Author(s): Juha Raisio & Samuli Helama

Title: Oak wood megafossils found from Kemiö island in SW Finland

Year: 2026

Version: Published version

Please cite the original version:

Raisio, J., & Samuli, H. (2026). Oak wood megafossils found from Kemiö island in SW Finland. Memoranda Societatis Pro Fauna Et Flora Fennica, 102, 19-32. https://journal.fi/msff/article/view/182075

Memoranda Soc. Fauna Flora Fennica 102: 19–32. 2026
Helsinki 7 May 2026

ISSN 0373-6873 (print)
ISSN 1796-9816 (online)

Oak wood megafossils found from Kemiö island in SW Finland

Juha Raisio & Samuli Helama

Raisio, J., Aalto University Finland, FI-01250 Espoo. juha.raisio1@gmail.com
Helama, S., Natural Resources Institute Finland, FI-96200 Rovaniemi. samuli.helama@luke.fi

Subfossil tree trunks recovered from the Holocene deposits are commonly used as indicators of past vegetation shifts and climatic fluctuations. Such findings must be scientifically dated prior to any palaeobotanical or palaeoclimatic interpretations. This study concentrates on a subfossil specimen of oak (*Quercus* sp.) wood unearthed from Kemiönsaari, SW Finland. The specimen available for scientific examination represents a mature tree with > 150 annual rings and stem diameter c. 25 cm. The age of the tree specimen was determined by radiocarbon dating as 3340 ± 28 BP. Radiocarbon calibration results in a calendar year age range between 1732 and 1532 cal BC. The implications of the results are discussed in a multi-disciplinary context. The investigated oak specimen may not be the first one ever discovered in Finland. However, at least to our knowledge, it represents the first piece of evidence of its kind, rigorously dated and described in the scientific literature.

Introduction

Oak wood macrofossils in the form of oak trunks – which could also be called megafossils by virtue of their size or subfossils due to their depositional history – have been more commonly found in Southern Scandinavia peatlands and even in the Baltic states due to the milder climate and much wider former distribution of oaks throughout the vegetation history in the Holocene (e.g. Edvardsson & al. 2024, Vitas & al. 2023). From Scania (Sweden) and Denmark more than 1 000 oak trunks have been reported, whereas from Baltic sites the number of specimens is counted in tens of trees.

Distribution of the common oaks (*Quercus robur*) extended further north also in Finland when the climate was warmer during the Atlantic period in the middle of the Holocene. Since then, the distribution has been gradually limited down to a very narrow coastal strip of SW Finland mainly due to the long-term climatic cooling and as the main competitor, spruce (*Picea abies*) has entered the region from the east. Moreover, the occurrence of the oak species is restricted by the edaphic factors. In the coastal area of SW Finland, the oaks are mainly growing in eutrophic oak-groves, often with e.g. linden (*Tilia cordata*) and hazel (*Corylus avellana*). Many of the former forests may also have evolved in the region when the historical agriculture cleared up forested landscape to cultivated fields. In Finland, old oaks have also been suffering from the severe droughts (Helama & al. 2014, 2016), alongside a rapid re-expansion of oak seedlings.

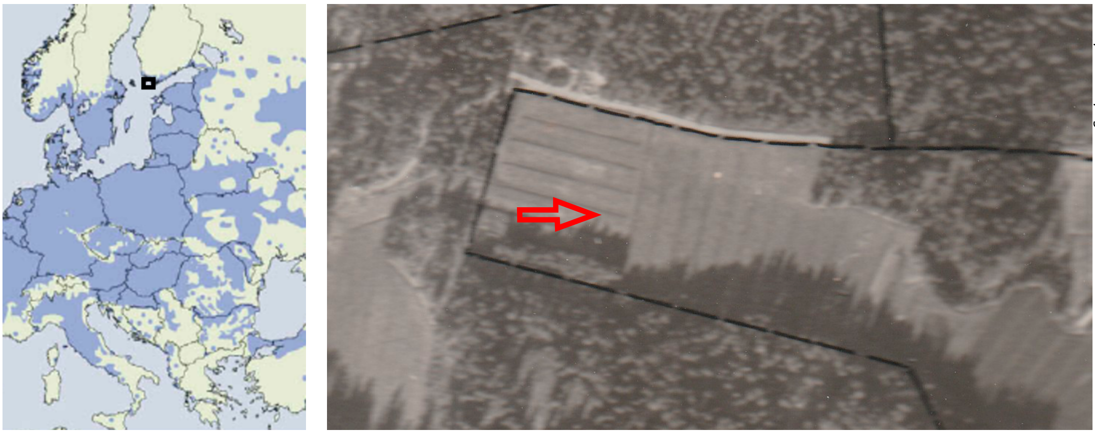
Compared to Swedish, Danish and Baltic sites, there appears to exist no scientific description of subfossil oak wood unearthed from Finland. This paper fulfils this gap by presenting the finding of megafossil oak wood found from SW Finland and discussing the significance of the presented palaeobotanic evidence. In fact, the oak trunk was found already in 1957 from the untouched layers of under cultivation taken, about 1 ha field plot near the center of Kemiönsaari municipality (Sjöberg 2019). The site consists of a field area that may have been a basin of a former bay or lagoon of the Baltic. Later it may have evolved as a pond or lake for a while. The field lies about 1 km to the south-east from the bottom end of Norrlångviken – a long, narrow fjord like bay. The land uplift and the ancient sea-level drops have exposed the bottom end of the former bay now as a narrow agricultural landscape, which continues 2–3 km further towards the main village of the island. The Norrlångvik village reaches to the end of the ”fjord”, with relative steep bedrock hills many places on both sides. (e.g. Tikkanen & Westerholm 1992).

About 3000 years ago the Norrlångviken was one of the many narrow straits, which divided the later Kemiö island (Kemiönsaari in Finnish) still at that time as archipelago. The strait connected the waters from the western parts to its eastern coastal areas. The straits may have been used as channels of transport by the early fisherman-hunters, the first settlers or later sporadically even by the Vikings. The Bronze Age activity sites roughly more than 3000 years ago in Kemiö islands are associated with the ancient cairns marked in fig. 7 map C with the black points. Later the land uplift of the central areas of Kemiö drained the straits (Tikkanen & Westerholm 1992). Today the open sea lies a few kilometers to western from the oak find site. The bottom of the bay has for long been a landscape of the agriculture. Aside the main village some smaller farms lie with their tiny field plots between the bedrock hill tops, which may rise up to 40–50 m above the sea-level. The oak find site, the field plot, lies about 22,5 m a.s.l. In the last decades also the feldspar and calcareous rock have been mined here and there from the bedrock in the region. The mining begun as a local scale industry and has since enlarged now to a minor export business. The main industrial site and little wharf being now on the coast of Norrlångviken, about 2 kilometers from the actual oak find site.

Today, the widest oak groves in the municipality of Kemiönsaari are around Lappdal and Ekhamn. Some of the most prominent small oak forests in region, broadly 20–35 km from the actual oak find site, are e.g. Lenholm in Parainen, Vaisakko in Salo and Framnäs in Raseborg (Fig. 8., see also e.g. Helama & al. 2014, 2016). All these groves reach to the present coastline. We anticipate that our results could lead to new findings of subfossil oak as the information gathered from the discovery site are presented. That it, the details we provide could help locate new specimens from the future excavations. While in southern Scandinavia the dendrochronologists aim for a 9000-year oak tree-ring chronology, which may be possible due to the vast amount of subfossil oak trunks already located (Edvardsson & al. 2024), the Finnish research could benefit from a higher number of findings to detail the former distribution of the oaks in both space and time. As previously alluded to, distribution and occurrence of the species have likely increased mainly due to warming caused by the climate change. Past distribution has been is mainly studied by the palynological analyses. The oak area was wider in warmest period of the Holocene, the Atlantic, and the occurrence probably more frequent. As previously alluded to, the distribution and occurrence of the species were likely much extended in the past due to the warmer Atlantic period in the middle of the Holocene. In Finland, the past distribution of the oak has mainly been studied so far by means of palynological analyses. Megafossils, by contrast, are expected to throw more light on the local occurrence of the species in the past, in comparison to pollen analysis that provides more general information of the tree species prevalence.

