Forest Continuity and Human Impact
- vegetation history of Torup forest, south-western Scania

Skoglig kontinuitet och mänsklig påverkan
- vegetationshistoria i Torup skog i sydvästra Skåne

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Abstract

The aim of this study was to reconstruct the vegetation history of Torup forest in south-western Scania, Sweden. Pollen from a small forest hollow was analysed in order to provide data on long-term local forest history beyond the record of maps and written sources. The pollen record covered 6000 years, of which the results of the past 300 years were compared to the historical record.

During the oldest period (4000-350 BC), the site was a forest with striking abundance of *Alnus* (alder), but also *Quercus* (oak), *Tilia* (lime), *Ulmus* (elm) and *Pinus* (pine) occurred, while herbs and grasses were rare. The forest could be considered “natural” without a major human impact, up to the Bronze Age. At that point, around 350 BC, *Alnus* and *Tilia* decreased and a grazed forest dominated by *Quercus*, *Betula* (birch), and with time *Fagus* (beech), replaced the former non-grazed *Quercus*, *Tilia* and *Corylus* (hazel) forest. *Fagus*, *Carpinus* (hornbeam), cereals, herbs and other anthropogenic indicators established, and the number of species increased very suddenly.

The opening of the forest during the Bronze Age could be seen as the reflection of a changed land use. During the period around year 0, mowing as well as harvesting of leaves for fodder was introduced in Scania. From year 0 to the late Middle Ages, the forest was diminished, and herbs became more abundant. *Fagus* established in Torup around 900 BC, but did not become common until the Middle Ages. The period between the establishment and expansion of *Fagus* is the time when the most charcoal was found, i.e. the period with most forest fires, concluding that beech expanded after the use of slash and burn cultivation stopped. From the 16th century, mainly *Fagus* and *Betula* dominated the forest, while other species decreased rapidly. Starting in 1694, the pollen diagrams could be supported by historical maps. At that point, *Fagus* dominated the forest, although other broadleaves also were common. Conifers were rare in Torup until the last couple of centuries.

Torup forest has a continuity of at least 6000 years, which is very rare in the agricultural areas of southern Sweden. Despite its long forest continuity, the density of Torup forest has fluctuated, from being a rather dense mixed broadleaved forest to an open, grazed forest with numerous herbs, as well as light demanding tree species such as *Quercus* and *Betula*. Using historical maps, it is possible to draw the conclusion that the openness is likely to have been greater than indicated by the pollen diagram.

Introduction

The forests of southern Sweden have experienced great changes in structure and composition since the last glacial. Southern Scania was the first area in Sweden the ice withdrew from, about 17 000 years ago (Lindström et al. 2000, Berglund et al. 2007). Temperate deciduous trees (e.g. *Quercus* (oak), *Ulmus* (elm), *Fraxinus* (ash), *Tilia* (lime) and *Acer* (maple)) reached the area 7000 BC, and dominated the forests for thousands of years (Berglund et al. 2007). The traditional view is that the primeval forests were dense and dark with no, or very sparse, undergrowth. Large mammals were believed to be rare, and forest regeneration should have taken place in gaps caused by for instance storms or trees dying of senescence (Iversen 1973, Regnéll 1989, Vera 2000). The hypothesis was backed up by findings of abundant tree-dependent, but only scarce herb- and dung dependent beetles in sites with low NAP (non arboreal pollen) (≤10 %) (Svenning 2002). Opposite to this, Vera (2000) claimed that most northwestern Europe was an open, savannah-like landscape, opened up by browsing, grazing and trampling of large herbivores. The presence of *Quercus* and *Corylus* (hazel) (which do not regenerate in closed forests) in pollen analyses from large parts of Europe supports this hypothesis (Vera 2000).

Approximately 4000 BC, “landnam” (from ancient Icelandic, meaning, “to take land”), the beginning of an organised agriculture and hence diminishing of forest, started in southern Scandinavia (Berglund 1991, Berglund et al. 2007). The decline was very obvious concerning *Ulmus*, and has been explained with the cutting of forest for creating grazing areas, and coppicing (Iversen 1941; in Vera 2000) as well as by Dutch Elm Disease, and harvesting of elm foliage (Vera 2000). During the following centuries, a dramatic opening of the landscape took place, where *Ulmus*, *Tilia*, *Fraxinus* and *Corylus* decreased (Berglund et al. 2007). In southern Scandinavia, traces of organised agriculture has been seen from 3000 BC (Lindbladh 1998).

Fagus and *Carpinus* (hornbeam) reached southern Sweden around 3000 BC, but did not expand until 0-500 AD. From 1000 AD (Iron Age/Viking Age), *Fagus* peaked and dominated the area, in southern Scania mixed with *Alnus* (alder), *Quercus* and *Tilia* (Lindbladh 1998, Niklasson et al. 2002, Berglund et al. 2007). Still during the 16th and 17th century the *Fagus* forest had a larger distribution than today, and during the 17th century it was the dominating forest tree in southern Sweden (Brunet 1995, Björkman 1997). The *Fagus* forests have been managed by man for a long time, and since they were used for forest grazing, the 16th – 19th century beech forests were more open than today, up to half the density has been proposed (Brunet 2007). Many present *Fagus* forests are believed to have continuity since the 17th century (Brunet 1995). In central Europe, the expansion of beech has mainly been explained by changes in climate (Tinner and Lotter 2006). In Scandinavia the expansion was more irregular in time, and it has been claimed that *Fagus* was not mainly favoured by climate, but by antropogenic factors such as the reduction of small, man-made fires. Further, *Fagus* pollen are often found together with cereal pollen, indicating a connection to man when *Fagus* expanded (Niklasson et al. 2002, Bradshaw and Lindbladh 2005, Lindbladh et al. 2007a).

Today, *Fagus* dominated forests cover ca 50 000 ha in Scania, including many areas with great importance to biodiversity and recreation. Today, the from a biodiversity point of view most valuable forests of northern Europe are fragmented and surrounded by production forests, arable land, or urban areas. Torup forest is one of the remaining beech forests in southern Scania (fig. 1) and has one of the highest densities of red-listed saproxylic species (mainly insects) in Scania (Arup et al. 2001), indicating that the forest has a long continuity.

Historical maps show that Torup has been a beech forest since the 16th century (fig. 2), but it is not known how long the forest continuity is, or how long the forest could be considered natural (i.e. unaltered by man). Pollen data from small peat deposits within a forest may provide information on local forest history for a much longer period of time than historical maps and decriptions.

Small forest hollows are expected to be dominated by local taxa, mainly from a <800-1000 metre radius (Sugita 1994, Calcote 1995, Calcote 1998, Broström 2002). Trees close to the hollow contributes more than trees further away, and 40-50% of the pollen in forest hollows comes from trees growing within 50-100 metres, providing a stand scale (1-3 ha) record of nearby vegetation (Calcote 1995, Calcote 1998). Additionally, charcoal preserved in peat provides a record of past fire occurrences (Patterson et al. 1987). The vast majority of the charcoal produced in a forest fire sediment in, or very close to burned areas and can thus be used as evidence for local fires (Ohlson and Tryterud 2000, Lynch et al. 2004).

