Exploring oaks in modern wetland woods in Europe to trace the climate signal in tree-ring series of sub-fossil bog oaks

U. Sass-Klaassen[1,2]

[1] *Nederlands Centre for Dendrochronology, RING foundation, P.O. Box 1600, 3800 BP Amersfoort, The Netherlands*

[2]*Wageningen University, Forest Ecology and Forest Management, P.O.Box 342, 6700 AH Wageningen, The Netherlands, e-mail: ute.sassklaassen@wur.nl*

Introduction

Long tree-ring chronologies have been derived from sub-fossil bog oaks, i.e. oaks preserved in peat, from various sites in NW Europe. They cover the period from about 6000 BC to AD 1000 (Jansma 1995; Pilcher *et al*. 1996; Spurk *et al*. 1998; Leuschner *et al*. 2002). There are three main reasons why these bog-oak chronologies have great potential as proxy data for studying natural changes in past climate. First, bog-oak chronologies cover a long period and therefore enable the reconstruction of natural variation of certain climate aspects. Second, bog oaks are considered to contain a strong environmental most likely climate-related 'signal' because they grew close to their ecological limit in wetland woods that were characterised by high ground-water level and/or frequent inundation. The specific growth pattern of sub-fossil bog oaks with alternating phases of normal and depressed growth confirms this last assumption (Sass-Klaassen *et al.* 2003*,* this issue). Third, bog-oak chronologies from different locations in NW Europe contain common variation, i.e. a common 'signal', indicating that large-scale climatic factors influenced the growth of these oaks (Leuschner *et al.* 2002).

To assess the relationship between climate and growth in the tree-ring patterns of sub-fossil bog oaks, a straight-forward approach was used: living oaks that grow in modern wetland woods under comparable site conditions as sub-fossil bog oaks were sampled and analysed. The idea was to study the relationship between climate and growth and to calculate a model that can subsequently be projected to the long bog-oak chronologies.

Material and Methods

Sampling took place at 14 wetland woods, located in the Netherlands (8), Germany (2), Estonia (1) and Poland (Biebrza National park; 3). At these sites, oaks are growing in different types of wetland woods, which match the description of wetland woods where bog oaks grew together with other wetland species (Leuschner et al. 1987; Kooistra et al. 2003). Alder (*Alnus glutinosa*) is the dominant species at all sites. Other common species are birch (*Betula spp.*), ash (*Fraxinus excelsior*) and, on somewhat dryer sites, beech (*Fagus sylvatica)* and hazelnut (Corylus spp.). The trees all grow on (mineralised) peat.

On each site, 10 to 20 dominant oaks were sampled by taking one core per tree. Measurement and data processing was done using standard dendrochronological equipment and software (TSAP, Rinn 1996; COFECHA, Holmes 1983). Site chronologies were calculated using program ARSTAN (Cook 1985). Climate data were taken from the nearest climate station with long data records (sources: www.knmi.nl (The Netherlands), www.dwd.de, (Germany), University of Torun (Polen), Tartu University (Estonia). Response-functions were calculated using program PRECON (Fritts, unpubl.)

Results and discussion

Growth pattern of oaks from modern wetland woods

Most of the sampled oaks at the investigated sites are between 30 and 70 years old, with some trees reaching an age of 100 years. The mean annual growth rate of the oaks varies between 3 and 5 mm, meaning that the oaks were good growing. Prolonged periods of depressed growth are absent in all tree-ring series. Figure 1 shows an example of the growth pattern of oaks from the *Unterspreewald*, a wetland wood in Eastern Germany. The growth pattern of these oaks does not resemble the growth pattern of the sub-fossil bog oaks (see Sass-Klaassen *et al.*, this issue; Fig 2).