The oak find site in the former peatland

The first finding of subfossil oaks was made by a local farmer from the depth of about 30 cm of the peatland when the agricultural subsurface drainage of the field was implemented in 1957. The oak wood was notably hard and unabraded, for which reason it was not expected to be particularly old. While the cutting edge of the plough can tear up roots and stumps from this depth, it is not exceptional in the beginning of the bog field cultivation. The hidden trunk was a giant for the horse-drawn machinery in use at that time, so the drainpipes had to be located going the trunk (Sjöberg 2019). In former bog soils, drainpipes are in average usually installed much deeper, for the depth of about 100–120 cm. In the first stage, the drainage causes relatively fast flattening of the humus-rich surface.



Aerial photo: Topografikunta 1957

Fig. 1. (a) Distribution of *Quercus robur* (modified after Ducousso and Bordacs 2003 and Haneca et al. 2009) and location of Kemiönsaari municipality in SW Finland (box). (b) The finding site of the oak pinpointed in the aerial photo taken 1957. The arrow points to the original oak find site. Direction of the arrow is to the north. The oaks growing nearby the forest edge to the west would be most typical for the Finnish oaks today. The habitat in front of the heat-storing bedrock heading to the west provides micro-climatically advantageous conditions. Subsurface drainage was not yet implemented in the field when the aerial photo was taken but the surface was still in the open-ditch condition. Another subfossil oak was found in the 1970´s near the narrow strait between the forest edges, when the drainage was complemented.

Photo: J. Raisio

Fig. 2. The oak find site in October 2025. The landowner in the right corner of the photo, nearby the original find site. The other oak was found from the narrow strait in the middle. No oaks of similar size are known to have grown around in the last decades. The probable oak stand position has been to the west, in the lower part of the bedrock slope. It is very typical position for oak nowadays in SW Finland due to the beneficial microclimatic aspects. Organic matter rich, still mostly turf soil have preserved the fallen oak logs for thousands of years. The scene has originally been a bay of the sea, while the descending sea-level may have turned it first to a eutrophic coastal forest, then transforming it as a sloping fen. The sloping terrain may have prevented the independent lake phase from the bog/fen succession.

In the 1970's another oak trunk was noticed about 150 m from the first find site. It was pulled up to the forest with a tractor and the aim was to saw it as crude timber, but the hard looking oak wood was soon badly decayed before any sawing had been done. The pH of the peatland find site soil was quite high, above 5 (Sjöberg 2019). The relative high pH-value indicates that it may actually have been a fen than a bog before.

In the year 2003, the excavator took the oak trunk originally discovered in 1957 entirely up, when the drainage was complemented, and the trunk was pulled out to the forest. The trunk of 3 m in length and 30 cm in diameter was later washed and sawn as crude timber i.e. planks. A small part of the oak wood was used as material for home carpentry, as clock faces. Most of the sawn oak wood has been maintained in the barn of the farm (Sjöberg 2019). In this last occasion also a subsurface bedrock formation, hindering free water flow downwards from the field plot, was partly detonated broken to ensure the drainage of the field plot. When the landowner begun to speculate about the age of trunk the authors of this article were also contacted.

Methods

The oak sample was investigated using (^{14}C) radiocarbon and tree-ring analyses. First, a fragment of subfossil wood, representing three outermost rings of the sample (Fig. 3), was used for ^{14}C determination at the Laboratory of Chronology, University of Helsinki (Uusitalo & al. 2022). First, the dates were given in conventional ^{14}C year BP (before AD 1950) with uncertainties pertaining to the counting statistics and activity measurements. Second, the conventional ^{14}C date was calibrated into calendar years (cal BC) reported here with the two-sigma age range using the Oxcal (version 4.4) software (Bronk Ramsey 1995, 2009). The Northern Hemisphere IntCal20 ^{14}C calibration curve was used for calibration (Reimer & al. 2020). Second, tree-ring widths were measured from the cross-section of the subfossil sample. Six radii were measured under a light microscope and the tree-ring series were synchronised (cross-dated) against each other visually and by using Cofecha software (Holmes 1983). Third, the dating position of the oak tree was compared with depositional histories of subfossil oaks from southern Scandinavia (Sweden and Denmark) where the increased phases of subfossil oak supply are commonly linked with dry peatland surface conditions promoting regeneration (Edvardsson & al. 2024). While there are no oak records from Finland, similar comparison was done with the subfossil pine records from Finnish Lapland, originating from lacustrine sites more than 150 meters above sea level, where the availability of subfossil trees is expected to reflect summer warmth which is essential to seed production (Helama & al. 2004; Helama & Oinonen 2019). Both records span roughly over the past 7600 years over which period they were plotted for comparison.

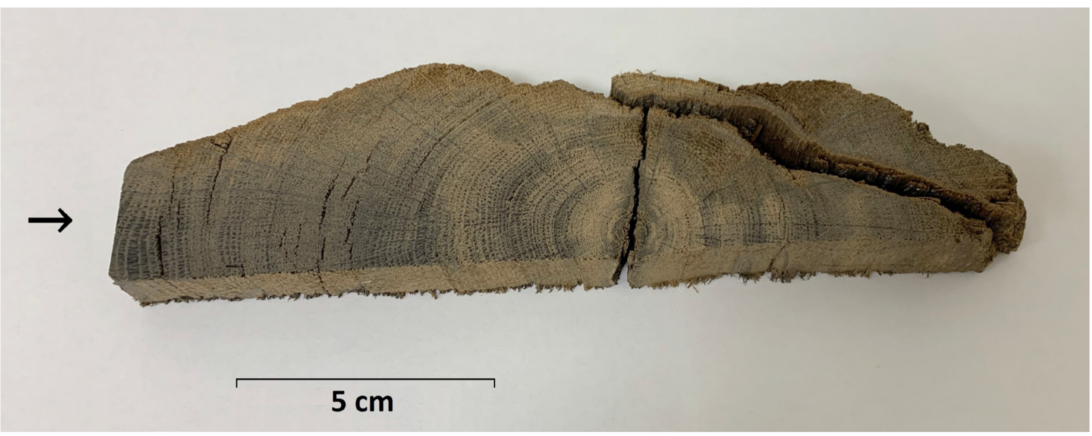


Photo: S. Helama

Fig. 3. A disk sample of subfossil oak used for radiocarbon and tree-ring analyses. The rightward arrow indicates the location of a fragment used for radiocarbon analysis.