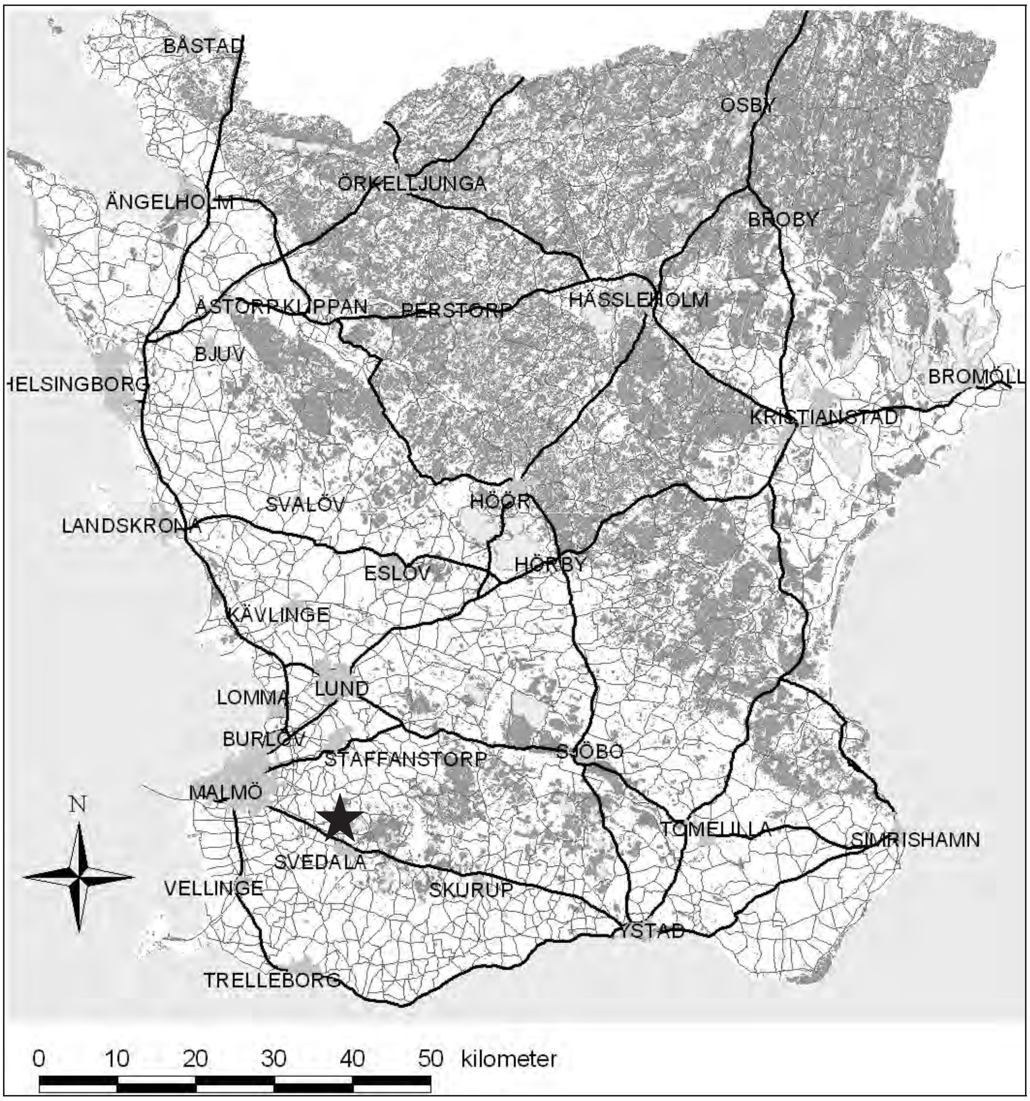

Figure 1. Present land cover in Scania (map from Brunet 2005). The star is marking Torup forest.

Objectives

The present study is focusing on the following questions:
(1.) how long is the unbroken forest continuity of the Torup forest?
(2.) when did significant human influence of the forest start to appear?
(3.) is it possible to reconstruct changes in former forest openness using pollen records and historical maps?
The answers are crucial for conservation biology in general, but also in specific cases such as the coming nature reserve in Torup (Persson and Dahlberg, pers. comm. 2007).

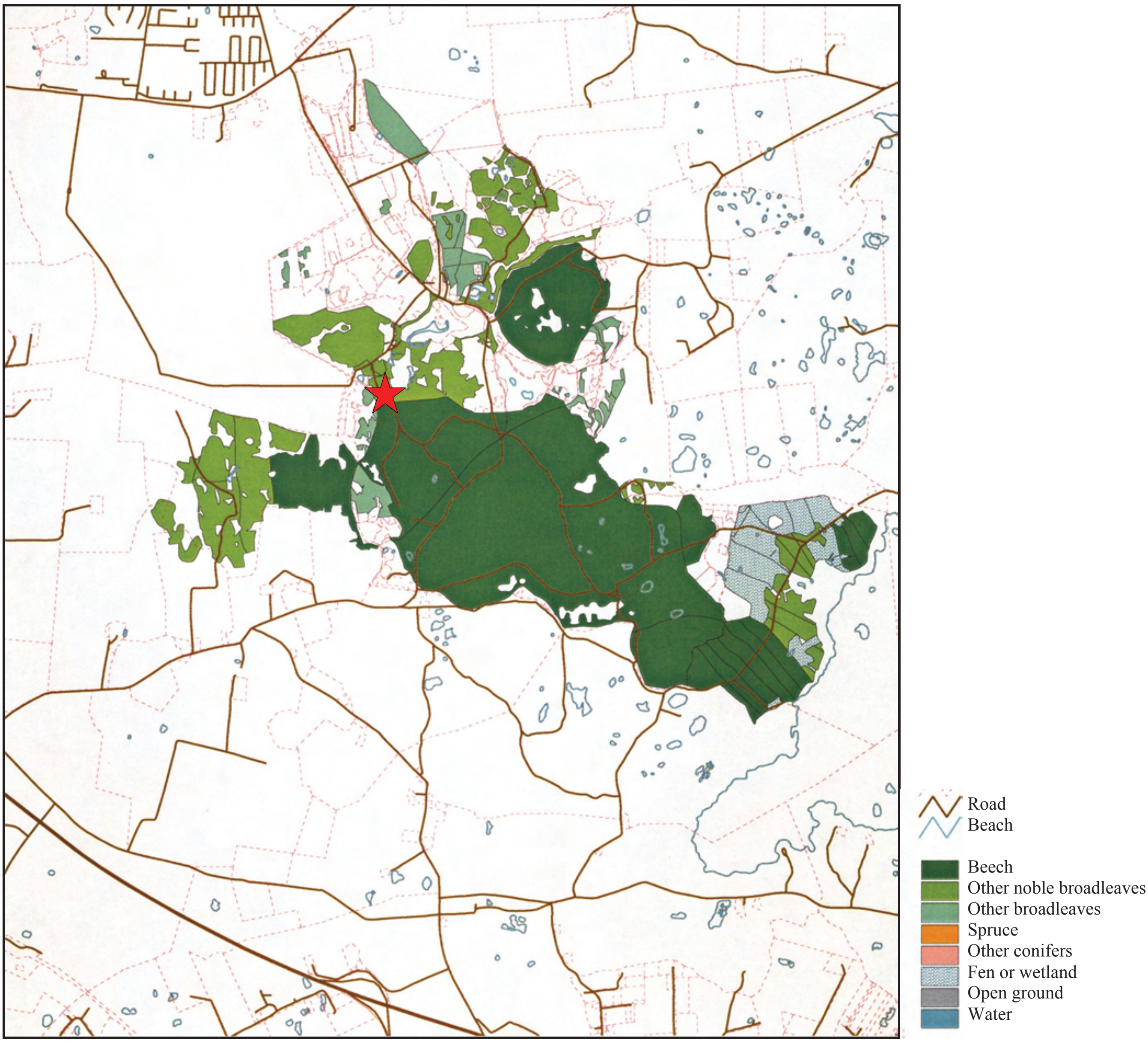

Figure 2. Torup forest 1694 (map from Lindhagen 1999). The star is marking the site.

Materials and methods

The study site

Torup forest (N55° 33' 47.20", E13° 12' 19.92") is ca 360 ha in size, and located in Svedala municipality in Scania, southern Sweden. The vegetation period is 210 days, the mean temperature in January is -2°C and in July 16°C and the mean annual precipitation is 700 mm (Raab and Vedin 1995). The bedrock is calcareous and geologically much younger than other parts of Scania, and Sweden (Lindström et al. 2000, Emanuelsson et al. 2002). The dominating soil type is moraine clay (Lundqvist 1958).

Torup estate is known since the Middle Ages, and the present castle was established in the middle of the 16th century (Trellid and Bontin 1999). The first historical sources concerning Torup forest is from early 17th century, and the first maps are from 1694 (Leithner et al. 1997, Brunet 2003). At that point, the forest mainly consisted of *Fagus*, but also *Quercus* was common. Between 1660 and 1735 the forest was royal property, and a large share of the forest was cut during the Swedish-Danish wars (1675-79), as well as in the early 19th century (Brunet 2003).

Using a detailed map showing all peat deposits (scale 1:10 000), the area was searched for potential study sites. Most wetlands were heavily influenced by former peat extraction. The site chosen for the study was one of very few small peatlands still intact in the area. The investigated site is a small forest hollow, <10 metres in diameter, surrounded by beech forest (fig. 3 and 4), ca 400 m SSW of Torup castle. The hollow is overgrown with *Glyceria fluitans* (Floating sweet-grass) (60%), *Carex elongata* (Elongated Sedge) (10%), *Juncus effusus* (Common rush) (10%), *Scutellaria galericulata* (Scullcap) (1%), *Carex* sp. (Sedge) (3%), and the edges with *Athyrium filix-femina* (Lady-fern) (5%).

Field and laboratory techniques

Pollen

Angiosperms and gymnosperms produce pollen, which contains the plants male gametofyte. The outer coat of the pollen grain, the exine, consist of the very resistant substance sporopollenin. Pollen can not disperse itself, but requires aid from wind, water, or vectors. To simplify dispersal the grains are small, usually 20-40 µm and aerodynamically shaped (Moore et al. 1991). Using fossilised pollen grains, vegetation history can be investigated down to individual taxa present at a site (Moore et al. 1991).

The main factors affecting the relationship between the amount of found pollen and the surrounding vegetation are pollen production, dispersal and deposition, the distance from each plant to the sample site, as well as the size of the lake or wetland from which the sample was taken (Andersen 1970, Broström 2002). Basically, there are two important biases; the production bias (how much pollen different species produce, i.e. independent of basin size), and dispersal bias (how far the pollen grains disperse, i.e. dependent of basin size) (Broström 2002).