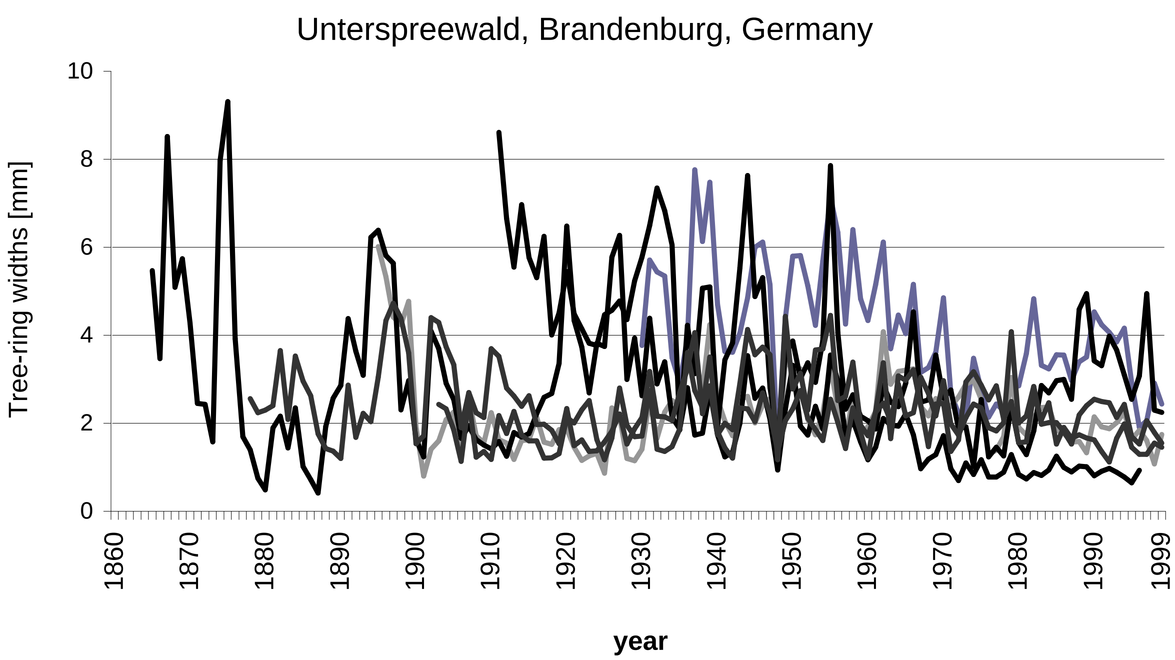

Figure 1: Tree-ring series of six oaks from the Unterspreewald, Germany

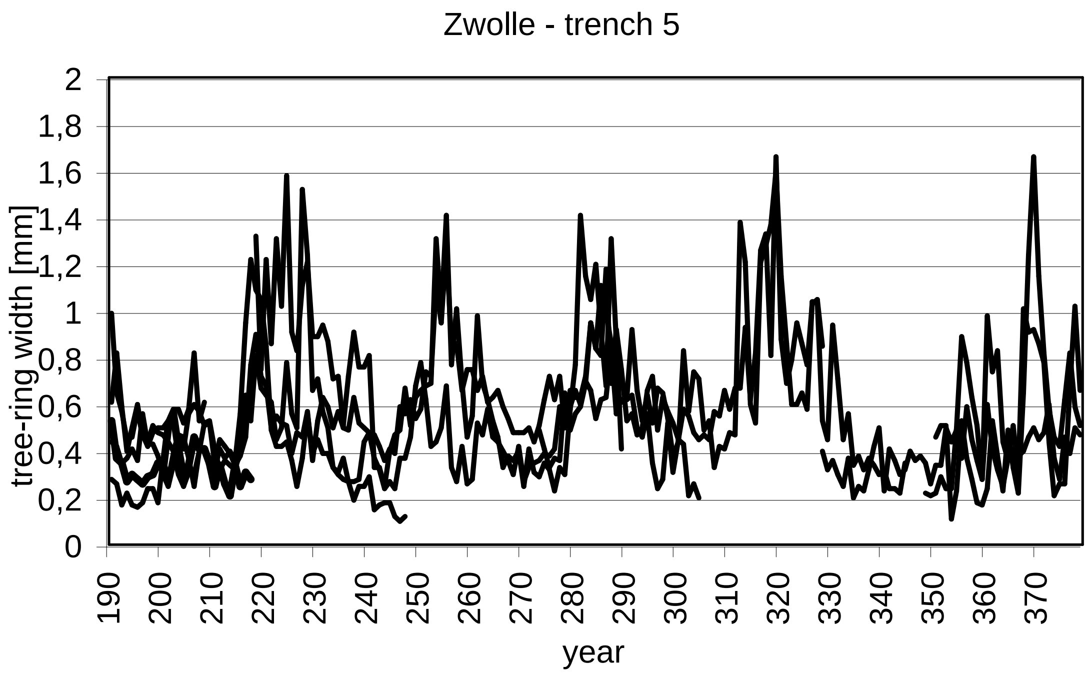

Figure 2: Tree-ring series of sub-fossil bog oaks from Zwolle Stadshagen, The Netherlands with alternating phases of normal and depressed growth