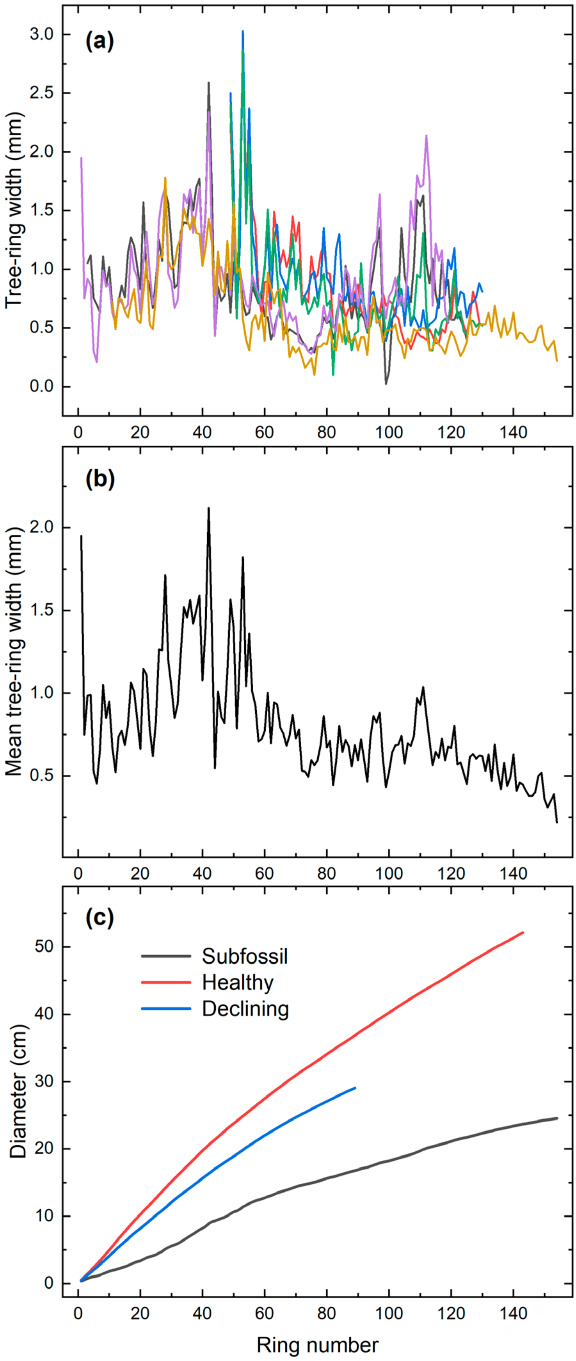


Fig. 4. Tree-ring data of the subfossil oak, as a function of tree number from the pith. Tree-ring series measured as separate radii (a) were averaged into a mean growth record (b). Diameter of the tree trunk was calculated from tree-ring data and compared with recent data from healthy and declining oaks cored at breast height in six sites in SW Finland. The recent tree-ring data consisting of 118 trees originate from Helama et al. (2014, 2016).

Results

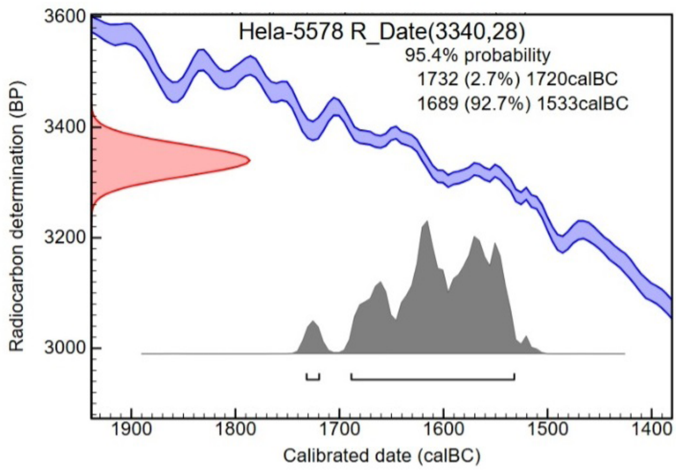
A disk sample sawn from the unearthed subfossil oak trunk was used for ^{14}C and tree-ring analyses. Radial growth of the oak was investigated using tree-ring data, portraying growth variations on inter-annual to longer scales (Fig. 4a). The mean growth record containing 154 rings (Fig. 4b) showed that the tree had reached maturity. The widths of the 25th to 55th rings of the sample (counted from the pith) were markedly wide, with notable variability, indicating an unstable growth phase from which the tree had nevertheless survived, as it continued to grow for at least the next 100 years. The growth level of the subfossil oak was markedly reduced, in comparison to recent oaks investigated previously from the same region (SW Finland). That is, the growth of both healthy and declining oaks representing six sites was notably higher than the growth measured from the subfossil specimen (Fig. 4c).

Regarding the ^{14}C determination, the dating resulted in an uncalibrated age of 3340 ± 28 BP (Table 1). Based on general ^{14}C calibration curve (Klein & al. 1982), this age appears to roughly correspond to calendar year dates between 1850 and 1550 cal BC. Next, the ^{14}C date was calibrated using IntCal20 curve. This more sophisticated analyses resulted in an age range of 1732–1532 cal BC. However, a narrower age range from 1689 to 1532 cal BC comes with higher probability (Fig. 5), indicating that the subfossil trunk had preserved at least 3500 years in the sediment. Considering the 150-year lifespan (see Fig. 4) of the tree and that the ^{14}C dating was based on a fragment of wood from the outermost part of the cross-section (Fig. 3), these results mean that the analysed oak grew somewhere between the 17th and 15th BC centuries.

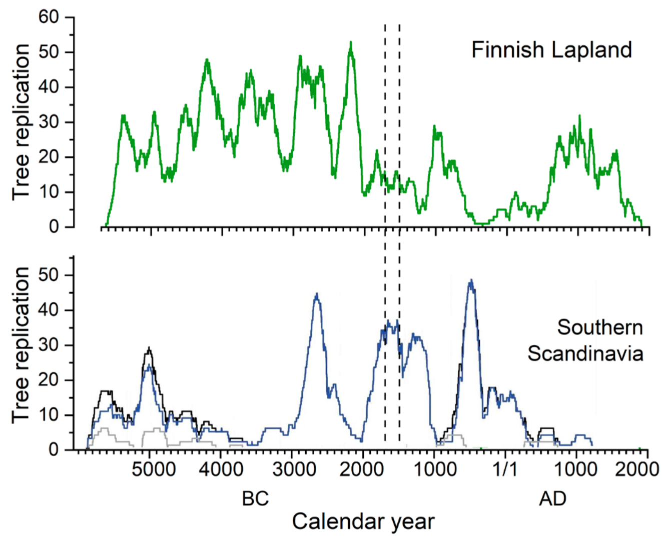
Table 1. Determination of radiocarbon age of the sample under investigation characterised using the sample ident (Lab ID) from the Laboratory of Chronology (University of Helsinki), sample material, uncalibrated age BP (uncal BP; before AD 1950), and calibrated BC years (cal BC) with two-sigma (94.5%) age-range using the OxCal software (Bronk Ramsey, 1995, 2009) and initially the Northern Hemisphere IntCal20 ^{14}C calibration curve (Reimer et al. 2020).

Lab ID	Material	uncal BP	cal BC (94.5%)
Hela-5578	Subfossil oak	3340 ± 28	1732-1720 (2.7%) 1689-1532 (92.7%)

► **Fig. 5. Radiocarbon calibration of the date 3340 ± 28 BP using the Oxcal software (Bronk Ramsey, 1995, 2009) and Northern Hemisphere IntCal20 14C calibration curve (Reimer et al. 2020). Calibrated calendar years (cal BC) show an age range between 1732 and 1533 cal BC.**



► **Fig. 6. Subfossil tree records. Depositional history of Scots pine from lacustrine sites in Finnish Lapland (Helama et al. 2004; Helama & Oinonen 2019) and peatland oaks from southern Scandinavia (Edvardsson et al. 2024) over the past 7600 years. The vertical dashed lines indicate the age range of the radiocarbon dated subfossil oak from Kemiönsaari site. Green and blue samples are dendrochronologically dated. Grey samples are radiocarbon-dated, the black line depicting the sum of both types of chronologies (lower plot).**



The dating position was further compared with records of subfossil oak and pine tree availability from Holocene sedimentary deposits in southern Scandinavia and Finnish Lapland, respectively (Fig. 6). It appears that the oak of this study was growing during a period when the number of northern pines was reduced, in comparison to the levels predating 2000 BC. By contrast, this was a period when the number of southern oaks was much increased. Combined, these findings could indicate relatively cold and humid climatic conditions. Moreover, the oak recovered from Kemiönsaari site appears to originate from a period when the availability of subfossil oak trees was generally increased, given that site conditions controlling the oak regeneration were similar in southern Scandinavia and Finland.

The subfossil oaks – how they came to preserved in the soil?

The postglacial warming and rapid oak expansion were followed by conditions less favorable to oaks and significant stepwise cooling of climate led to the regression of the oak trees and oak stands. As shown here, some of the ancient oaks from more beneficial climate periods may still be found as subfossils in the former basins of sea or lakes. Especially in the peatlands the tree trunks may remain in a relatively good shape, as our oak specimen from the Kemiönsaari demonstrates. The mechanisms how the oak trunks were preserved thousands of years locally in subsoil conditions could now be clarified in more details.