Figure 3. The investigated forest hollow, June 2007.

Figure 4. Extraction of the peat monolith, June 2007.

Pollen samples and laboratory procedures

A monolith of fen peat (99 cm) was collected with a Russian peat sampler, June 26th 2007. The stratigraphy of the monolith was: 0-4 cm very loose, 4-29 cm homogeneous peat, 29 cm a weak black layer, 29-35 cm homogeneous peat, 35-39 cm a clear black layer, 39-89 fen peat, many layers. On 60, 63 and 66.5 cm were less clear layers, and on 89-99 cm the monolith was more vaguely layered.

The peat monolith was subsampled into 0.5 cm pieces, kept in labelled plastic bags, and stored cold. The pollen preparation was carried out according to standard procedure. From the subsamples, 40 levels were extracted, and ≥422 pollen grains from each level were counted using a Leitz Dialux 20 EB microscope, 400 magnification. Grains ≥50 % hidden were not counted, and grains which were not possible to identify because they were too digested, broken or folded were marked as hidden/broken. Unknown were considered indeterminable pollen. As exotic marker, *Lycopodium* was added. The identification was carried out with the aid of a reference collection, as well as keys and illustrations in Moore et al. (1991), and Reille (1992).

Charcoal

1 ml peat samples were taken at the same depth as the pollen samples and put in NaOH for >12 hours. The samples were passed through a 280 µm sieve, and searched for charcoal using a Photonic PL 2000 microscope.

Radiocarbon dating

Subsamples for dating were extracted and dried (dry weight ca 1 g). Radiocarbon dating (^{14}C) was carried out at five levels; 11 cm, 25 cm, 34.5 cm, 65 cm, and 94.5 cm depth, by Beta Analytic Inc., Miami. Calibration from radiocarbon years to calendar years was made using Oxcal. The limitations of the historical periods were perceived from The Swedish National Heritage Board (Riksantikvarieämbetet 2007).

Data analysis

A CONISS analysis was performed in TGView. CONISS carries out Constrained Incremental Sums of Squares cluster analysis, and was used as a tool to group periods with similar vegetation. TGView was also used for creating the pollen diagram. Floristic diversity was calculated for each sample using rarefaction analysis, estimating the number of different taxa, E(T.), that would be expected if all the pollen counts had been the same size (Birks and Line 1992).

Calculations of historical forest density were made on a 1000 metre, as well as a 2000 metre radius from the site on historical maps. Using compasses, circles were drawn and split into 12.5% parts, where the occurence of different species could be calculated. On the maps, everything unmarked (i.e. not trees, water, wetland, or rock), were considered open land, as was all non-arboreal pollen (shrubs, dwarf shrubs, cereals, grasses, and herbs) in the pollen analysis. Cyperaceae pollen was used to indicate wetland, while the amount of water was estimated from modern maps.

Results and discussion

General vegetation development

Cluster analysis and general patterns

According to the CONISS analysis, the pollen diagram could be separated into two large clusters, with several subgroups. The general trend in Torups pollen diagram is the change from a closed forest to a more open landscape with a higher content of herbs.

A natural forest (4000- 350 BC)

Based on the pollen records, the surroundings of the site was a forest when the record started 6000 years ago. Trees were the dominant vegetation during the oldest period (from 4000 BC to 350 BC), counting for ≥ 85% of the pollen, the highest levels found in the profile. Also shrubs occurred, while herbs and grasses were very rare. Herbs reached 5% in periods when the amount of tree pollen was somewhat reduced. The dominating species was *Alnus*, but also *Quercus*, *Corylus*, *Tilia*, *Ulmus* and *Pinus* (pine) occurred, *Quercus* and *Tilia* frequently. Both *Pinus* and *Tilia* peaked during this period. *Alnus* is likely to have dominated the very site, i.e. the fen, while the surrounding forest was constituted mainly by *Quercus*, *Tilia* and *Corylus*.

During the first period, up to 2000 BC, *Pinus*, *Tilia*, *Juniperus* (juniper) and Poaceae (grasses) were more abundant than during the following (2000 BC-350 BC). This resembles somewhat of what has been seen in other areas (e.g. the Krageholm area), a decline in *Ulmus*, *Fraxinus*, *Tilia* and *Quercus*, parallel to an increase in *Betula* and Poaceae around 3000 BC (Regnéll 1989). In Torup, the decline, mainly affecting *Quercus* and *Tilia*, is not very obvious and occurred somewhat earlier than in Krageholm. Poaceae peaked just before 3000 BC, coinciding with a decline in *Alnus*. A hypothesis for this change in species is fire (Regnéll 1989), but in Torup no traces of fires are found until several centuries later, and the main occurences of charcoal fragments, although in low numbers are from 200 BC- 1400 AD.

The Iron Age and the Viking Age (350 BC- 1000 AD)

The site appears to have been natural, undisturbed forest up to 350 BC. A change at that point in time is visible in the influx analysis, showing a major disturbance around year 0, followed by a lower and more constant pollen accumulation rate indicating a decrease in forest density (fig. 6). The short period 350 BC- 0 is also the clear division between the two main clusters in the CONISS analysis. This shift is probably connected to the changed land use in southern Sweden during the Iron Age (500 BC-500 AD) (Mattsson 1985, Larsson et al. 1999). Already during the Bronze Age (1500-500 BC), the climate changed towards a colder and damper weather, which lead to the need for keeping cattle indoors during the cold season. Mowing, as well as the harvesting of foliage, was introduced to provide winter fodder, and new, open biotopes such as mowed meadows and wooded meadows were created (Mattsson 1985, Larsson et al. 1999). During the same period, the use of iron garments as well as horses was introduced, and more land could be cleared for agricultural purposes (Mattsson 1985).

In ca 1000 years (1000 BC- 0) *Alnus* decreased drastically and very suddenly from 60% to 30%, and was replaced mainly by *Quercus* and *Betula*. This is the same pattern found by Berglund (1991) in other parts of Scania during the Viking Age (800-1100 AD). The reduction of *Alnus* has been interpreted as human use of wet areas for fodder etc. (Berglund et al. 1991, Berglund et al. 2007). According to Moore et al. (1991), sudden declines, such as the *Alnus* decline in this survey, could be a consequence of the surrounding vegetation, i.e. the species was out-competed by others, but could also be associated to pathogen outbreaks, anthropogenic manipulation, or change in climate. In Torup, *Alnus* pollen were most abundant

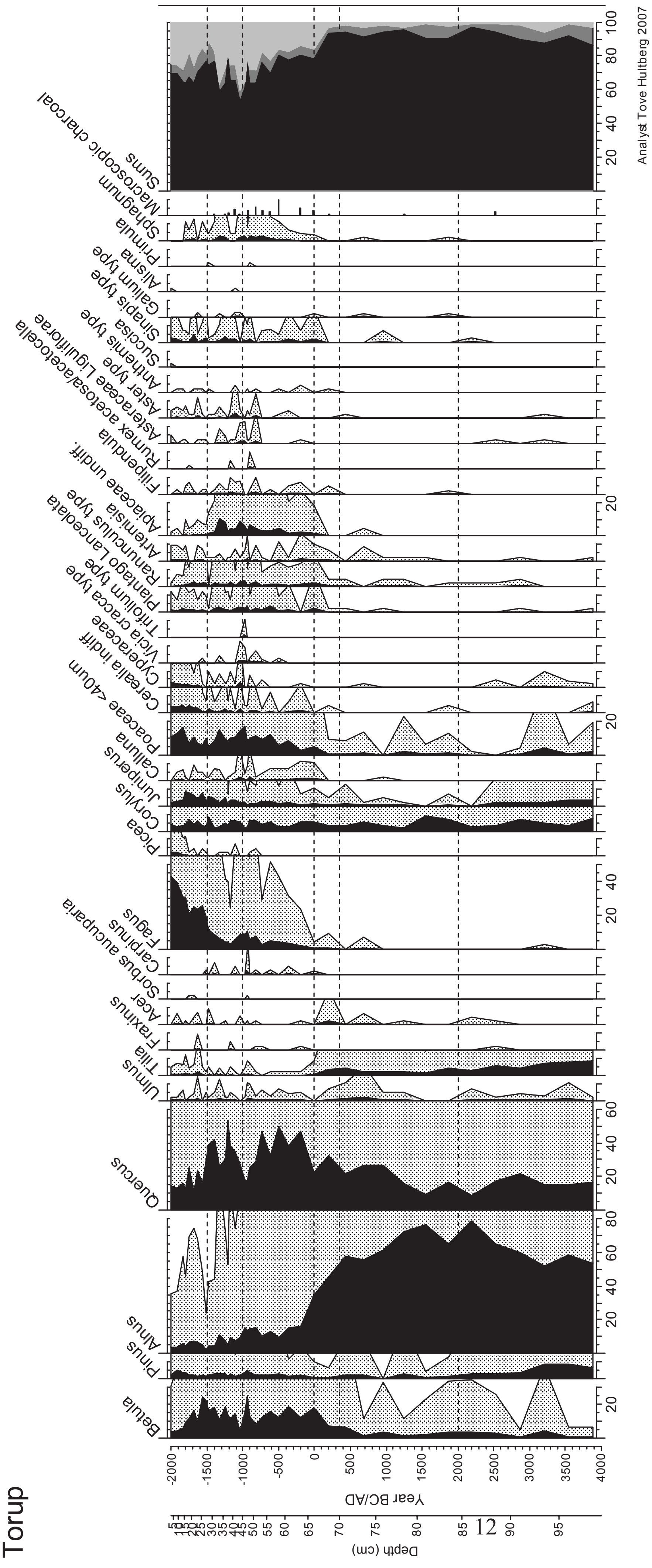

Figure 5. Pollen diagram of Torup forest, including all identified taxa. The pollen sums include trees (black), shrubs (dark grey) and field layer species (light grey).