Climate-growth relationship

The response functions for the oaks from the different wetland sites show no strong influence of either temperature or precipitation. However, there exists a general tendency towards a positive influence of winter and/or spring precipitation, whereas above-average precipitation during the vegetation period had a negative influence on the growth of the oaks. Figure 3 documents the positive relationship with winter- and spring precipitation for the oaks from the *Unterspreewald,* Germany.

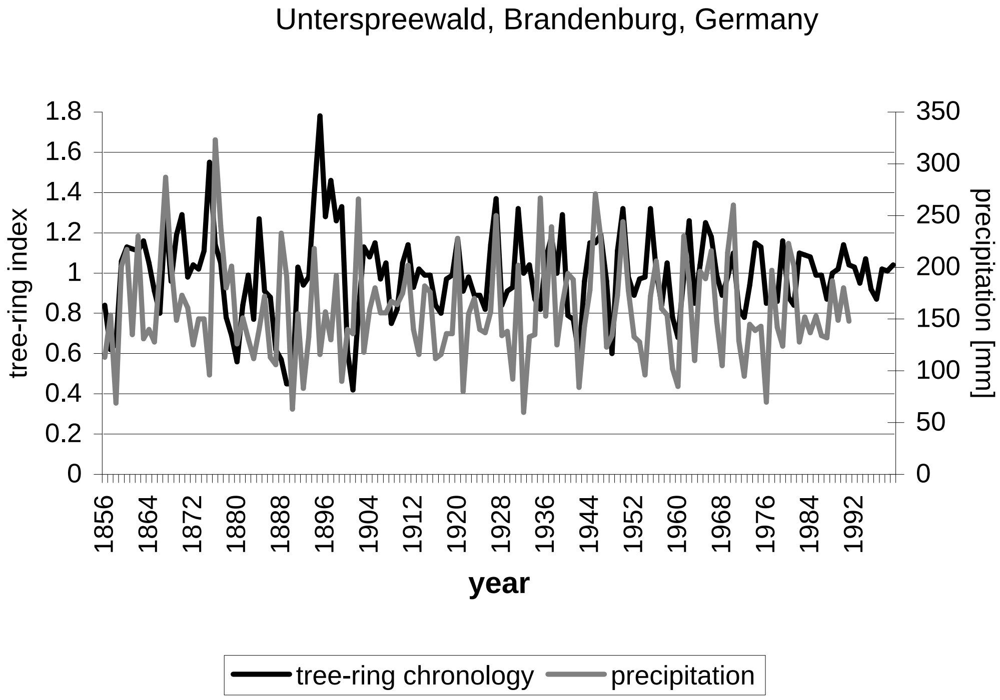

Figure 3: Comparison between the tree-ring chronology of oaks from the Unterspreewald, Germany, and the winter and spring precipitation from climate station Berlin

Ecological growth conditions of oak in modern wetland woods

Average ring width shows that the oaks in the wetland woods are growing under generally favourable site conditions. There is no indication that the relatively high ground-water level limits the growth of the oaks. The positive relationship with high precipitation in winter and spring most likely points to the refilling of the soil-water reservoirs before the start of the vegetation period (Fritts 1976). The hydrology at almost all investigated sites is directly (flooding) or indirectly (via ground water) linked to river systems. This ensures that the trees are provided with nutrient-rich (soil)water mainly during winter and spring. A negative response with above-average rainfall during the vegetation period indicates the susceptibility of the oaks to anoxic conditions in the shallow topsoil layer. A lack of oxygen in water-saturated organic soil may inhibit physiological activity of the roots and even damage them, which subsequently causes a reduction in growth activity (Kozlowski 1984; Armstrong *et al.* 1994).

Why can't we find "living bog oaks"?