The meandering rivers may also soon hide fallen trees under the preserving sand or silt cover. In the northern Finland, the meanders have been the main depositional environment, where fallen pine (*Pinus sylvestris*) trunks have preserved in subsoil conditions in the riverbanks (e.g. Koutaniemi 1987). In most cases, the soil there has mainly been sandy. Also in Latvia oak trunks have been found from the deposits of meandered rivers (Vitas & al. 2023). Another type of depositional environment has been demonstrated for oaks n central Europe where the die-off seems to occur more gradually. As a function of the bog development, the wet Sphagnum moss can surround the base of the trees, which in the beginning had grown on the mineral soil in the process which is killing the trees slowly. In southern Scandinavia, in Scania and Denmark, from an area of 300 km × 500 km, there are several hundreds of oak trunks excavated from the peatlands (Edvardsson & al. 2024).

In the southern Finland, the same can occur at least for pine, spruce, aspen (*Populus tremula*), birch (*Betula*), willow (*Salix*) and alder (*Alnus*). Regarding the death of the studied oak, we make a short note on the coincidence of its dating position in relation to the mid-second millennium BC event Thera (Santorini) eruption which may have been the largest known Holocene volcanic event (Johnston & al. 2014). Reductions in solar radiation reaching the Earth's surface and in summer temperatures are typically observed for 1–2 years after major volcanic eruptions (Robock 2000) and such effects have most likely been sizeable also after the Thera eruption. While the deposits resulting from the Thera eruption have been produced in several individual study, van der Plicht & al. (2020) gave an average radiocarbon date of the deposits as 3350 ± 10 BP, that correlates remarkably with the dating of the oak (3340 ± 28 BP). Considering that the radiocarbon sample used to data the oak specimen represents its terminal tree-rings (see Fig. 3), it cannot be ruled out that the post-eruption cooling and reductions in irradiance may have played a role in ecophysiological processes leading to oak's final life stage and, eventually, death.

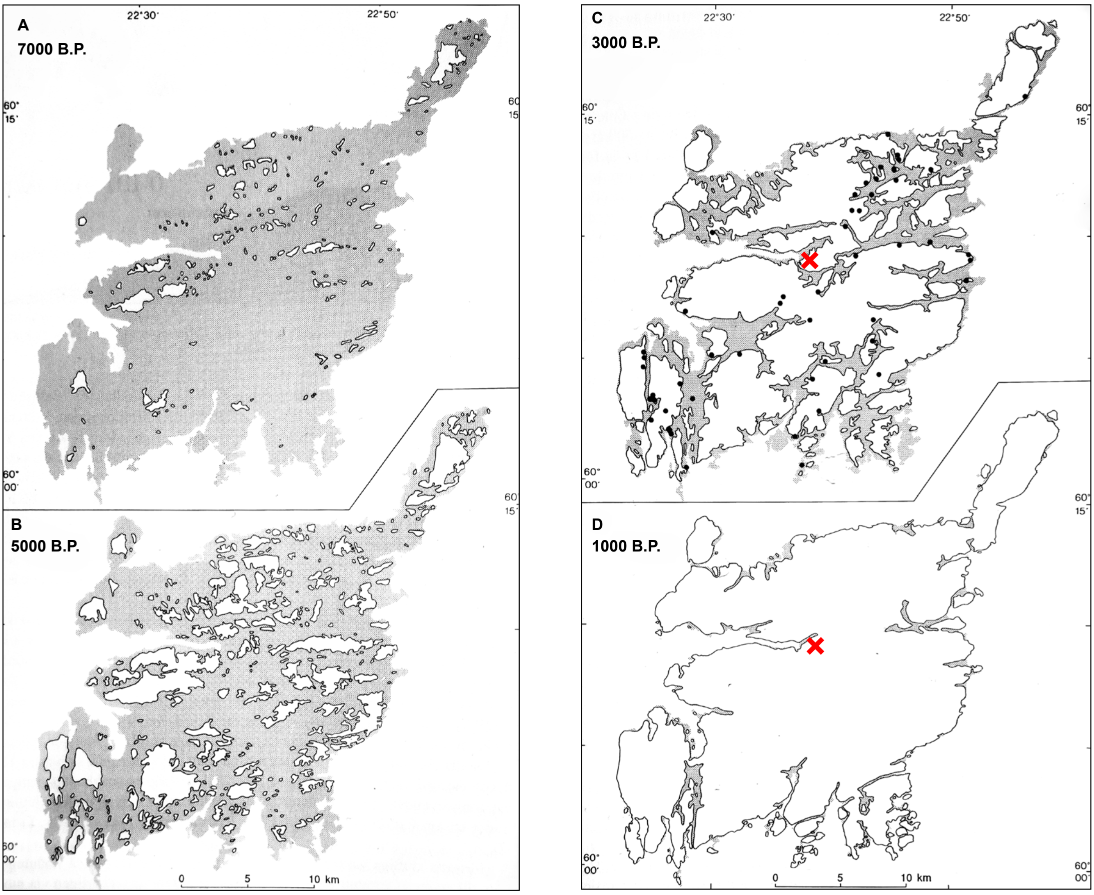
The Kemiönsaari oak trunks may first have fallen from the waterfront to the coastal waters and becoming covered first by the water and relatively soon by wet mud. The water body may first have been a small bay or lagoon of the Baltic, being then cut off from the sea as a small lake or pond, slowly transforming into a bog or fen. Covered first by water, then mud and at last overgrown by the moist peat the oak trunks could resist decay in the bog soil, oxygen lacking circumstances for a long time.

The dark colour of our sample (Fig. 3) is typical of subfossil oaks (Pukienė 2003) to the extent that such oaks have been occasionally called "black oaks" (Kalicki and Krąpiec 1995) and even used to manufacture black chess pieces (Parvilahti 1958). Even so, the darkness itself may be a poor indicator of the age (Pukienė 2003). Instead, the tone of the colour may be more directly related to the interactions between the water ferrous compounds and the tannins of the matter (van Bürck & al. 2012).

The Holocene sea-level changes and the land uplift

The main postglacial causes in the formation of Kemiö islands originate from the changing relative sea-level and the land uplift. The fastest changes in the Baltic Sea level have occurred due to the openings of the waterways to the Atlantic. In the beginning of Yoldia phase the highest bedrock hill tops of the Kemiö islands were 40 m under the sea level. Early this phase suddenly 'Billingeporten' opened up for a temporary stream through in Närke, Middle-Sweden to the Atlantic and the Yoldia sea-level sank quickly by 26–27 m. Another factor comes from the land uplift after the massive, 2–3 kilometers thick glaciers had first pressed the Kemiö region about downwards by 300 m and then, when the ice sheets retreated, the region experienced an uplift rate as fast as about 3.5 m in the first postglacial centuries. The uplift stopped the stream in Närke, but after few centuries land connection between Scania and Danmark was pierced by rising sea level and a new waterway, Stora Bältet, opened up 9300 years ago. (Tikkanen & Westerholm 1992). In streaming salty water caused a new phase, the Litorina Sea development, about 8500 years ago.

First, the land uplift revealed bare bedrock hill tops above sea-level roughly 8000 BP. At 7000 BP, in the early Baltic Litorina phase, only some



Credit: Tikkanen & Westerholm 1992: Kimitoön. En regionalgeografisk analys. Bidrag Kännedom Finlands Natur Folk 143.