during periods of low water and declined when the water level increased. The same pattern was found and discussed by Berglund et al. (1991), who noticed a dry out of wetlands and connected it to a major low-water period 0-750 AD. Despite this correlation, it is hard to draw the conclusion that the *Alnus* decline is solely dependant on climate, since the period when it decreased (the Bronze Age and Iron Age), also brought major anthropogenic changes such as mowing (Mattsson 1985, Larsson et al. 1999). A possible consequence is the minor, but continuous increase of *Sphagnum* 2000 years ago, coinciding with the *Alnus* decline. Once *Alnus* was gone, *Sphagnum* might have been able to colonise the fens and wetlands.

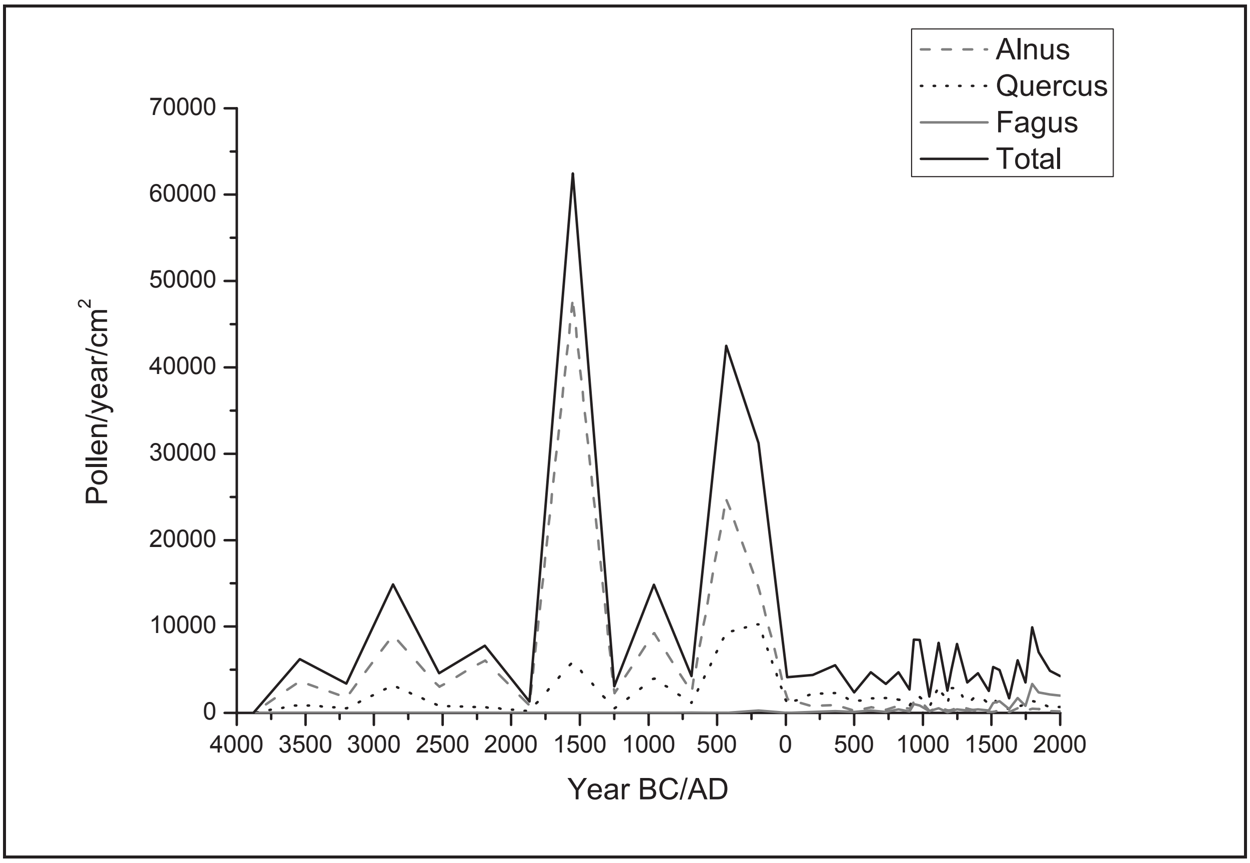

Figure 6. Change in pollen influx of selected taxa, and total amount.

Further, dramatic declines must not always be due to one single cause, but can be a combination of several (Moore et al. 1991). In Scania, clear declines in *Alnus* have been seen in Fårarps mosse and Bjärsjöholmssjön (Berglund et al. 1991), but not as markedly as in Torup. The entire Torup forest is very rich in fens, and the dominance of *Alnus* up to the Iron Age should most likely be seen as the site being such an alder fen surrounded by other broadleaves. The sudden decrease seems to be a combination of the climate change and human intervenience.

Fagus and *Carpinus* were established between 350 BC and 0, and pollen from cerealia started to occur continuously at that point of time. This is consistent with the findings of Bradshaw and Lindbladh (2005), that beech mainly established on sites where *Quercus*, *Alnus* and/or *Corylus* grew, or in successions with *Betula*. The pattern has also been seen in the other parts of Scania, such as Bökesjön and Fjällmossen (Gaillard and Persson, unpublished, pers. comm. 2007), as well as in Krageholmssjön (Regnéll 1989, Gaillard 1984: In Berglund et al. 2007). Herb pollen increased in Torup during the Iron Age. Grasses, as well as *Plantago lanceolata* (ribwort plantain), *Ranunculus*, *Artemisia*, Apiaceae, *Filipendula*, and *Sinapis* increased, and anthropogenic indicators and Ericaceae established. This increase in field-layer species could be seen as a reflection of an opening of the forest (Lindbladh 1998). Such as opening of the landscape could be expected up to 1000 AD, since human settlements and the cultivation of cereals increased, and the increased need for agricultural areas led to the introduction of fire to clear the landscape. The forests declined, and a mosaic landscape which partly still is present, was created (Berglund 1991).

Further, the number of taxa increased very sudden around 350 BC (fig. 7). An increase of herbs has also been seen in Krageholm, where they declined rather soon again, indicating a forestation of former pastures (Regnéll 1989). This is not the case in Torup. From around year 0, the herb pollen percentages were increasing, yet fluctuating up to the Middle Ages. During the same period (from the period 0 to the start of the Middle Ages), the main traces of fire in Torup are found. The highest findings of charcoal are from around 500 AD (late Iron Age), coinciding with a minor peak of Apiaceae.

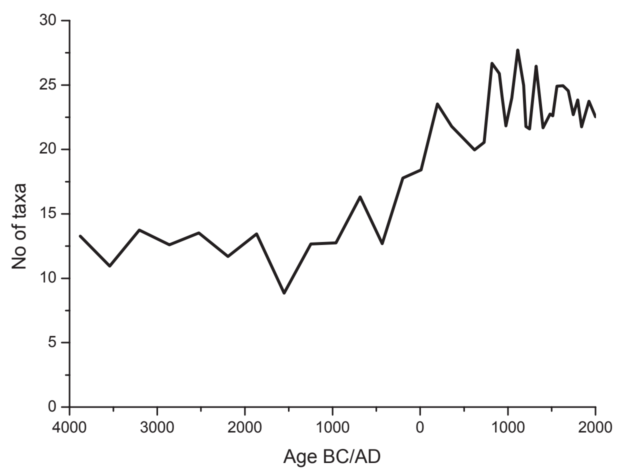

Figure 7. Number of taxa per level rarefied to 422 pollen grains.

