Sub-fossil Oak Timbers from the Mid Holocene as an Evidence for Lithuanian Forest History

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Mega-remnants of past vegetation like sub-fossil tree trunks are seldom used in Lithuanian vegetation history studies. The paper describes the analysis of sub-fossil oak timbers discovered in peaty ground in the Biržai Forest Enterprise, North Lithuania. Radiocarbon dating has revealed that these oak trees grew in the first half of the Atlantic period before 7-6.5 millennia. Annual radial growth series of the trees were analysed using dendrochronological methods. Having synchronized the growth series of four timbers a 207 years long mean series of the Mid-Holocene oak annual radial growth was compiled. The existence of boggy oak forest type on the territory of Lithuania in prehistoric times has been established. Chronological coincidence of the period of the investigated sub-fossil bog oak growth with the formation of a well-represented oak horizon in Northwest Germany bogs hints to inter-regional parallelism in the Holocene vegetation history.

Key words: *Quercus* spp., dendrochronology, prehistoric tree-ring chronologies, vegetation history, Lithuania

Introduction

The knowledge of the Holocene vegetation history and forest development on the territory of Lithuania is derived mainly from the pollen and peat composition analysis (Kabailiene 1990). The investigation of mega-remnants like sub-fossil tree trunks can reveal quite sophisticated information on past environmental changes, for example aspects of landscape dynamics, forest stand dynamics, hydro-regime changes, etc. (Pukiene 2001, Leuschner *et al.* 2002, Spurk *et al.* 2002).

In West European tree ring laboratories the investigation of sub-fossil oaks (*Quercus* spp.) excavated from different types of sediments started in the 1970s (Leuschner *et al.* 2000). At the same time the collection of oak trunks, buried in riverine sediments of the river Neris, has begun in Lithuania, in the laboratory of dendroclimachronology of the Botany Institute (Битвинскас *et al.* 1978). These trunks are the remnants from prehistoric oak-woods that grew in the river valley and later died and were buried by gravel deposits due to riverbank erosion.

In West European countries (Ireland, Germany, the Netherlands), in addition to river gravel deposits, oak trunks are also found in peat bog layers (Leuschner *et al.* 1987). At present peat bogs are not the typical sites for oak-woods all over the area of *Quercus robur* L. and *Quercus petrea* L. distribution. Therefore the layers of oak trunks in peat deposits are an interesting indicator of the boggy oak forest type, which existed in previous geological periods of the Holocene.

In Lithuania oak-woods usually grow in fertile and comparatively dry soil types (Vaičys, Karazija 1997). The main type of the present day Lithuanian oak forests is *Hepatico-oxalido-Quercetum* (Karazija 1997). The moistest oak forest type is *Carico-mixtoherbo-Quercetum* (ibid). At present peat soils are referred to as not suitable for oak (Vaičys, Karazija 1997).

The presence of sub-fossil oak trunks in peat deposits demonstrates that boggy oak-woods existed in Lithuania in the past too. Such trunks were excavated from peat layers in the Biržai district, North Lithuania. The aim of the presented study was to investigate this unique relict of ancient bog oak-woods and complement the knowledge of the postglacial history of Lithuanian forests.

Materials and methods

Partly destroyed oak trunks were found in the Biržai forest enterprise in peaty ground during excavation of a pond. Geographical co-ordinates of the site are 56°12'N 24°44'E. Several meters long and up to 0.5 m in diameter oak trunks were embedded in layers of peat deposits at 2 – 4 m depth. Crown and root parts were rotted away but central parts of stems were sound enough to carry out the analysis of wood and annual tree rings.

Five well-preserved trunks of oaks were examined. Annual radial growth sequences of the buried trees were analysed and temporal position of the tree growth was established using dendrochronological and radiocarbon analysis. The width of annual tree-rings has been measured using a stereomicroscope with an accuracy to 0.025 mm. The measurement was carried out on cross-sections of trunks along radial tracks prepared by a razor blade, two or three radii per specimen. Tree-ring width sequences for each radius have been plotted, synchronised and averaged to get a single tree-ring series representing the specimen (a single tree). The specimen ring series were then synchronised among themselves. Synchronisation has been carried out using standard technique by looking for the position of ring series overlap with highest values of statistical correlation and best visual cross-match of graphs. Student's t-value of the correlation coefficient calculated according to Baillie and Pilcher (1973) was used as a statistical test for the correlation between the compared series.

For radiocarbon dating of the excavated trees, wood samples consisting of 16 to 40 annual rings were prepared for each specimen. Chemical treatment of the wood was carried out in the Radioisotope Laboratory of the Lithuanian Institute of Geology and Geography. The content of ^{14}C isotope in the samples was measured in the Laboratory of Radioisotopes of Vytautas Magnus University by using highly precise LSC "Quantulus-1220" equipment.