Fig. 7. The land uplift of Kemiö islands after the ice age presented in 2000-year intervals: 7000 (A), 5000 (B), 3000 (C) and 1000 (D) BP. At 7000 BP only the highest landcover tops peaked out as scattered islands. At 5000 BP, tens of smaller islands had exposed from the sea and the topographically highest areas of the archipelago were already seen as larger separate islands. At 3000 BP, the full length of Norrlångvik "fjord" was still under the water, but the watercourse through the island was already cut out. The megafossil oak site had emerged above the sea level several hundreds of years ago. At 1000 BP, the main features of Kemiö islands were as they are today. The dark grey background refers to the current coastline of the Kemiö islands. Black points in the map C refer to the ancient, mainly Bronze age tombs found in the islands. The megafossil oak site marked with X in maps C and D. Tikkanen & Westerholm 1992.

of the slowly largening islands peaked out from the sea in the Kemiö area. At approx. 5000 BP, tens of smaller islands had already emerged from sea. It is anticipated that most likely also the megafossil oak site had emerged above the sea level by then. At 3000 BP, the main features of the Kemiö island had been exposed, only the main agricultural areas, most of the cultivated clay fields lying still under the sea water. The radiocarbon dating of the found oak is dated to 3340 BP, by which date the site was probably forested, near Norrlångviken, for a long period. Spruce was slowly invading the Kemiö islands probably about that time based on increasing *Picea* pollen amounts found in many bogs (e.g. Alenius 2008). At 1000 BP, the features of the Kemiö islands are mainly congruent to the topographic map of today. (Tikkanen & Westerholm 1992). Here should be noted that the land uplift maps in Tikkanen & Westerholm (1992) presentation are mainly based on Glückerts (1976) results. The overall accuracy in the sea-level change data is still adequate for many purposes, but the recent studies have also shown anomalies detected in Finnish sea-level data (e.g. Miettinen & al. 2007).

The natural distribution and the regeneration of oaks in Finland was until the early 1970's mainly limited to site most beneficial for the species in the SW coastal areas, to the oak groves. The rapid expansion of the oaks from the natural and cultivated stands in the last decades has most probably been caused by the climate change. The speed of the recent spreading of the oaks has been the one of the most astonishing trends of the vegetational changes in the nature of the SW-Finland. An increasing number pf young oak plants have appeared again in the cultivated forests around Norrlångviken, but their success can vary due to the long shadow of the old spruces. Any old-grown oaks are not known to have thrived nearby the megafossil site at least from the early 1900's (Sjöberg 2019).

Ecology and genetics linked to the return of the oaks

The postglacial history related to ecological and genetical aspects of the common oaks should also be noted here. This review suggests that the Kemiönsaari site may actually belong to latest areas where oak arrived in SW Finland, around 5500–4500 years ago. The delay was likely related to the land uplift.

The oaks have suggestively arrived, independently, from the eastern and western source regions. When the western migration to the study region may have occurred is more uncertain, mainly due to the fairly complex postglacial transformation of the Åland archipelago with tens of thousands of islands rising from the sea. When was the archipelago a suitable habitat for example for the European jays (*Garrulus glandarius*), the main agent to carry the acorns over the sea from the west? It is generally suspected that a jay cannot deliver the acorns more than approx. 20 km. Could a longer seed conveyance by birds be possible, is another question. Many stepping-stone islands were certainly needed for the oaks to overstep the sea between Sweden and Finland. Sometimes even hydrochory has been proposed, but the well-known fact is that while the bad acorns tend to float, the viable ones are more likely to sink. In this sense, the later an earlier arrival route via the Karelian isthmus from the eastern source regions would be a more plausible proposition.

During the ice ages, the oaks escaped from the coldness mainly to the three faraway refugial destinations located in the mild enough Mediterranean area. In the longtime isolation represented by separate shelters, a special genetical chloroplast cytotypes were developed. But probably the main cytotypes were present already before the last glacial cycle (Ferris & al. 1998). After tens of thousands of years, the cytotypes from each main refuge can still be detected by analyzing the currently growing oaks using the methods based on the chloroplast DNA. The cpDNA is conservative, not exposed to recombination, and it is inherited via maternal genotype (Ferris & al. 1998).

When the climate warmed up again and the continent was freed from the ice sheets, the oaks could produce pollen and acorns on their journey further to the north. The northward migration should have mainly been assisted by the jays on average distance of at least some kilometers in each tree generation. The oaks in the Kemiönsaari region belong to the western refugial source from south of the Alps. Even today, the astonishingly clear border between the eastern and western cytotypes may be detected in Tammisaari (Ferris & al. 1998), in the southern Finland, which is located approx. 40–50 km from the megafossil oak site.

Recent genetical studies show how the common oak and its closest relative, the sessile oak, may have conjointly moved to the north (Leroy & al. 2017, 2020a, b). They can easily hybridize with each other, the sessile oak most often as pollen donor to common oak. It seems that both species may have gained ecological advantage of the gene flow during the transition in the form of adaptive introgression. In the central Europe, the common oak prefers wetter sites than sessile oak. Hybridizing with common oak, the sessile oak has gained a genome chance to manage and survive in such unfavorable conditions. A tendency to the backcrossing and the maintenance of species barriers seems to have kept the oak species genome separate, although they commonly share for example the chloroplast cytotypes. In the SW Finland spruce has in any case a clear competitive advantage in such wetter sites, for which reason the common oaks can be found here in drier soils, alongside the pines (e.g. Väre & al. 2021).

In their Finnish habitats, the common oaks have shown some infrequent features more typical to the sessile oaks (*Q. petraea*) including for example late leaf-unfolding-date, relative short pedicel, long leaf stalk and rarely stellate hairs underneath the leaves (e.g. Väre & al. 2021). Approx. 8000-year-old oak leaf macrofossil found from the Ancylus clay of Lammaslampi Lake, near Helsinki, shows the lateral leaf segment typical to the sessile oaks (Aalto & Uusinoka 1978). The finding implied for the postglacial occurrence of sessile oaks or their hybrids in southern Finland during the periods climatically more favourable to this oak species.

Palaeoecological evidence of the former woodland cover in the Salo-Kemiö region

The postglacial expansion of the oaks to northern Europe and the former wider distribution of the species during the mid Holocene have mostly been studied from the pollen deposits i.e. microfossils. In southern Finland, the oak pollen is well represented in many of the core samples retrieved from the bogs in conjunction to investigations of the archaeology and settlement history of the region.

The palynological studies near the megafossil oak site have been carried out in Stormossen, Mossdalen, Ilsokärret, Labboträsket, Söderbyträsket and Gärdorna (Fig. 8). These studies indicate a sustained presence of oaks in the Kemiö islands (Glückert 1976, Asplund and Vuorela 1989, Alenius 2008). Overall, similar findings are evident in the larger Salo-Kemiö region represented by pollen studies from Vohtenkellarinsuo in Paimio and Lemunsuo in Perniö (Vuorela 1983, 1985). The results from Isokylä and Pukkila in the Salo region reinforce the view (Tolonen 1985a, b). All these peatland locations lie about 30-40 km from Norrlångviken and happen to situate nearby (0–5 km) the Turku-Karjaa railway (Fig 8).

Especially Lemunsuo in Perniö pollen sites show signs even of such thermophilous species as hornbeam (*Carpinus betulus*) and beech (*Fagus sylvatica*), suggesting that such trees may have been formerly present in or nearby the sites (Vuorela 1985). The pollen counts exceed the threshold values for both species demonstrating their local occurrence during the warmest Holocene intervals. Possibly, it cannot be ruled out that the pollen fallout may also have arrived as pulses of long-distance transport for example from Poland, where the pollen ratio between these two species have remained at similar levels. In addition to these indications, minor pollen concentrations of the hornbeam have been detected also from other bogs in the region including Isorahka in Perniö, Stormossen in Kemiö and Karevansuo in Masku (Glückert 1976).

All the discussed sites represent peatlands, which hints at the possibility of megafossils to be retrieved from the corresponding natural archives, however, little or no attention seems to have been paid for this aspect during the former fieldworks. As an encouraging anecdote, there appears to be several notes of wood fragments found from different depths in nearly of the abovementioned pollen studies during the coring of the bogs. Without megafossils, or at least macrofossils, the enigma, the former occurrence of the oaks and the other thermophilous tree species rare to the region today, remains to be indicated only by microfossils. New methods make it possible to provide more specific details on the agricultural history and the local settlement history (Alenius & al. 2017). Whether the future development will be able to more accurately disentangle the evidence of long-distance transport remains to be seen.