The medieval opening of the forest (1000- 1500 AD)

The Middle Ages was a turbulent time in Scania. The denser village structure, resembling modern villages, established and a social layering took place, creating a nobility. Great changes in society also mean great changes in vegetation. The need for new arable land, cultivation and forest grazing decreased the forest (Mattsson 1985, Larsson et al. 1999). This opening of the landscape can be seen in Torup. Apiaceae and several other herbs peak, while tree pollen reached its lowest levels ever at the site. The amount of shrub pollen increased around 1300 AD, and herbs peaked (close to 20%) as did *Sphagnum* and anthropogenic indicators, showing high levels (10-15%) during the entire period 0-1550 AD. According to Berglund (1991), the mosaic landscape created during the Viking Age is often visible in pollen diagrams by high amount of herb layer species and anthropogenic indicators. This landscape is well visible in the Torup diagram, where herbs and anthropogenic indicators peaked during the Viking Age. The only period with slightly higher abundance is during the 14^{th} century. Further, the cultivation of cereals slowly started to expand from that point onwards, although with major dips.

The levels of *Fagus* dipped during the Middle Ages, and both *Fagus* and *Juniperus* pollen percentages were continuously low up to ca 1400 AD, while Poaceae, as well as *Plantago*, *Ranunculus*, Apiaceae and *Sinapis* showed constant high levels. Also herbs such as *Galium* (bedstraws), *Vicia* (vetch), *Primula* (primrose) and *Trifolium* (clover) occurred, but only in low amounts. *Quercus* and *Betula* fluctuated, rather well connected to each other; when one increased, the other decreased and vice versa, indicating a succession between them. The levels of *Ulmus*, *Tilia*, *Fraxinus*, *Sorbus aucuparia* (rowan), and *Acer* sp., were very low during the entire period, while *Carpinus* established and occurred in low but frequent amounts. This landscape including both forest trees and herbs could be the landscape described by Adam of Bremen in the late 11th century. According to him, Scania lacked forest along the coasts, while dense deciduous forests prevailed in the northern parts and the area along the ridges were covered by a mosaic landscape, including minor forests (Fritzbøger 1994).

From the 13th century, *Fagus* showed an almost continuous increase up to modern time. The medieval expansion ended with the plague 1348-51, which is seen as the start of the late medieval agrarian crisis (Larsson et al. 1999). In Torup, the rise in tree pollen at that point in time indicates a denser forest. That could on the other hand also be due to Torup becoming a noble estate, which were known to treasure their forests (Regnéll 1989).

The modern time (1500- 2000 AD)
The coldest period in thousands of years occured during the 16th century (fig. 8), which was a period of major vegetation change, implying that the change was climate induced. But it was also a period of dramatic change in society, during which the large farms, present since the Iron Age grew bigger and became more important (Nilsson 2002).

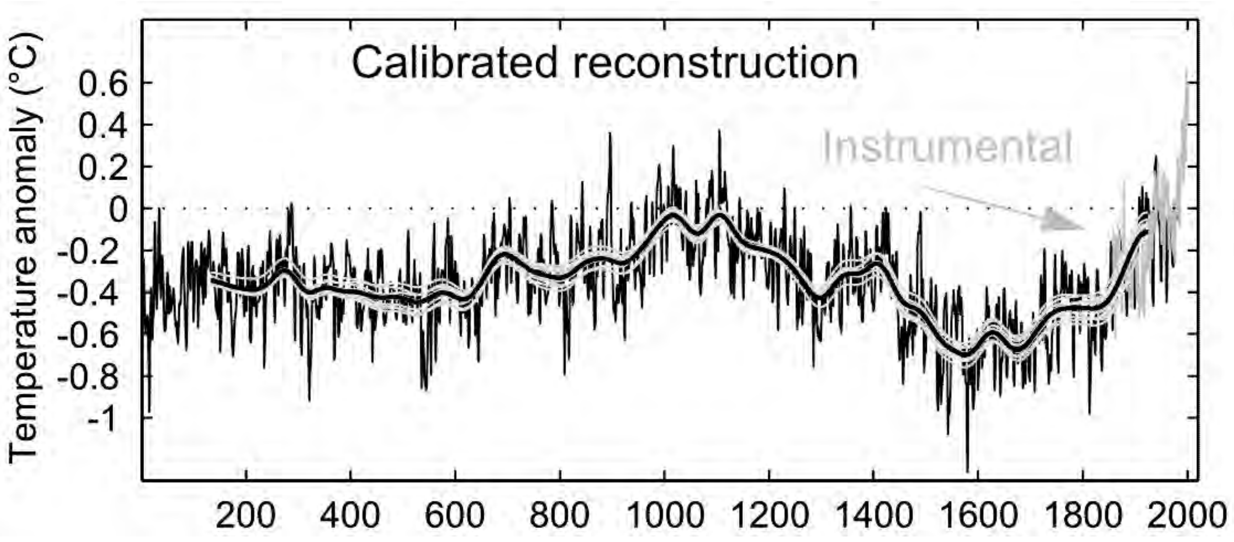

Figure 8. Fluctuations in annual temperature for the last 2000 years. From Moberg et al. (2005), with permission from Moberg, pers. comm. 2007.

During the 16th and 17th century the number of estates increased in Scania, and in the middle of the 17th century, the nobility owned 54% of the 15 000 farms (Arcadius and Sundberg 2001). Many new agricultual areas were established during the 16th century, followed by stagnation. The forests were heavily reduced due to the production of tar, as well as charcoal for iron making (Larsson et al. 1999). Concerning Torup's vegetation, a new large change took place. *Fagus* pollen showed a dramatic increase, replacing mainly *Quercus* but also *Alnus*, as well as anthropogenic indicators, *Plantago* and Apiaceae. This shift is likely to be a reflection of the reduction of the forest, probably including grazing.

After the 16th century, a continuous decrease of *Betula* and *Alnus* took place in Torup, while *Fagus*, as well as Poaceae and cereals expanded (*Fagus* from 25% in the 18th century to over 40% in the uppermost samples). During the early 17th century, the population of Torup rose dramatically (Andersson Palm 2000). At the same time the amount of tree pollen declined somewhat, but it is impossible to date this reduction carefully enough to connect it to a population change. The same is true for the plague striking Bara county in August 1712 (Persson, pers. comm. 2007). During the abandonment following a plague, the tree and herb pollen are expected to increase, and cerealia pollen decrease (Broström, pers. comm. 2007). In Torup, the amount of cerealia pollen decreased a little, but also these events are impossible to link to each other. From the 18th century, the vegetation is more or less the same as for modern time. *Quercus*, *Betula* and anthropogenic indicators decreased, while *Pinus*, *Tilia*, *Ulmus*, *Acer* as well as Poaceae, cereals, Cyperaceae, and *Sinapis* all increased (the latter possibly due to the increased cultivation of rape). Although the first traces of *Picea* in Torup are from 800-900 AD, it did not expand until after the 19th century.

Pollen source area

To be able to draw conclusions on a past landscape, the structure of it is very important. In order to improve the possibilities to estimate former openness in Torup, I compared the pollen data to historical maps, from 1694 to present.

Table 1. Translation of pollen indicators to historical map legends.

Pollen indicator	**Map legend**
Herbs and grasses, except Cyperaceae	Open land
Cyperaceae	Fen or swamp
Non, data taken from modern map	Water
Pine and juniper	Other conifers
Spruce	Spruce
Birch and alder	Other broadleaves
Oak	Other noble broadleaves
Beech	Beech

Comparing historical maps to pollen records, the most obvious deviation is the underestimation of openness in the pollen record (fig. 9). The Torup maps in general indicated 10-15% more open land than did pollen. This is reasonable, concidering that most herbs and grasses produce far less pollen than do *Fagus*, *Quercus* and *Betula* trees, which makes pollen records biased towards trees. The deviation becomes greater the further from the site you get (fig. 10), indicating that most pollen in the diagram have a local origin. This is not unlikely, since many of the species found in Torup do not have a very good dispersal, e.g. *Fagus*, *Quercus* and Poaceae (Broström 2002). It is also consistent with the findings of Broström (2002), that a large share of the pollen at a site comes from within 1000 metres. In the 2000 metre radius, the amount of openness differs 30% between maps and pollen records.