After sampling and dendrochronologically investigating oaks from various wetland woods in different geographical regions, it has to be concluded that it is impossible to find oaks that show the characteristic growth pattern of the sub-fossil bog oaks (see Fig 2). The assumption is that the growth depressions in sub-fossil bog oaks are the result of (temporary) high ground-water level (groundwater level above the soil surface) and/or inundations (Pilcher *et al*. 1996; Leuschner *et al.* 2002; Sass-Klaassen *et al.* 2003, this issue) most likely in the beginning of the growing period (Poole et al. 2003, this issue). A surplus of water during the growing season may moreover have resulted in an early growth stop, which also resulted in narrow tree rings. Following this assumption the only conclusion can be that the hydrology at the investigated modern wetland woods differs from that at the ancient wetland woods. With large-scale exploitation of the peat-land areas beginning in the 10th century AD in the Netherlands (Vervloet, pers. comm.) a lot of wetland woods were destroyed. The hydrology of wetlands has been irreversibly changed by the drainage of vast areas for peat exploitation and subsequently agricultural use. This process took place even in more remote areas like North-eastern Poland. The consequences are that only few natural wetlands (still) exist in NW Europe (Succow & Joosten 2001) and that none of them has reached the phase of a wetlands wood with oak.

Alternative research approaches

Based on the above, other approaches have to be used to assess the climate signal in the long bog-oak chronologies, if they are to be used as proxy data for past climate. Two of these approaches are described elsewhere in this issue (Sass-Klaassen *et al*. 2003, this issue; Poole *et al*. 2003, this issue).

Acknowledgements

This research was made possible by funding from The Netherlands Organisation of Scientific Research (NWO/AWL 750.700.04). Many thanks to Angela van Luerthe, Tomasz Wazny, Alar Läanelaid, Marta Dominguez and Elsemieke Hanraets for their help during the sampling campaigns.

References

Armstrong, W., Brändle, R. & M.B. Jackson (1994): Mechanisms of flood tolerance in plants. Acta Botanica Neerlandica 43: 307-358

Cook, E.R. (1985): A time series analysis approach to tree ring standardization. Thesis of the University of Arizona: 171 p.

Fritts, H. (1976): Tree Rings and Climate. Academic Press, London: 567 p.

Holmes, R.L. (1983): Computer-assisted quality control in tree-ring dating and measurement. Tree-Ring Bulletin 43: 69-78

Jansma, E. (1995): RemembeRINGs. The Development and Application of Local and Regional Tree-Ring Chronologies of Oak for the Purposes of Archaeological and Historical Research in the Netherlands. PhD. Diss. University of Amsterdam. Nederlandse Archeologische Rapporten (NAR) 19: 149 p.

Kooistra, M.J., Sass-Klaassen, U., Kooistra, L.I. & P. Van Rijn (2003) (submitted): Woodlands of the past: results of the excavation of Zwolle-Stadshagen (The Netherlands) V, Integrated reconstruction of landscape and woodland in its environmental context. Netherlands Journal of Geosciences

Kozlowski, T.T. (1984): Flooding and plant growth. Academic Press (New York): 356 p.

Leuschner, H.H., Delorme A. & H.-C. Höfle (1987): Dendrochronological Study of Oak Trunks Found in Bogs in Northwest Germany. Proceedings of the International Symposium on ecological aspects of tree ring analysis, New York: 298-318

Leuschner, H.H., Sass-Klaassen, U., Jansma, E., Baillie, M.G. & M. Spurk (2002): Subfossil European bog oaks: population dynamics and long-term growth depressions as indicators of changes in the Holocene hydro-regime and climate. The Holocene 12: 695-706

Pilcher, J.R., Baillie, M.G.L., Brown, D.M. & F.G. McCormac (1996): Hydrological data from the long Irish subfossil oak records. *In:* Dean, J.S., Meko, D.M. & Swetnam, T.W. (eds.): Tree Rings, Environment, and Humanity. Radiocarbon, Department of Geosciences, The University of Arizona (Tucson): 259-264

Rinn, F. (1996): TSAP -Time Series Analysis Program. For applications in forestry, tree-ring laboratories and dendrochronology. Rinntech (Heidelberg).

Spurk, M., Friedrich, M., Hofmann, J., Remmele, S., Frenzel, B., Leuschner, H.H. & B. Kromer (1998): Revisions and extensions of the Hohenheim oak and pine Chronologies - New evidence about the timing of the younger dryas/preboreal-transition. Radiocarbon 40: 1-10

Succow, M. & H. Joosten (2001): Landschaftsoekologische Moorkunde. Stuttgart : Schweizerbart'sche Verlagsbuchhandlung: 622 p.