What is known of the subfossil wood findings from Finland?

The macrofossils or megafossils of oaks, or even other tree species, have seldomly reported from the Finnish bogs, despite the fact that the deposition of tree trunks to bogs is a well-known natural phenomenon in Finland. An ancient ’lieko’ word has often been used for these tree remains, and the same word is nowadays understood as a waterlogged wood, most often referring to the pine buried in *Sphagnum*-moss. Etymology of the word ’lieko’ comes from even more ancient German word ’lēgō’ (’am Boden oder im Wasser liegender, verfaulter Baumstamm’) (SES). Regarding conifers, megafossil assemblages of Scots pine have been recovered from NW Finnish Lapland and SE Finland, indicating peatland pine phases

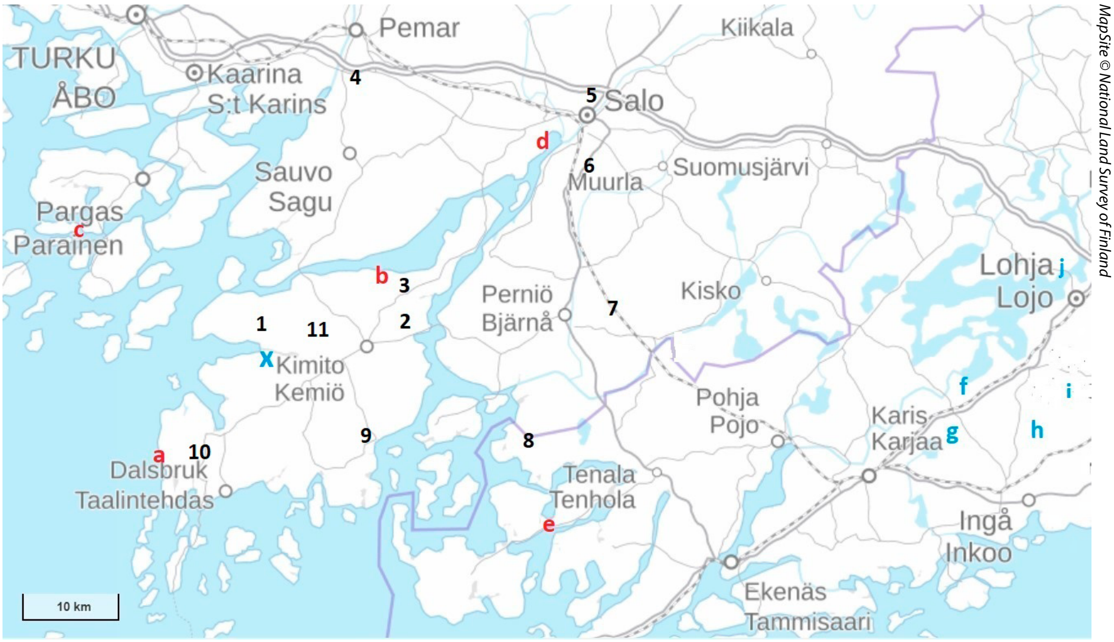


Fig 8. Archaeology and settlement history has been investigated by pollen studies in several bogs in the Salo-Kemiö region. The sites mentioned in the text include: 1. Stormossen, Kemiö, 2. Mossdalen, Kemiö, 3. Ilsokärret, Kemiö, 4. Vohtenkellarinsuo, Paimio, 5. Isokylä, Salo, 6. Pukkila, Salo, 7. Lemunsuo, Perniö, 8. Kuivaston Isosuo, Tenhola, 9. Labboträsket, Västanfjärd, 10. Söderbyträsket, Dragsfjärd, 11. Gärdorna, Kemiö. All these sites show signs of oaks in the region. Some currently most prominent oak groves in the coastal areas of SW Finland are also shown as follows: a. Ekhamn, Kemiö, b. Lappdahl, Kemiö, c. Lenholm, Parainen, d. Vaisakko, Salo, e. Framnäs, Tenhola. The sites with oak macrofossils studied by Gunnar Andersson (1898) in the Lohja region are shows as follows: f. Anta, Lohja, g. Bråberg, Lohja, h. Stormossen, Inkoo, i. Stubbängen Siuntio, j. Humppila, Lohja. Our megafossil site is shown with a cross (X) in the main island of Kemiö (Kimito in Swedish).

dated to 4900–3400 cal BC and around AD 1000, respectively (Helama & al. 2017, 2023).

Regarding the regions neighboring our megafossil oaks site, Aartolahti (1965) has systematically presented also all the wood fragments detected from the different bog layers, from the limnic basins to the uppermost layers, from the SW Häme province. Of the listed 115 bogs of the survey, the nearest and largest, Torronsuo, lies in Somero, about 85 km from the megafossil site in Kemiönsaari. Indeed, according to the discussed evidence, the SW Häme province belongs to areas where oak could have formerly grown during the climatically favourable Holocene periods.

Further details of Aartolahti's (1965) investigations were collated into one table representing the 11 ombrogenous bogs and peatlands layers of the altogether 115 studied sites. Most of his observations of wood fragments were made from the early *Carex*-turf layers. More infrequent observations were also made on wood fragments from the *Sphagnum* -turf and *Sphagnum* -moss layers. In Rahamaansuo and Viksberginsuo bogs in Tammela, wood was found only in the uppermost layers (Aartolahti 1965). In any case, the ligneous material he detected may mostly have been pine, spruce and birch wood.

In the coastal areas of north Satakunta province land uplift is still occurring at approx. double as fast than in SW Finland, with a rate of 6 mm/year. In Kemiönsaari, the rate of uplift has recently been around 3 mm/year and in the bottom end of Gulf of Bothnia even 9 mm/year (Ekman & Mäkinen 1996). The succession from the sea bays to isolated lakes and further to bogs is overall in much more acute phase in the northern Satakunta region than in the inland plateau typical to the SW Häme (Aartolahti 1965).

Rare oak macrofossils seldom found in Finland

A Swedish botanist, dr. C. F. Gunnar Andersson made a short-term macrofossil study in southern Finland in the late 1800's. Originally, he had begun plant macrofossils studies already in Scania, Sweden. In Finland, his fieldwork and laboratory analysis took 7 weeks in the summer of 1894 and was assisted with the Finnish enthusiasts. In his publication, Andersson (1898) could demonstrate how the clay and limnic sediments of Ancylus- and Litorina-periods he has investigated in the southern coastal lake and bog basins in southern Finland contained various macroscopic plant relics of different plant species, including the oaks.

All the observations Andersson (1898) made on oak relicts originate from the south of Lake Lohja, which is one of the most eutrophic regions in Finland. The oak macrofossils were found from Anta and Råberg bogs, nearby Svartå village in Karjaa, Stormossen nearby Lilltötar village in Lohja and also Stubbängen, nearby Kalkulla farm in Inkoo (Fig 8). It seems that all of the sites represented by oak relicts had been already then at least partly cleared and under cultivation as fields. In his day, only a minor part of these sites was still bogs or even under the water. For more detailed information, one should go back to old farmhouse scale maps from the beginning of the 1900's, to ensure the exact condition of the sites.

In the forests nearby the sites were in any case mostly dominated by spruce, pine and birch, but no remarks of living oak or linden trees was made. It seems that no oak megafossils were found (Andersson 1898). All the sites with oak relicts occurred in conjunction with agricultural fields at least partly, like in the Kemiönsaari.

As for the other macrofossil oak finds, the abovementioned study by Aalto & Uusinoka (1978), demonstrating the approx. 8000-year-old oak leaves, should be borne in mind.

Hidden subfossils may appear from under the ground in excavation sites

Construction of the railways was underway in Finland approx. 160–170 years ago. We note that this phase could represent one candidate activity for finding subfossil wood material or other relics in larger national scale. In fact, our investigation of newspaper article of that period shows that there appears to be short reports from the construction work sites published in the old press. However, these news seem to usually cover findings of rare human artefacts retrieved from the railway embankment soil, for example wooden carvings (Anonymous 1897b) or stone ax and chisel (Anonymous 1897a). It seems that the archaeological items had more value in those early press days.