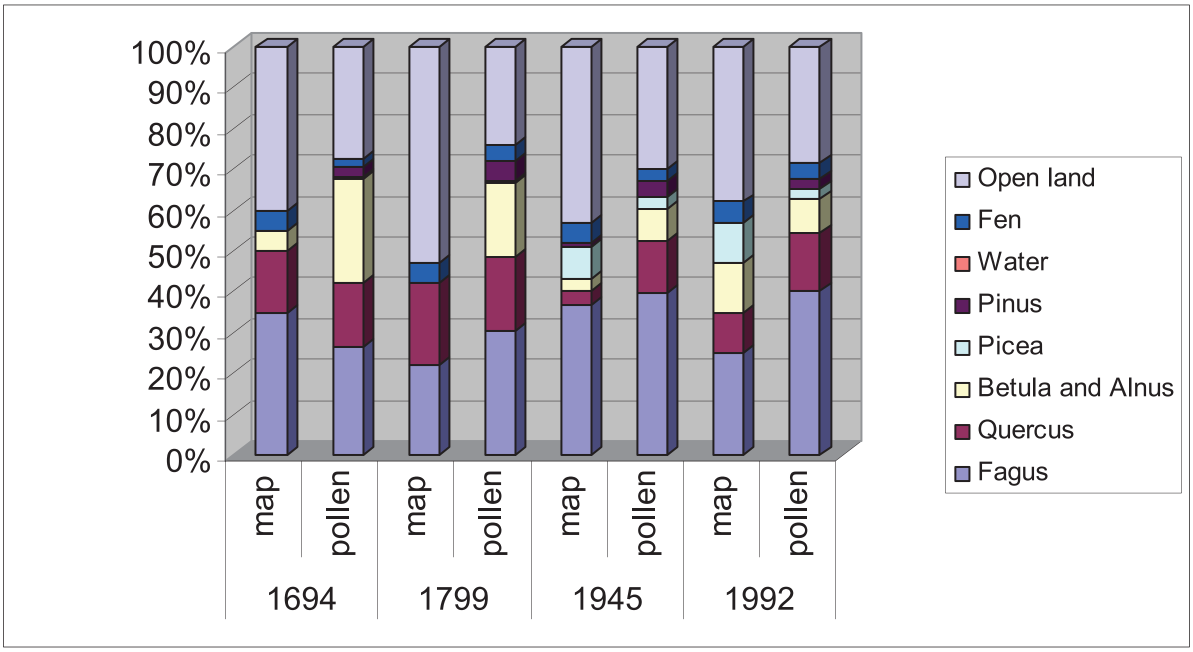

Figure 9. Distribution of tree species, water, wetland and open land, based on maps and pollen records, in a 1000 metre diameter from the site.

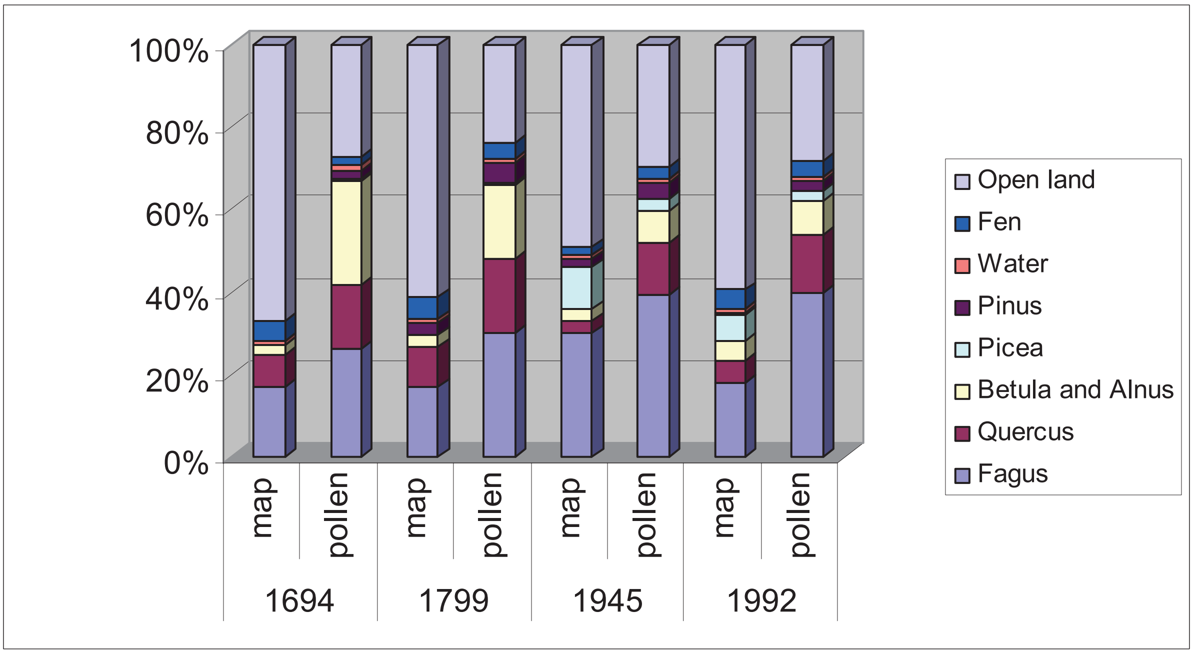

Figure 10. Distribution of tree species, water, wetland and open land, based on maps and pollen records, in a 2000 metre diameter from the site.

Further, the comparison shows that *Betula* and *Alnus* are overrepresented in the pollen diagrams compared to maps, most likely due to the high pollen productivity, as well as efficient dispersal of *Betula* (Broström 2002). One exception is in the modern map of 1992, where *Betula* and *Alnus* are less frequent according to the pollen record. *Fagus* is generally overrepresented in pollen records, although not as extreme as *Betula* and *Alnus* (Broström 2002). *Fagus* pollen are produced in large quantities, and although they are not dispersed very well, it is reasonable to believe that pollen grains are abundant where the trees are located.

The pattern of 1694 is probably due to low pollen production of *Fagus* at the time, as the forest was affected by heavy cuttings in connection to the Danish-Swedish wars (Brunet 2003). In the later maps, the *Fagus* forest is more fragmented, and hence the area covered by *Fagus* is smaller. *Picea* were first noted in the map of 1799, but did not become common until in the map of 1945. All through its existance in Torup, it is possible to see an underrepresentation of *Picea* in pollen records, due to that it produces little pollen, that are not able to disperse far (Broström 2002). The occurence of fens in the maps are well correlated to the occurence of Cyperaceae in the pollen record. "Other conifers" are more common in the pollen record than in the maps. These include both *Pinus* and *Juniperus*, and it is known that at least in the 1799 map, the majority of the "other conifers" are juniper meadows. *Pinus* pollen are easily dispersed (Broström 2002), and earlier pollen analyses have concluded that *Pinus* pollen <10% often have been transported from other sites (Niklasson et al. 2002, Lindbladh et al. 2007a). Also *Juniperus* have easily dispersed pollen, which might have been transported from juniper meadows outside the site (Broström 2002).

In summary, openness indicated by pollen is smaller than openness indicated by historical maps in Torup. This might be due to the pollen productivity and dispersal of different taxa, but could also depend on how exact, or in-exact, the maps are or the limited possibility to date the pollen levels in relation to the maps.

Openness

Human impact is considered one of the most important factors affecting vegetation change in Europe the last 7000 years, and it is thus important to date the first human settlement(s), marking the change from "natural" to "managed" vegetation (Behre 1986, Hannon 1999). When interpreting a pollen record, there are two main approaches; using indicator species, or a comparative approach where fossil pollen records are compared to modern vegetation types. Since the present vegetation is heavily influenced by human activities and do not always resemble past vegetation types, the latter is rarely used in northwestern Europe (Gaillard et al. 1992). The use of anthropogenic indicators, species whose ecology can be linked to human activity such as fire, disturbed soils or open canopies (assuming is that the requirements and ecology of the species has not changed) is more common (Moore et al. 1991).

Low amounts of non-arboreal pollen (NAP) has traditionally been interpreted as closed forest (Vera 2000). By comparison to modern pollen samples, as well as by simulations, it has been shown that NAP can not be directly translated to openness, and that openness might have been underestimated in the past (Broström 2002). According to Myrdal (1998), the landscape was opened up rather sudden (>40%, mainly by coppicing) around 1000 BC in southern Sweden, due to an increased need for arable fields, as well as for grazing areas. The next big change in openness did not come until 1000 AD (ca 65%, mainly arable fields, meadows and grazed lands). In Torup, the first large opening is not visible until 350 BC, when the tree layer declined and herbs increased, followed by a further reduction around 1000 AD. The openness seems to have fluctuated with time, with a new increase in the tree layer during the 16th century. NAP values of 10-15% were common in Torup during Viking Age and Middle Ages, as well as during the 19th and 20th century, which following the findings of Broström (2002), could reflect an openness of up to 50%.

To put Torup in a larger context, the site was compared to other sites in the vicinity. Krageholmssjön, a large lake app. 50 km from Torup, provides a regional signal, while Bökesjön is somewhat smaller but closer to Torup. When comparing the openness, it is possible to see that it shifted much between them (fig. 11). The share of openness is larger in

Krageholmssjön than in the other two areas. The openness (according to pollen diagram) of Krageholmssjön outsize even the openness indicated by maps i Torup, meaning that Torup (and Bökesjön) are likely to have been much more closed than generally in the region during the last couple of centuries.