Results

After measuring tree-ring width of the sub-fossil oak specimens, time series of 113 to 183 years were constructed. The analysis of the annual radial increment has revealed that despite the moisture and progressing peat accumulation, the site conditions were suitable for oak growth. Tree-ring width fluctuated within the range from 0.5 to 2.5 mm, the average annual radial increment was 1.56 mm.

By comparing the series of ring width on different measurement radii it was established that all the specimens had more or less expressed trunk growth eccentricity. Cumulative annual increment measured along two different radii of specimen Bra002_m stem is presented in Figure 1. Despite the prevailing higher increment rate along one trunk radius, inter-annual fluctuations of the radial increment were highly synchronous comparing different radii in all examined trees.

After synchronization of the tree-ring series representing the specimens, series of four specimens were relatively dated against each other. In synchronous overlap position t-values of series correlation ranged from 3.32 to 21.64 (Table 1). In Figure 2, visual cross-match of the synchronized growth series of two trees (Bra001_m and Bra005_m) is demonstrated. Tree-ring series of specimen Bra004_m could not be dated against the series of the remaining specimens because the growth fluctuation lacked similarity and statistical test values were low in all series overlap positions.

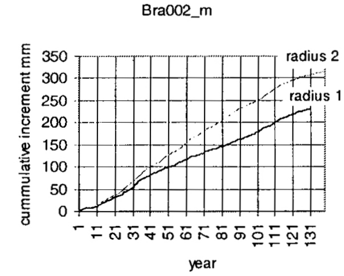

Figure 1. Cumulative annual increment along two different radii of specimen Bra002_m cross-section demonstrating trunk growth eccentricity.

Table 1. Relative position of the synchronised tree-ring series of the investigated sub-fossil oak trees and results of statistical t-test of correlation between the series

Specimen code	Length of ring series	Relative dates		Correlation coefficient t-value			
		First ring	Last ring	bra01_m	bra02_m	bra03_m	bra05_m
bra01_m	183	1	183	*	3.63	3.49	11.78
bra02_m	139	59	197	*	*	21.4	3.53
bra03_m	140	60	199	*	*	*	3.32
bra05_m	133	75	207	*	*	*	*

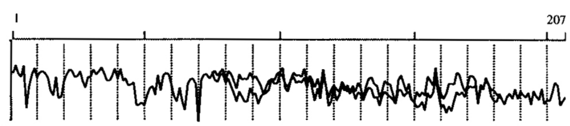

Figure 2. Visual cross-match of the growth series of two subfossil oak trees (Bra001_m and Bra005_m) in the synchronised position

Radiocarbon dating of wood has revealed that all the examined oak trees grew in the Middle Holocene, in the Atlantic period that lasted from 7500 to 5000 years before present. The established ^{14}C dates of the specimens ranged from 5490+/-40 to 6130+/-40 years before present (BP). The Atlantic period is referred to as the warmest period in the postglacial history and most suitable for broadleaf tree species spread (Kabailienė 1979). Radiocarbon dates with the laboratory indices and the ranges of calibrated calendar years of wood formation are presented in Table 2. Radiocarbon dates were calibrated according to the Stuiver and Pearson (Stuiver, Pearson 1993; Pearson, Stuiver 1993) calibration curve, expressing the deviation of the real amount of radiocarbon in the atmosphere from the theoretically stable level.

Table 2. Subfossil oak radiocarbon dating results

Laboratory index	Specimen code	Length of ring series	Range of sampled rings	Conventional radiocarbon age, years BP*	Calibrated age within 1 σ probability range, calendar years BC
VDU-153	Bra003_m	140	17-34	5730 +/-60	4678-4638; 4621-4502
VDU-156	Bra004_m	113	40-80	6130 +/-40	5194-5185; 5073-4960
VDU-157	Bra001_m	183	139-162	5665 +/-40	4534-4460
VDU-158	Bra002_m	139	102-118	5490 +/-40	4438-4427; 4365-4321; 4285-4260
VDU-159	Bra005_m	133	70-95	5660 +/-60	4565-4451; 4421-4395

* BP – before present, i.e. before AD1950

Radiocarbon dating of four specimens that were cross-dated by dendrochronological method (Bra001_m, Bra002_m, Bra003_m and Bra005_m) has showed close ^{14}C dates. These oaks grew about six and a half millennia before present, i.e. around 4600 – 4400 years BC. Calibrated ^{14}C date of oak No. Bra004_m, the tree-ring series of which could not be dated against those of the rest specimens, has revealed that this tree grew on the same boggy site several centuries earlier. It grew in the first half of the Atlantic period, around 5100 – 5000 years BC. In Figure 3 approximate positions of the growth span of the examined oaks on a time scale are presented.