Due to the circumstances the rails had to be constructed also through the wetlands and several rivers had to be surpassed while the work for the railways was under progress. The Turku-Karjaa railway was built between the years 1897 and 1902, and crossed also several peatlands, including Lemunsuo in Perniö. This is a bog site with wood remnants, albeit the findings have not been reported in details (Vuorela 1985). During the railway construction work from Salo to Perniö, there occurred an accident in 1900, when the railway embankment was swallowed under the wet surface of the construction site (Anonymous 1900). The accident took place nearby the existing remnants of the former larger oak forest stand opposite side of Lake Pohjanjärvi wetland. We note that the area is certainly one of the strongest candidates for locating new findings of oak megafossils nearby the study region.

Apart from railway construction, many hundreds of thousand kilometers of ditches have been produced for the forested bogs in Finland, to ensure the tree production even in the mires and wetlands. Moreover, peatlands have been taken to the peat production – tens thousands of hectares during the last decades – about 0,5% of total bog area in Finland – but only very few scientific articles have touched the ligneous material, i.e. the 'lieko' wood, found from the different soil layers. Even so, it is certain that quite a high number of ancient wood material, including pines and oaks, has been chipped and burned as part of the energy production, without becoming included in any scientific research.

Norway spruce, the competitor of oaks, arrived to the eastern Finland approx. 6500 years ago (Seppä & al. 2009). Due to the land uplift history (see above), the Kemiö islands were probably invaded by this species not earlier but approx. 3100–3400 years (e.g. Asplund & Vuorela 1989, Glückert 1976), the dating that could possibly be elaborated by the developed research methods (e.g. Alenius & al. 2017).

We can only imagine how the forests looked when the specimen represented today by the megafossil retrieved from the Norrlångviken was a young tree. So far, most of the knowledge of tree and forest history stems from the palynological research as part of the archaeological and settlement history studies. Yet, it would be important to focus on understanding how the oak trees may have managed to survive in the changing climates of the past. The oak trunks hidden still in the bogs may give us great retrospective perspectives to what might be happening to our remaining oak trees and stands today and even in the foreseeable future under the scenarios of changing climate. Considering the rarity of oak megafossil and even macrofossil findings, the scientific values of every single new specimen from Finnish sites can hardly be underestimated. Such findings will detail the postglacial and Holocene history of the species that is otherwise told by pollen counts, to account for the past distribution and survival history of this important European tree species – the common oak.

Acknowledgements. Björn Sjöberg is thanked for providing the subfossil oak sample for this research, for field guidance and for the Elis Sjöberg's details on the original excavation. Reviewer comments are acknowledged. We also thank Eero Tirkkonen for information on the radiocarbon sample. The work of SH was supported by the Research Council of Finland (339788. 355268).

References

Aalto, M. & Uusinoka, R. 1978: 8000-year-old Quercus and Myriophyllum leaves from bottom of clays of a lake in Southern Finland. − Memoranda Societas pro Fauna et Flora Fennica 54(1): 7–11.

Aartolahti, T. 1965: Oberflächenformen von Hochmooren und ihre Entwicklung in Südwest-Häme und Nord-Satakunta. − Fennia 93: 1−268 + Karten, Tabellen.

Alenius, T. 2008: The palaeoecological study of tree mires on the island Kemiönsaari, in SW Finland. – Appendix 2. In: Asplund, H., Kymittae. Sites, centrality and longterm settlement change in the Kemiönsaari region in SW Finland. – Annales Universitatis Turkuensis B 312: 565−584.

Alenius, T., Haggren, G., Koivisto, S., Vanhanen, S. & Sugita, S. 2017: Landscape dynamics in southern Finland during the Iron Age and the Early Modern Era – Pollen-based landscape reconstruction (LRA), macrofossil and historical data from Western Uusimaa. − Journal of Archaeological Science: Reports 12: 12−24. doi.org/10.1016/j.jasrep.2016.11.041

Andersson, G. 1898: Studier öfver Finlands Torfmossor och Fossila Kvartärflora. − Bulletin de la Commission Géologique de Finlande 8: 1−210.

Anonymous 1897a: Fynd. [Short news from old press: Stone ax or stone hammer and stone chisel found from railway embankment construction site about 6 km from Turku. In Swedish]. − Åbo Underrättelser 14.9.1897.

Anonymous 1897b: Muinaismuistoyhdistys. [Short news from old press: From railway embankment site in 8 m depth found wood carving in Skuru, nearby Karjaa. In Finnish]. − Uusi Aura 27.11.1897.

Anonymous 1900: Turun-Karjan rata. [Short news from old press: The swallow under the railway embankment construction between Perniö and Salo. The accident site lies nearby existing remnants of the former larger oak forest stand. In Finnish]. − Uusi Aura 9.2.1900.

Asplund, H. & Vuorela, I. 1989: Settlement studies in Kemiö – Archaeological problems and palynological evidence. − Fennoscandia archaeologica VI: 67−79.

Bronk Ramsey, C. 1995: Radiocarbon Calibration and Analysis of Stratigraphy: The OxCal Program. − Radiocarbon 37: 425−430. doi.org/10.1017/S0033822200030903

Bronk Ramsey, C. 2009: Bayesian Analysis of Radiocarbon Dates. – Radiocarbon 51: 337−360. doi.org/10.1017/S0033822200033865

Bürck, U., van, Wagner, F.E. & Lerf, A. 2012: Mössbauer studies of subfossil oak. − Hyperfine Interact 208: 105–110. doi.org/10.1007/s10751-011-0439-9

Ducousso, A. & Bordacs, S. 2003: EUFORGEN Technical Guidelines for Genetic Conservation and Use for: Pedunculate and Sessile Oaks (Quercus robur and Quercus petraea). – 6 p. International Plant Genetic Resources Institute, Rome.

Edvardsson, J., Christensen, K., Jensen, J.O., Lindersson, H. & Baittinger, C. 2024: Exploring potential for a 9000-year tree-ring chronology consisting of subfossil oak material from southern Scandinavia. – Dendrochronologia 88. doi.org/10.1016/j.dendro.2024.126268

Ekman, M. & Mäkinen, J. 1996: Recent postglacial rebound, gravity change and mantle flow in Fennoscandia. – Geophysical Journal International 126: 229−234.

Ferris, C., King, R.A., Väinölä, R. & Hewitt, G.M. 1998: Chloroplast DNA recognizes three refugial sources of European oaks and suggests independent eastern and western immigrations to Finland. − Heredity 80: 584−93.

Glückert, G. 1976: Post-Glacial shore-level displacement of the Baltic in SW Finland. − Annales Acad. Scient. Fennicae. Ser A. III, 118: 1−92.

Haneca, K., Čufar, K. & Beeckman,H. 2009: Oaks, tree-rings and wooden cultural heritage: a review of the main characteristics and applications of oak dendrochronology in Europe. − Journal of Archaeological Science 36: 1−11. doi.org/10.1016/j.jas.2008.07.005

Helama, S. & Oinonen, M. 2019: Exact dating of the Meghalayan lower boundary based on high-latitude tree-ring isotope chronology. − Quaternary Science Reviews 214: 178−184. doi.org/10.1016/j.quascirev.2019.04.013

Helama, S., Herva, H., Uusitalo, J., Moir, A., Mielikäinen, K., Nöjd, P., Oinonen, M. & Sutinen, R. 2023: Depositional history of peatland pines (Pinus sylvestris L.) in NW Enontekiö, Finnish Lapland: implications for Middle Holocene drought and temperature fluctuations. − Boreas 52: 427–439. doi.org/10.1111/bor.12616

Helama, S., Lindholm, M., Timonen, M. & Eronen, M. 2004: Dendrochronologically dated changes in the limit of pine in northernmost Finland during the past 7.5 millennia. − Boreas 33: 250−259. doi.org/10.1111/j.1502-3885.2004.tb01145.x

Helama, S., Luoto, T.P., Nevalainen, L. & Edvardsson, J. 2017: Rereading a tree-ring database to illustrate depositional histories of subfossil trees. − Palaeontologia Electronica 20 (1): 1−12. doi.org/10.26879/696

Helama, S., Sohar, K., Läänelaid, A., Mäkelä, H.M. & Raisio, J. 2016: Oak decline illustrated through plant-climate interactions near the northern edge of species range. – The Botanical Review 82: 1–23. doi.org/10.1007/s12229-016-9160-3

Helama, S., Läänelaid, A., Raisio, J., Mäkelä, H.M, Hilasvuori, E., Jungner H. & Sonninen, E. 2014: Oak decline analyzed using intraannual radial growth indices, $\delta^{13}C$ series and climate data from rural hemiboreal landscape in southwesternmost Finland. – Environmental Monitoring and Assessment 186: 4697−4708.