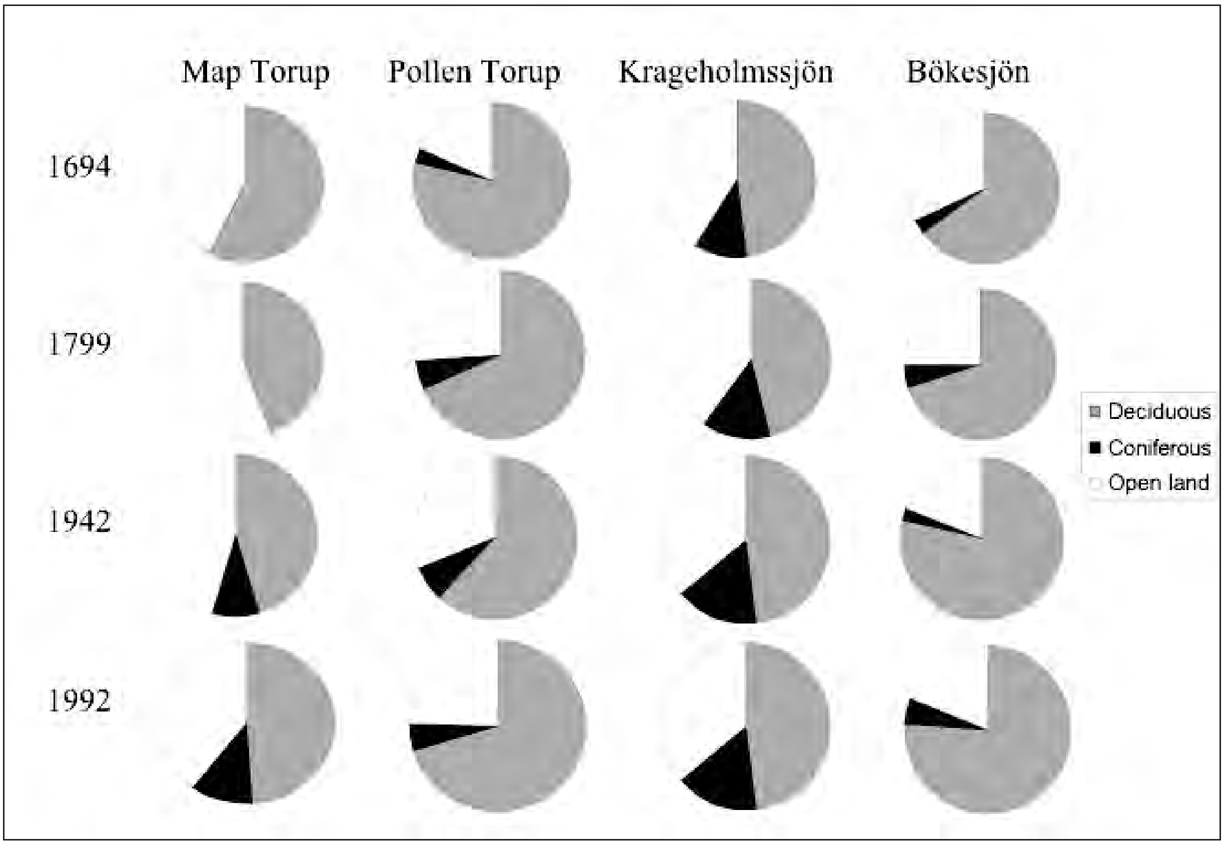

Figure 11. Openness in Torup (according to pollen, and maps), compared to Krageholmssjön and Bökesjön.

Wooded meadows or dense forest?

Estimating the density of a historical forest is not an easy task. The decline in tree pollen from year 0 is probably exactly what it looks like, a decrease in forest density. Following the pollen/map comparison carried out above, openness was 10-15% higher than indicated by pollen, indicating that the opening was even more drastic than it appears. The sudden reduction in tree pollen is likely to be the result of mowing, which together with improved and hence more widespread agriculture, was introduced during the Bronze Age. Also other sources speak of a forest reduction, due to an increased need for housing material and firewood, as well as forest grazing and extensive wars (Fritzbøger 1994). It is reasonable to assume that this was the case also in Torup, an increasing population in need of wood cutting in a forest which was formerly not very influenced by human activities.

Using pollen to look into past time forests, it is important to remember the different amount of pollen produced, and dispersed, by different taxa, as well as the fact that the denser the forest is, the less pollen is produced. For instance, *Quercus* and *Betula*, which are both rather common trees in Torup's pollen record, produce 7.6 and 8.9 times respectively more than grasses do (Broström 2002). The same is true for *Fagus*, which replaced *Quercus* as the dominant tree species. *Fagus* produce close to seven times more pollen than do Poaceae, and approximately double the amount of many herb species. The only herb producing as much pollen as trees is *Plantago lanceolata*, while most others (e.g. *Ranunculus*, *Filipendula*, Poaceae and Cyperaceae) produce between 1/2 and 1/7 of what *Betula* does. This means that trees are heavily overestimated, and herbs underestimeated pollenwise, and hence that past time forests are likely to be considered denser than they really were. The increase in tree pollen during the last few centuries might be due to the forest of today being denser than the past times grazed forest. According to Brunet, (2007) mature *Fagus* stands (100-160 years old) during the 16th–19th century on average contained about 50% of the timber volume compared to present production forests under the same conditions.

Forest continuity

According to the present pollen analysis, Torup has a forest continuity of at least 6000 years. This is totally opposite a common opinion (Emanuelsson et al. 2002), stating that Scania was almost completely deforested in the 17th century and that *Fagus* declined during the 18th and 19th century. In Torup, *Fagus* did show a minor decline during the 17th century, but increased very soon again. The percentages tree pollen was lower from 350 BC and onwards than it had ever been before. Despite this opening, the amount of tree pollen at the site never fell below 55%, indicating a rather intact forest but with changes in density and type (from an un-touched, dense forest to a much more open, grazed forest with high human impact). Following the pollen/map comparison, the forest cover is likely to have been even smaller. Although the surroundings changed and were opened up, the forest ecosystem remained. This makes Torup a final outpost of forest towards the open Scanian plain. When comparing a soil map to the forest edge (based on historical maps from 1694 to present) the open areas surrounding Torup were all placed on the better soils, such as glacial clay and glacial silty clay, as well as fine sand and glaciofluvial deposits, south and northwest of Rydskratt. The forest on the other hand was located on clayey to sandy till, which is less suitable for agricultural purpose.

The long forest continuity is likely to be due to Torup being a noble estate, at least since the Middle Ages. During this period of forest decline, forests were more common close to estates than in village areas. The forests (often dominated by *Fagus*) were used for hunting, as well as for feeding of pigs (Regnéll 1989). Up to the 17th century, Scania belonged to Denmark, and was one of the countries largest, and economically most important parts. High forests belonged to the nobility at that time, while low forest (coppiced forest) belonged to the peasants, i.e. it would be highly unlikely that a high forest on noble land would be cut down, since it would then turn into a peasant forest (Fritzbøger 1994).

Distribution of species and indicators

Concerning the distribution of taxa, the pollen productivity and fall speed is crucial. For instance, *Quercus*, which was a common tree in Torup, produces almost six times as much pollen as *Tilia*, and more than nine times as much as *Ulmus*. This means that *Ulmus* and *Tilia* might have been common trees, rather than rare occurrences as the pollen record indicates. The same goes for e.g. *Carpinus* (producing app. 1/3) and *Acer* (almost 1/6) of *Quercus*. Not only the production of pollen, but also the possibility to disperse is important for a taxas abundance in pollen records. Some of the best dispersed tree species are *Betula*, *Corylus* and *Alnus*, which all have small and light pollen grains and hence are dispersed further than e.g. *Fagus* and *Picea*, which produce large and heavy grains. In Torup's case, this means that it is possible to draw the conclusion that *Fagus* was the dominant tree species in modern time at the very site (although taxa such as *Tilia* and *Ulmus* probably were more common than the pollen records indicates) while the easier dispersed pollen of *Pinus*, *Juniperus* and *Betula* could have flown in from the surroundings. This is consistent with the comparison of Torups pollen record to historical maps, showing that *Fagus* are somewhat, and *Betula* and *Alnus* heavily overrepresented in the pollen diagram (Broström 2002). The herbs found at the site generally disperse at the same fall speed as the tree species, for instance grasses are dispersed at the same speed as *Quercus*. Some herb species, such as *Filipendula* and *Ranunculus*, are easily dispersed and might have arrived from adjacent areas (Broström 2002).

Using the indicator species from Gaillard et al. (1994), the majority of the species found in Torup are associated to forested, or open woodland sites (e.g. *Quercus*, *Tilia*, *Fagus*, and *Corylus*, *Alnus*, and *Betula*, respectively). According to the findings of Gaillard et al. (1992), the historical vegetation in Torup forest indicates few fires, pH between 5 and 6, and shifts between very weak (or no) grazing and moderate to strong grazing. Further, many of the species indicating open land (grazed or arable), e.g. *Plantago lanceolata*, *Artemisia* and cereals (Iversen 1973, Lindbladh 1998, Berglund et al. 2007) as well as Poaceae, Apiaceae, *Rumex* and *Corylus* (Vera 2000), were found in Torup from time to time. Also *Quercus* could be seen as an indicator of open forest due to its incapability to regenerate in shadow (Vera 2000). This would even more enhance the impression of Torup as an open, light forest, *Quercus* being a common tree through most of the forests known history. From year 0, *Plantago lanceolata* expanded, indicating hay meadows, grazing or mowing in or in the vicinity of the forest (Lindbladh 1998, Lagerås 2007). Among the grasses and herbs, it is usually hard to draw conclusions based in indicator species. Some of the herbs in Torup, such as the *Ranunculus* type and *Filipendula*, are favoured by grazing, while abundant grass pollen, as well as *Plantago lanceolata* are not known to correlate very well to actual presence of the taxa, but rather indicate lack of, or low pressure grazing. *Plantago lanceolata* is considered a better indicator of settlements and arable lands than cereals, since the latter are poorly dispersed (Regnéll 1989).

