog began, and to address the question of the history of forests on the bog itself and in its vicinity.

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References

Blasing, T.J., Solomon, A.M. and Duvick, D.N. 1984. Response functions revisited. *Tree-Ring Bulletin* 44: 1-15.

Cook, E.R. and Kairiukstis, A. 1992. Methods of dendrochronology. *Kluwer Academic Publishers.*

Cedro, A. 2004. Zmiany klimatyczne na Pomorzu Zachodnim w świetle analizy sekwencji przyrostów rocznych sosny zwyczajnej, daglezji zielonej i rodzimych gatunków dębów [Climatic changes in Western Pomerania in the light of analysis of tree-ring sequences of Scots Pine, Douglas Fir and native species of Oak]. Oficyna In Plus, p. 30-36 (In Polish, with English summary).

Cedro, A. in press. Dendrochronologiczna analiza sosny zwyczajnej (*Pinus sylvestris* L.) występującej na obszarze torfowiska „Białe Ługi" [Dendrochronology analysis of Scots pine (*Pinus sylvestris* L.) growing on "Białe Ługi" peatbog], (In Polish).

Fritts, H.C. 1976. Tree rings and climate. *Academic Press,* London-New York-San Francisco.

Fritts, H.C. and Xiangding, W. 1986. A comparison between response-function analysis and other regression techniques. *Tree-Ring Bulletin,* 46: 31-46.

Freléchoux, F., Buttler, A., Schweingruber, F.H. and Gobat J. 2000. Stand structure, invasion and growth dynamic of bog pine (*Pinus uncinata* var. *rotundata*) in relation to peat cutting and drainage in the Jura Mountains, Switzerland. *Can. J. For. Res.,* 30: 1114-1126.

Freléchoux, F., Buttler, A., Gillet, F., Gobat, J. M. and Schweingruber, F. H. 2003. Succession from bog pine (*Pinus uncinata* var. *rotundata*) to Norway spruce (*Picea abies*) stands in relation to anthropic factors in Les Saignolis bog, Jura Mountains, Switzerland. *Ann. For. Sci.,* 60: 347–356.

Herbichowa, M. 1998. *Ekologiczne studium rozwoju torfowisk wysokich właściwych na przykładzie wybranych obiektów z środkowej części Pobrzeża Bałtyckiego* [An ecological study on the development of raised bogs proper, as exemplified by selected bogs in the central part of the Baltic coast]. Gdańsk: Wydawnictwo Uniwersytetu Gdańskiego (In Polish).

Holmes, R.J. 1983. Computer-assisted quality control in tree-ring dating and measurement. *Tree-Ring Bull.* 43: 69-78.

Holmes, R.J. 1994. Dendrochronology Program Library. Users Manual. University of Arizona, Tucson.

Jasnowski, M., Jasnowska, J. and Markowski S. 1968. Gin¹ce torfowiska wysokie i przejściowe w pasie nadbałtyckim Polski [Vanishing raised and transition peat bogs in the Baltic region of Poland]. *Ochrona Przyrody* 33: 69-124 (In Polish, with English summary).

Jasnowska, J. and Jasnowski, M. 1981. Kotłowe torfowiska mszarne na Pojezierzu Bytowskim [Oligotrophic basin bogs in Lake District of Bytów]. Zeszyty Naukowe Akademii Rolniczej we Wrocławiu, Rolnictwo XXXVIII/134: 13-37 (In Polish, with English summary).

Kaennel, M. and Schweingruber, F.H. 1995. Multilingual Glossary of Dendrochronology. WSL FNP, Haupt.

Kondracki, J. 1988. Geografia fizyczna polski [Geography of Poland]. PWN, Warszawa (In Polish).

Krawczyk, A. 1995. Program komputerowy TREE RINGS [Computer software TREE RINGS]. Kraków 36 (In Polish).

Krawczyk, A. and Krąpiec, M. 1995. Dendrochronologiczna baza danych. [Dendrochronological data base. In: Proceedings of the Polish Conference on Computer Assistance to Scientific Research] W: Materiały II Krajowej Konferencji: Komputerowe wspomaganie badań naukowych, Wrocław: p. 247-252 (In Polish).

Kulczyński, S. 1949. Peatbogs of Polesie. *Mem. Acad. Pol. Sci. Lett. Cl. Sci. Math. Nat.*

Pawlaczyk, P., Herbichowa, M. and Stańko, R. 2005. *Ochrona torfowisk bałtyckich* [Protection of Baltic peatbogs]. Świebodzin: Wydawnictwo Klubu Przyrodników (In Polish).

Lamentowicz, M., Cedro, A., Gałka, M., Goslar, T., Miotk-Szpiganowicz, G., Mitchell E.M. and Pawlyta, J. in prep. Last millennium multi-proxy record from a Baltic bog in northern Poland.

Läänelaid, A. 1982. Radial increment of bog pines and climatic changes. Peatland ecosystems, Estonian contributions to the international biological programme, No. 9: 135-148.

Linderholm, H.W. 2001. Climatic influence on Scots pine growth on dry and wet soils in the Central Scandinavian Mountains, interpreted from tree ring widths. *Silva Fennica,* 35(4): 415-424.

Linderrholm, H.W., Moberg, A. and Grudd, H. 2002. Peatland pines as climate indicators? A regional comparison of the climatic influence on Scots pine growth in Sweden. *Can. J. For. Res.* 32: 1400-1410.