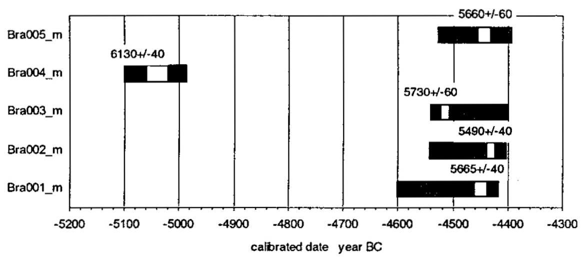

Figure 3. Positioning of the growth spans of the examined oaks on a time scale according to dendrochronological and radiocarbon dating results. Lighter shading points out the tree-ring intervals sampled for radiocarbon analysis, nearby numbers indicate conventional radiocarbon dates BP

Synchronised tree-ring series of the contemporaneous oak specimens (Bra001_m, Bra002_m, Bra003_m and Bra005_m) were averaged and 207 years long mean series of the Mid-Holocene oak annual radial growth was compiled. This mean series BRAMEAN2 is presented in Table 3.

Discussion

Buried in specific anaerobic conditions wood as well as other remnants of past vegetation can be preserved for centuries. Investigated sub-fossil oak timbers were preserved in peat deposits for almost seven millennia. Accumulating peat had covered dead trees and inhibited wood decomposition. Formation of peat layers around tree remains is an indicator of site bogginess and proves the existence of boggy oak-woods on the territory of Lithuania in the Atlantic period.

Table 3. Mean series of annual radial growth of sub-fossil oaks that grew in the Atlantic period in the middle of the 5th millennium BC (in 0.01 mm)

Series index	Years / Decades	0	1	2	3	4	5	6	7	8	9
BRAMEAN2	1		191	241	191	173	237	72	131	184	221
BRAMEAN2	10	169	198	204	193	169	119	103	172	95	99
BRAMEAN2	20	153	184	213	208	172	177	203	154	129	173
BRAMEAN2	30	175	214	185	204	224	192	158	156	179	220
BRAMEAN2	40	163	219	156	168	137	141	150	79	80	85
BRAMEAN2	50	77	104	128	134	105	183	118	183	195	143
BRAMEAN2	60	158	154	125	147	61	54	85	134	168	101
BRAMEAN2	70	111	222	234	233	183	215	194	167	217	225
BRAMEAN2	80	157	169	183	203	196	200	172	193	195	193
BRAMEAN2	90	226	225	192	208	154	173	163	217	152	194
BRAMEAN2	100	243	220	142	131	180	203	202	217	195	225
BRAMEAN2	110	144	170	150	163	175	163	224	206	97	147
BRAMEAN2	120	205	189	169	171	125	133	149	131	156	160
BRAMEAN2	130	171	130	153	167	169	119	144	120	125	157
BRAMEAN2	140	158	183	145	115	162	204	170	173	136	113
BRAMEAN2	150	96	126	126	133	112	145	144	140	218	142
BRAMEAN2	160	126	137	137	174	154	153	182	204	179	147
BRAMEAN2	170	172	190	181	161	100	134	140	179	174	124
BRAMEAN2	180	128	113	129	110	83	105	109	94	117	100
BRAMEAN2	190	109	102	97	107	88	102	92	90	116	101
BRAMEAN2	200	92	90	114	151	139	80	90	100		

Specific dark colour is characteristic of oak wood that has been lying in wet ground or water for a long time (such wood is called "black oak"). The intensity of colour change is sometimes used as an indicator of oak wood age. But the wood of the investigated oaks from peat layers is lighter (dark gray colour) in comparison with the wood of oak trees (black colour) from gravel of the river Neris (Битвинскас *et al.* 1978) though the latters are millennium or two younger. Low intensity of darkening coincides to the characteristic of bog oak findings of type A horizons in North-West Germany (Leuschner, Delorme 1988). These horizons are embedded in the peat layer at the base of oligotrophic deposits. The darkening of oak wood was not so intensive in fast growing fen peat because of lack of iron ions (ibid). Not so intensive black colour of the investigated sub-fossil oak trunks from Biržai allows us to suppose that similar rapid bog development process enabled the preservation of the trunks. The investigation of Lithuanian vegetation history by pollen analysis has demonstrated that humid Atlantic period was one of the most favourable times for intensive bog formation in the Holocene (Kabailienė 1979).