Helama, S., Raisio, J., Sohar, K. & Läänelaid, A. 2018: Tammen rinnankorkeusikä ja rungon ympärysmitta. Abstract: Breast height age and circumference of pedunculate oak. – Sorbifolia 49 (4): 171–181.

Holmes, R.L. 1983: Computer-assisted quality control in tree-ring dating and measurement. – Tree-Ring Bulletin 43: 69–75.

Johnston, E.N., Sparks, R.S.J., Phillips, J.C. & Carey, S. 2014: Revised estimates for the volume of the late bronze age minoan eruption, santorini, Greece. – Journal of the Geological Society, London 171: 583−590.

Kalicki, T. & Krąpiec, M. 1995: Problems of dating alluvium using buried subfossil tree trunks: lessons from the "black oaks" of the Vistula Valley, Central Europe. – The Holocene 5: 243−250. doi.org/10.1177/095968369500500213

Klein, J., Lerman, J.C., Damon, P.E. & Ralph, E.K. 1982: Calibration of radiocarbon dates: tables based on the consensus data of the Workshop on Calibrating the Radiocarbon Time Scale. – Radiocarbon 24: 103−150. doi.org/10.1017/S0033822200005002

Koutaniemi, L. 1987: Paleohydrology of the rivers Ivalonjoki and Oulankajoki, Finland. – Fennia 165(1): 89−132.

Leroy, T., Louvet, J-M., Lalanne, C., Le Prevost, G., Labadie, K., Aury, J-M., Delzon, S., Plomion. C. & Kremer A. 2020a: Adaptive introgression as driver of local adaptation to climate in European white oaks. – New Phytologist 226(4): 1171−82. doi.org/10.1111/nph.16095

Leroy, T., Rougemont, G., Dupouey, J.-L., Bodénès, C., Lalanne, C., Belser, C., Labadie, K., Le Provost G., Aury J.-M., Kremer A. & Plomion, C. 2020b: Massive postglacial gene flow between European white oaks uncovered genes underlying species barriers. – New Phytologist 226(4): 1183−97. doi.org/10.1111/nph.16039

Leroy, T., Roux, C., Villate, L., Bodénès, C., Romiguier, J., Paiva, J.A.P., Dossat, C., Aury, J.-M., Plomion, C. & Kremer, A. 2017: Extensive recent secondary contacts between European white oaks species. – New Phytologist 214(2): 865−78. doi.org/10.1111/nph.14413

LUOMUS 2025: Radiohiilimäärityksiä. Kemiö, tammi, puu. − Tutkimusraportti 2025-7-3.

Miettinen, A., Jansson, H., Alenius, T. & Haggren, G. 2007: Late Holocene sea-level changes along the southern coast of Finland, Baltic Sea. – Marine Geology 242: 27−38.

Millard, A. 2014: Conventions for reporting radiocarbon determinations. − Radiocarbon 56(2): 555−559.

Parvilahti, U. 1958: Berijan tarhat: havaintoja ja muistikuvia Neuvostoliitosta vuosilta 1945−1954. – 344 p. Otava, Helsinki.

Plicht, J., van der, Bronk Ramsey, C., Heaton, T.J., Scott, E.M. & Talamo, S. 2020: Recent Developments in Calibration for Archaeological and Environmental Samples. − Radiocarbon 62: 1095−1117. doi.org/10.1017/RDC.2020.22

Pukienė, R. 2003: Sub-fossil oak timbers from the Mid Holocene as an evidence for Lithuanian forest history. − Baltic Forestry 9: 71−75.

Reimer, P.J., Austin, W.E.N., Bard, E., Bayliss, A., Blackwell, P.G., Bronk Ramsey, C., Butzin, M., Cheng, H., Edwards, R.L., Friedrich, M., Grootes, P.M., Guilderson, T.P., Hajdas, I., Heaton, T.J., Hogg, A.G., Hughen, K.A., Kromer, B., Manning, S.W., Muscheler, R., Palmer, J.G., Pearson, C., van der Plicht, J. , Reimer, R.W., Richards, D.A., Scott, E.M., Southon, J.R., Turney, C.S.M., Wacker, L., Adolphi, F., Büntgen, U., Capano, M., Fahrni, S.M., Fogtmann-Schulz, A., Friedrich, R., Köhler, P., Kudsk, S., Miyake, F., Olsen, J., Reinig, F., Sakamoto, M., Sookdeo, A. & Talamo, S. 2020: The IntCal20 Northern Hemisphere Radiocarbon Age Calibration Curve (0–55 cal kBP). − Radiocarbon, 62(4): 725−757. doi.org/10.1017/RDC.2020.41

Robock, A. 2000: Volcanic eruptions and climate. − Reviews of Geophysics 38: 191−219. doi.org/10.1029/1998RG000054

Sjöberg, E. 2019: En ek ur det förgångna. [Former landowner Elis Sjöbergs remarks of the found two oaks and of the find site. In Swedish]. – 1 p. Nedtecknat 2019.

Seppä, H, Alenius, T, Bradshaw, R.H.W, Giesecke, T. Heikkilä, M. & Muukkonen, P. 2009: Invasion of Norway spruce (Picea abies) and the rise of the boreal ecosystem in Fennoscandia. − Journal of Ecology 97: 629−640. doi.org/10.1111/j.1365-2745.2009.01505.x

SES. Suomen etymologinen sanakirja. Keyword: lieko.

Tikkanen, M. & Westerholm, J. 1992: Kimitoön. En regionalgeografisk analys. − Bidrag till kännedom av Finlands Natur och Folk 143: 1−95.

Tolonen, M. 1985a: Palaeoecological reconstruction of vegetation in a prehistoric settlement area, Salo, SW Finland. − Annales Botanici Fennici 22(2): 101−116.

Tolonen, M. 1985b: Late Holocene vegetational history in Salo Pukkila, SW Finland with particular reference to human interference. − Annales Botanici Fennici 20: 157−168.

Uusitalo J., Arppe, L., Helama, S., Mizohata, K., Mielikäinen, K. & Mäkinen, H. 2022: From lakes to ratios: ^{14}C measurement process of the Finnish tree-ring research consortium. − Nuclear Instruments and Methods in Physics Research B 519: 37−45.

Vitas, A., Daly, A., Läänelaid, A., Mažeika, J., Pukiene, R. & Zunde, M. 2023: Subfossil oaks from riverine sediments of the Seda River in Latvia: The first results of dendrochronological and radiocarbon analysis. − Dendrochronologia 80. doi.org/10.1016/j.dendro.2023.126115

Vuorela, I. 1983: Vohtenkellarinsuo, a bog in Paimio, SW Finland with a cultural origin. – Bulletin of the Geological Society of Finland 55: 57−66.

Vuorela, I. 1985: On the vegetational and agricultural history of Perniö, SW Finland: results of pollen and ash residue analysis 14C dating. − Annales Botanica Fennici 22(2): 117−127.

Väre, H., Saarinen, J., Kurtto, A. & Hämet-Ahti, L. (eds.) 2021: Suomen puu- ja pensaskasvio. Woody Flora of Finland. Third fully revised edition. – Publication of the Finnish Dendrological Society 10: 1−552.