Linderholm, H. W., Solberg, B. O. and Lindholm, M. 2003. Tree-ring records from central Fennoscandia: the relationship between tree growth and climate along a west–east transect. *The Holocene,* 13, 887–895.

Meyer, F.D. 1997-1998. Pointer years analysis in dendrochronology: a comparison of methods. *Dendrochronologia,* 16-17: 193-204.

Mindur, B. 2000. Dendrometer 1,0 (Dendrometer 1.0 Software). Kraków.

Obidziński, A., Kloss, M. and Cedro A. in press. Is spontaneous recreation of raised mires vegetation possible? A case study of the "Czarne Bagno" mire in Bystrzyckie Hills (South Poland).

Pellerin, S. and Lavoie, C. 2003. Recent expansion of jack pine in peatlands of southeastern Québec: A paleoecological study. *Ecoscience,* 10: 247-257.

Roosaluste, E. 1982. Growth forms of the Scotch pine growing in bogs. Peatland ecosystems, Estonian contributions to the international biological programme, No. 9: 121-126.

Sarkkola, S., Hokka, H. and Penttila, T. 2004. Natural development of stand structure in peatland Scots pine following drainage: Results based on long-term monitoring of permanent sample plots. *Silva Fennica* 38, 405-412.

Szafrański, F. 1961. Polodowcowa historia lasów obszaru na północ od Wysoczyzny Staniszewskiej [Post-glacial his-

tory of forests north of the Staniszewska Upland]. *Bad. Fizj. Pol. Zach.,* 8: p. 91-131 (In Polish).
Tobolski, K. 2003. *Torfowiska, na przykładzie Ziemi Świeckiej* [Peatbogs, as exemplified by the region of Świecie]. Świecie: Towarzystwo Przyjaciół Dolnej Wisły (In Polish).
Tobolski, K. 2004. Kryterium geologiczne w badaniach zbiorników akumulacji biogenicznej [A geological criterion in studies on biogenic accumulation reservoirs]. *Regionalny Monitoring Środowiska Przyrodniczego*: Kieleckie Towarzystwo Naukowe, Kielce, p. 119-126 (In Polish).
Walanus, A. 2001. DendroGraph – program druku krzywych grubości słojów przyrostów rocznych. Instrukcja obsługi programu DendroGraph [DendroGraph – a software for plotting tree ring width curves. DendroGraph Software User's Manual]. Kraków (In Polish).
Walanus, A. 2002. Instrukcja obsługi programu TCS. Program TCS do obliczania lat wskaźnikowych [User's manual of TCS software. TCS software for calculation of signature years]. Kraków (In Polish).
Willis, K.J., Araujo, M.B., Bennett, K.D., Figueroa-Rangel, B., Froyd, C.A. and Myers, N. 2007. How can a knowledge of the past help to conserve the future? Biodiversity conservation and the relevance of long-term ecological studies. *Phil. Trans. R. Soc.* 362: p. 175-186.
Willis, K.J. and Birks, H.J.B. 2006. What Is Natural? The Need for a Long-Term Perspective in Biodiversity Conservation. *Science,* 314: p. 1261-1265.
Zielski, A. and Krąpiec, M. 2004. Dendrochronologia [Dendrochronology]. Państwowe Wydawnictwo Naukowe, Warszawa, p. 158-176 (In Polish).

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ДЕНДРОЭКОЛОГИЯ СОСНЫ ОБЫКНОВЕННОЙ НА ВЕРХОВОМ ТОРФЯНИКЕ СЕВЕРНОЙ ПОЛЬШИ ЗА ПОСЛЕДНИЕ 100 ЛЕТ: ВЛИЯНИЕ ЧЕЛОВЕКА И ГИДРОЛОГИЧЕСКИЕ ИЗМЕНЕНИЯ

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Резюме

С 22-ух сосен, произрастающих на верховом торфянике «Стожки», взяты керны с помощью бурава Пресслера. Ширина годовых приростов измерялась с точностью до 0,01 мм, после чего, используя классические дендрохронологические методы, была построена хронология, являющаяся основанием для дендроклиматических анализов: реперных лет и функции отклика. Хронология, обозначенная символом ST, насчитывает 143 года (1862-2004), средняя ширина годового прироста деревьев, входящих в её состав, достигает 0,87 мм. Зависимости «прирост-климат», полученные на основании дендрохронологического анализа сосны, не позволяют однако произвести климатическую реконструкцию. С помощью анализов реперных лет и функции отклика не удалось обнаружить доминирующий фактор и однозначно определить период зависимости для исследуемых элементов погоды (температуры воздуха и атмосферных осадков). Главным фактором, предопределяющим ширину годового прироста, являются изменения уровня грунтовых вод, зависимые преимущественно от деятельности человека. Отдельные деревья появились на торфянике в середине XIX века, тогда как их массовое распространение отмечается в последней декаде XIX века и есть оно результатом проведенной мелиорации и снижения уровня грунтовых вод в связи с разработками торфа, а тем самим возникновения условий, способствующих заселению поверхности торфяника сеянцами сосны. Последние 30 лет хронологии - это небольшое уменьшение ширины годовых приростов и отрицательный тренд скользящей средней, указывающие на зарастание мелиорационных каналов и уровня воды, что является результатом прекращения вмешательства человека.

Ключевые слова: верховой торфяник, дендрохронология, ширина годового прироста, *Pinus sylvestris* L., реконструкция среды