THE DENDROCHRONOLOGICAL SIGNAL OF OAK
(QUERCUS SPP.) IN POLAND*

Key-Words: Dendrochronology, oak, Quercus spp., Poland.
Parole chiave: Dendrocronologia, quercia, Quercus spp., Polonia.

INTRODUCTION

The forest vegetation in Poland since the last glaciation, the so-called Vistulian glaciation, has been reconstructed by pollen analyses (e.g. THOMASCHEWSKI 1933; RALSKA-JASIEWICZOWA 1968; LATALOWA 1982). Whereas in the Preboreal, birch-pine forests prevailed, a further temperature increase enabled the propagation of broadleaved trees, among them oak. The first oak pollen grains could be detected in deposits of the Boreal, i.e. some 8000 years ago. The warming during the Atlanticum resulted in the predominance of deciduous forests so that in some places pine was displaced by oak even on poor sandy soils (LATALOWA 1982). During this classic period the upper treeline in the Carpathian and Sudeten Mountains was 400 m higher than at present (TYCZYNSSKA 1957). As early as during the transition from the Atlanticum to the Subboreal, Neolithic man began to influence the forests. This is apparent from the decrease of broadleaved tree pollen grains in areas with fertile soils as a consequence of the clearing and burning of forest areas for agriculture (RALSKA-JASIEWICZOWA 1968). From then onwards forest history is closely connected with the history of human settlement. Since the

* We dedicate this publication to Professor Dr. Dr.h.c. mult. Walter Liese, Institute for Wood Biology, University of Hamburg, on the occasion of his 65th birthday (31 January, 1991).
early middle ages, human activities have had the most important impact on the composition and distribution of the forests. The forests have been used increasingly as a source of energy and building material. For example, for establishing the bulwark in Kruszwica 25,000 m$^3$ of timber were used, 80% of it was oak; this means the clearance of 73-85 ha of forest land. In addition, since the 13th century wood has become an increasingly important raw material for the far-distance trade. Its history, quantity and extent has been described, e.g. by Wazny and Eckstein (1987). As a result of this huge timber trade, one must expect to find quantities of wood from the Southern Baltic in various objects in western and southwestern Europe (Bonde 1991; Wazny 1991).

Profound dendrochronological studies were started in Poland only after the Second World War. They dealt primarily with coniferous tree species and with dendroclimatological questions (e.g. Zinkiewicz 1946; Ermich 1953, 1960, 1963). Later these studies were continued by Bednarz (1976, 1984) and Feliksik (1972, 1986). But until the 1980ies there was no systematic approach in Poland to establish long-term continuous tree-ring series as dating tools.

Therefore, in 1983 a common project was started by the Academy of Fine Arts in Warsaw and by the Institute for Wood Biology of the University of Hamburg in order to study living oak trees from all over Poland to obtain the dominant growth factors and to eventually structure the country, according to the correlations between sites, into dendrochronologically different areas.

**Study area**

Poland is part of Central Europe with an east-west extension of 690 km and a north-south extension of 650 km. It is a typical low-land with an average elevation of 173 m a.s.l.; 91.3% of its total area is lower than 300 m and only 2.9% is higher than 500 m (Kondracki 1988). Its relief is determined by various plains and hill chains, all running latitudinally. Poland is dominated by two large river systems, Vistula and Oder, and their prevailing direction is south-north; 99.7% of the country is drained to the Baltic Sea. Regarding climate, Poland takes a transitional position with both oceanic as well as continental climatic elements. The annual mean temperature is 6°C to 8.5°C (the high mountains excluded). In the coldest month, January, the temperature decreases from −0.9°C in
the coastal region to $-5^\circ C$ in the northeast of the country. The warmest month, July, is $16.5^\circ C$ to $19^\circ C$ warm. During the year the isotherms change their direction from meridional in winter to latitudinal in summer (Wiszniewski, Chelchowski 1975). The annual sum of precipitation is 500 to 750 mm (the high mountains excluded). The annual variability of the precipitation from year to year can be as high as 100%. From west to east the maritime climatic components decrease and the continental components increase. The influence of the Baltic Sea from the north extends southwards into the interior through the wide valleys of the Vistula and Oder rivers. Due to these climatic differences, the length of the vegetation period is 180 days in the north-east and 220 days in the south-west. In Poland several tree species have reached the limit of their natural distribution: for beech, sessile oak, sycamore maple and fir it is the north-east border, for larch and large-leaved lime the northern border; spruce has here both its southern as well as northern border.