By the analysis of sub-fossil oak trunks found in peat deposits in West European countries it was reconstructed that some bog oaks were rooted in mineral soil and overgrown by peat; but also there were oak forests with root systems distributed in the peat layer (Leuschner *et al.* 1987). Such forest communities, atypical for present day vegetation, could be formed in drier phases of previous geological periods of the postglacial at a particular stage of bog development (Baillie 1982, Leuschner *et al.* 1987, Pilcher *et al.* 1996).

As the root part of the investigated Biržai oaks has been rotted away and the information on the soil profile is missing, we cannot reconstruct the site conditions and site development process in detail. Radiocarbon dating of the trunks has revealed that the site was suitable for oak growth at least for several centuries. All the investigated trees were older than one hundred years and their annual radial increment rate was comparable to that in present day oaks growing on non-boggy mineral soils. The eccentric growth, specific to all the investigated trees, indicates non-vertical tension stress in trunks, probably due to expressed site relief. There is also assumption that oaks growing on peat could not be so stable as those on mineral soil because they had shallow root system and therefore were sensitive to wind-throw (Baillie 1982; Pilcher *et al.* 1996). Trunk Bra004_m, dated several centuries earlier than the rest of the trunks, was more decomposed and more blackened. It can be an indication of some change in peat accumulation and trunk preservation processes in the transition period. Peat deposits that had covered the former trunk had probably more intensive contact to ground water and larger amount of iron ions.

Dendrochronological synchronisation of tree ring series of the contemporaneous oak specimens Bra001_m, Bra002_m, Bra003_m and Bra005_m also reflected some aspects of stand dynamics. The oak trees were not evenly aged. The dates of their germination were separated by decades. The first ring of tree Bra001_m was formed 75 years earlier before tree Bra005_m started to grow.

The relative dates of the tree death could not be exactly fixed due to decomposition of the outermost part of the trunks and absence of last rings. But the analysis of the cross-dated ring series did not indicate simultaneous mass dying-off of the stand. The last remaining ring in specimen Bra001_m was formed 24 years earlier than that in specimen Bra005_m. But only specimen Bra001_m had remnants of sapwood rings. It means that this specimen had the least number of lost outermost rings. Other specimens missed all sapwood, on average consisting of 13 to 19 rings (Ważny 1990), and unknown number of hardwood rings. It is evident that these trees continued to grow for at least two decades after the death of tree Bra001_m.

Investigation of sub-fossil oaks found in West European bogs has revealed rather uneven temporal distribution of the finds throughout the Holocene (Brown, Baillie 1992; Leuschner *et al.* 2000). Periods with a great number of buried oaks were followed by phases of sparse findings. Significant intervals of growth depression were specific to those rare oaks that had grown during depletion phases. Formation of oak horizons, germination and dying off phases often were synchronous on different sites and even larger regions, reflecting a larger scale of climatic fluctuations (Leuschner *et al.* 2000, Leuschner *et al.* 2002). In north Germany the oldest and most represented oak horizon, named after "Meppen", was formed in 4900 – 4400 BC. (Leuschner *et al.* 1987, Leuschner, Delorme 1988). Dating of the sub-fossil oaks from North Lithuania chronologically coincides with the formation of this phase in north Germany bogs. This temporal coincidence suggests that in the first half of the fifth millennium BC the environmental situation was favourable for oak expansion onto bogs and preservation of dead tree remnants in peat deposits on a large territory of Europe from North Germany to Lithuania.

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СУБФОСИЛЬНЫЕ ДУБЫ СРЕДНЕГО ГОЛОЦЕНА КАК ИСТОЧНИК ИНФОРМАЦИИ ОБ ИСТОРИИ РАЗВИТИЯ ЛЕСОВ ЛИТВЫ

Р. Пукенс

Резюме

В изучении истории природной среды Литвы редко применяются такие растительные мега-остатки, как субфосильные деревья. В статье приводятся результаты анализа субфосильных дубов, найденных в торфяной почве в Биржайском лесхозе, северная Литва. Радиоуглеродное датирование показало, что дубы росли в первой половине атлантического периода, 7 – 6,5 тыс. лет тому назад. Серии годичного радиального прироста, найденых деревьев изучались дендрохронологическим методом. После успешной синхронизации серий прироста четырех деревьев была построена осредненная шкала годичного радиального прироста дуба, середины голоцена протяженностью 207 лет. Потверждено наличие на територии Литвы в прошлом болотных дубрав. Хронологическое совпадение периода произрастания исследованных субфосильных болотных дубов с формированием широко представленного дубового горизонта в болотах северозапада Германии предполагает межрегиональную параллель в истории развития растительности голоцена.

Ключевые слова: дуб, дендрохронология, преисторические дендрошкалы, история развития растительности, Литва.