**Material and Methods**

The tree sites of living oaks are distributed all over the country and represent various geographical as well as climatic areas (Fig. 1). Altogether 269 oak trees from 16 sites were sampled. The climatic data, mean monthly temperature and monthly sum of precipitation were obtained from 26 climatic stations; many of them had missing values which had to be estimated from neighbouring stations and inserted to complete the climatic records. These records were then spatially averaged.

The measurement of the tree-ring widths and the basic data processing were performed according to the acknowledged dendrochronological principles (e.g. Fritts 1987; Schweingruber 1983). The data were checked using the ‘Catras’ program (Aniol 1983) and the similarities between the tree-ring series were assessed by two algorithms, t-value (Baillie, Pilcher 1973) and sign-test (Eckstein, Bauch 1969). For further data checking the ‘Cofecha’ program (Holmes 1983) was used. The tree-ring series of each site were autoregressively transformed by the ‘Arstan’ program (Cook, Holmes 1986) and assembled into site chronologies. These standardized chronologies were free of persistence. They were used for cross-correlations and principal component analyses. Finally, climate-growth relationships were calculated using regionally averaged
chronologies and the corresponding climatic data by means of the 'Respo' program (LOUGH, unpubl.).

RESULTS AND DISCUSSION

Altogether 269 living oak trees within a network of 16 sites all over Poland were investigated. All 16 site chronologies and their statistical qualities have been summarized for the raw data as well as for the autoregressively standardized versions (Tab. 1). All further considerations are based on the standardized chronologies.

The relationships between all 16 site chronologies are shown in a correlation matrix (Tab. 2). It appears that the similarity between the chronologies is higher in latitudinal direction, above all in the north
## Table 1 - Statistical features of the 16 Polish oak chronologies before and after standardization.

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Tab. 2 - Correlation matrix for the 16 Polish oak chronologies between 1883 and 1979.
Fig. 2 - Distribution of the 16 Polish oak chronologies with regard to the 1st and 2nd eigenvectors; □ sites in the Polish interior, ▼ sites in the coastal area.
of Poland. A central location among all sites is Torún [7], this chronology correlates well with most of the other chronologies (mean \( r = 0.33 \)), even with those in the east of Poland [10] \( r = 0.31 \).

The result of the principal component analysis of the variation of all chronologies (Fig. 2) supports the idea that Poland can be split into at least two dendrochronological areas. The first eigenvector (x-axis) explains the variance common to all chronologies. Because there is no grouping at all with regard to the first eigenvector, it is likely that the tree-ring widths of all Polish oaks contain a large component of common variance, which is impressed by some transregional influence, presumably climate. However, there is a quite clear grouping of the sites regarding the second eigenvector (y-axis) into the Polish coastal area and the Polish interior (see Fig. 1). The cause behind this split is not so obvious but may also be a climatic one. A main additional factor influencing the similarity between the oaks in different Polish forest is the distance between the sites (Fig. 3).

![Fig. 3 - Correlation-distance diagram of the 16 Polish oak chronologies.](image-url)
3). There is a sufficiently high correlation over distances of about 400 km, it is higher in latitudinal than in meridional direction. In some years the dendrochronological signal reaches far beyond this distance, that is in so-called pointer years (SCHWEINGRUBER et alii 1990). For Poland such country-wide signature years are, e.g. 1800, 1940, and 1952. All three can be explained by climate: 1800 is the year subsequent to the very dry year 1799 (INGLOT 1968); in 1940 an extremely cold winter with subsequently little precipitation prevailed; in 1952 the trees suffered from a preceding dry autumn and winter.

In order to assess how far the signal of the Polish oak chronologies extends outside Poland, 11 Polish site chronologies were
compared with 11 chronologies from various European countries for the period from 1820 to 1950 (Fig. 4):

- Southern Sweden \{ Bartholin, Lund \\
- Denmark \\
- Germany, Schleswig-Holstein \{ Eckstein, Hamburg \\
- Germany, Hamburg \\
- Germany, North Sea Coast \\
- Germany, hilly area along the upper Weser river \{ Leuschner, Göttingen \\
- Germany, area north of the Harz mountains \\
- Germany, south-western part, Hollstein, Trier \\
- Germany, Spessart mountains, Dujesiefken, Hamburg \\
- Lithuania, Balneriskio \{ Kairaitis, Vilnius \\
- Lithuania, Punios \\

There is a remarkable similarity between chronologies in the west of Europe and Scandinavia and those in the south-baltic coastal area, but also between the Lithuanian chronologies and those along the whole of the Polish coast and even in central Poland. However, there seems to be no common signal between the chronologies of the entire southern part of Poland and of the afore-mentioned countries.

What is the common signal? In Figure 5 the response functions are shown for the oaks grouped into three regions: «north» stand for the entire coastal area including Torun (site 7 in Fig. 1); «west» includes sites nos. 14, 15 and 16, and «east» sites nos. 10-13. The climate-growth relationships are as follows: The growth of the Polish oaks on the entire territory is dominated by far by precipitation, especially from April to August; temperature is of less importance, but quite evidently the oaks prefer mild winters.

Conclusions

For a long time Poland has been a dendrochronological ‘white spot’ within Europe despite the early works of e.g. Ermičh (1953). This gap can now be considered as closed, the more so since the Universities of Lund, Sweden, and Torún in a common effort have now undertaken a comprehensive work on Polish pine which is similar to our study on oak (e.g. Zielski 1987). A long-term chronology for oak in northern Poland was established going back to
Fig. 5 - Response functions (line) and simple correlation (bars) for oak in northern, eastern, and western Poland; significant months are labelled by circles (multivariate regression) and crosses (simple correlations); $r^2 = \%$ variance explained by climate.
996 AD by using historical timbers from 20 architectural monuments and several important archaeological excavations (WAZNY 1990). In this context sapwood statistics was ascertained on the basis of 164 historic timbers. The number of sapwood rings found in Polish oak is 15 + 8/-6, where 15 is the median and +8 and -6 cover the range which includes 90% of all cases. This result confirms an earlier assumption by BAILLIE et alii (1985), that there might be a tendency towards decreasing numbers of sapwood rings from west to east within Europe. This new Polish chronology has enabled the absolute dating of all so far ‘floating chronologies’ derived from panels of paintings of Dutch and English masters (ECKSTEIN ET ALII 1986; BONDE 1991) and will be useful in the future to detect timber of Polish origin within western and central European objects of art and architecture. Finally, due to its climatic signal the long-term Polish oak chronology is an important grid-point within the European network of tree-ring chronologies for the reconstruction of past climates, the more so since there is good hope to extend this chronology by thousands of years far back into the past by including subfossil oaks from the river valleys.

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**SUMMARY**

*The dendrochronological signal of oak (Quercus spp.) in Poland.*

In this study, 269 oak trees from 16 sites all over Poland are dendrochronologically investigated to assess which climatic signal they include and how far this signal extends within the country and eventually also into neighbouring regions. The growth of the oaks benefits countrywide from high precipitation, especially during summer, and mild winters. But there are regional modifications of this general pattern. Based on the first principal component of the variance of all 16 site chronologies, Poland is dendrochronologically uniform. However, the second principle component suggests a splitting of the country into the coastal area and the interior. The chronologies of the coastal area contain a far-reaching signal within Poland, but also to Lithuania as well as to the west of Europe and the south of Scandinavia. The long-term chronology, established for northern Poland, extends back to 996 A.D. and is well applicable as a dating tool. At the same time it is a climatic record within the network of European chronologies.

**ZUSAMMENFASSUNG**

*Das dendrochronologische Signal der Eichen (Quercus spp.) in Polen.*

Signal innerhalb Polens, aber auch nach Litauen sowie nach Westeuropa und Südkandinavien. Die für Nordpolen aufgebaute vieljährige Eichenchronologie reicht zurück bis 996 n. Chr. und ist als Datierungswerkzeug geeignet. Sie bietet sich auch als Klimareihe im Netz der europäischen Chronologie an.

RIASSUNTO

Il segnale dendrocronologico della quercia (Quercus Spp.) in Polonia.

Questo studio prende in considerazione 269 alberi di 16 stazioni, localizzate in tutta la Polonia, per valutare con le tecniche dendrocronologiche quale segnale climatico contengano e quanto questo si estenda all'interno del territorio polacco, ed eventualmente anche nelle regioni circostanti.

L'accrescimento delle querce risente in tutta la regione delle precipitazioni, specialmente estive, e degli inverni miti.

All'interno di questo modello generale esistono tuttavia delle differenze regionali.

La Polonia è uniforme dal punto di vista dendrocronologico se ci si basa sull'analisi dei primi componenti principali della varianza: mentre nel secondo componente principale compare una differenziazione del territorio tra area costiera ed interna.

Le cronologie dell'area costiera contengono un segnale esteso all'interno della Polonia, alla Lituania, alla Scandinavia.

La cronologia costruita per la Polonia settentrionale fino al 996 A.D. è un valido strumento di datazione e allo stesso tempo rappresenta una interessante registrazione climatica all'interno della rete delle cronologie europee.

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