Establishment and expansion of Fagus

In Torup, *Fagus* first occurred just before year 0, but did not expand until 500-1000 AD. The findings of microscopic charcoal at the site indicate that some forest fires occurred from around year 0, and stopped during the Middle Ages. This pattern is consistent with the findings in similar areas in southern Sweden, such as Siggaboda nature reserve in Småland, and Holkåsen in Halland. These areas show very few traces of forest fires, but in both cases *Fagus* expanded after such fires (Björkman 1998, Björkman and Karlsson 1999).

Comparing the establishment and expansion of *Fagus* in different areas in southern Scania, *Fagus* seems to first have established in southeastern Scania, several thousands of years before it established further to the northwest (Berglund et al. 1991). Despite this lead, the amounts of *Fagus* were continuously low in all surveyed sites up to year 0 (Berglund et al. 1991, Lindbladh et al. 2007b, Gaillard and Persson, pers. comm. 2007). Comparing Torups pollen curve to the ones of Ageröds mosse, Krageholmssjön and Bökesjön it is possible to see similarities. The four have different pollen source areas, Ageröds mosse and Krageholmssjön are large and provides a regional signal, while Bökesjön is a small lake and Torup is a small hollow. All are located within 50 km from Torup. Concerning *Fagus*, the curves are very similar up to 500 AD (fig. 12). Of all the four sites, non showed pollen amounts >10% until around 300 AD. *Fagus* seems to have peaked in the other sites during the Middle Ages, and then decreased during the 18th-20th century. Torup deviates from this pattern by showing a sudden decline in the 12th century. Hence, it did not reach the levels of the other areas until the others declined. Neither did Torup decrease in modern time, as Ageröd, Krageholm and Bökesjön did. In the 16th century, written sources mention Torup forest as “a beautiful beech forest”, which is consistent with the influx, showing a marked increase in *Fagus* pollen from the 16th century. Perhaps, this “beautiful beech forest” was the first more or less pure beech forest at the site.

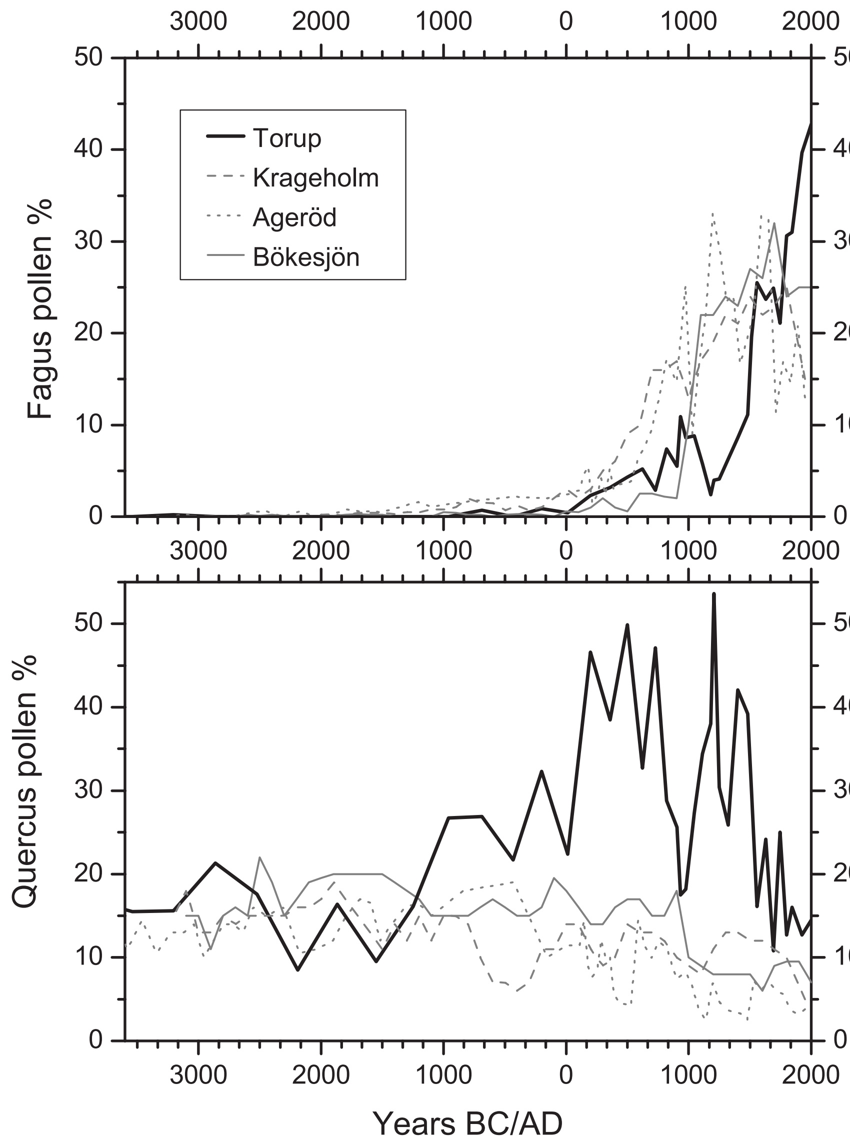

Figure 12. Comparison of *Fagus* and *Quercus* between Torup, Bökesjön, Ageröds mosse, and Krageholmssjön, concerning establishment and expansion.

The similarities between Ageröds mosse, Krageholmssjön and Bökesjön are valid for *Quercus* up to 1000 BC. *Quercus* was a common tree species (ca 15%) around all four sites 3000 BC. At 1500 BC it decreased in the other three areas, whereas there was a rapid, but fluctuating, increase in Torup (fig. 11). During the following 3000 years, *Quercus* only fell below 20% two times in Torup (1000 AD and after 1600 AD), a value which was never exceeded in the other areas. The peaks of *Quercus* coincide with periods of low amounts of *Fagus* pollen in Torup, but high amounts in the other areas.

Human influence on *Fagus*

Seen in a longer perspective, Torup, commonly known as “the beech forest”, only rather recently became a beech forest. The sudden expansion indicates human involvement, and in less than 1000 years *Fagus* went from scattered occurrences to total dominance. The sudden expansion, as well as the fact that *Fagus* expanded after the influx of charcoal stopped, resembles several other areas in southern Sweden (Björkman 1998, Björkman and Karlsson 1999). In areas in northeastern Scania, *Fagus* expanded early, during the 7^{th}-9^{th} century but declined again 1000 years later when fire was reintroduced in the forest (Lagerås 2007).

According to the macroscopic charcoal at this site, forest fires occurred in Torup up to 1350 AD, after which no charcoal was found. Very little charcoal was found, and it is thus hard to draw any conclusions on the fire history of the site, but being so irregular in time and suddenly stopping, it is likely that the fires in Torup were man-made, which is thought to be the case also in other parts of the country (Granström 1995, Niklasson 1998, Niklasson et al. 2002). Fires being very rare might be one of the reasons for the present dominance of *Fagus*, since it is fire sensitive compared to other tree species.

Another reason for the sudden expansion of *Fagus* might be that Torup is an ancient noble estate. According to Selander (1987), *Fagus* mainly established in areas formerly dominated by *Quercus* in southern Sweden, and out-competed the light demanding oak with its shade. To avoid this, *Fagus* was removed from the wooded meadows, and during the 17th and 18th century it was mainly found in the out-fields. In Torup, *Fagus* could have been actively removed up to the Middle Ages, to avoid competition with oaks. With the establishment of an estate, *Fagus* suddenly got a new value, since beech forest was appreciated for pig feeding, aswell as for hunting (Selander 1987, Regnéll 1989). According to Brunet (2007), some areas near Torup, e.g. Ryds Kratt at the adjacent estate of Skabersjö (in 1860), were actively converted from *Quercus* to *Fagus*. This could have been the case also in other areas, explaining the late shift from one species to the other.

Conclusions

Torup has been inhabited for a long time. A ruined medieval castle, as well as the present one, built during the 16th century, is evidence for the activity of an estate in Torup. But findings of flint axes, dating back to the Stone Age, shows that it has been home to people for a long time before that (Riksantikvarieämbetet 2007). This is important, since it indicates that the forest is characterised by the cultural history, by humans and their animals. It is not a “natural forest” we are dealing with, but a forest highly connected to management and human use. This is worth noting not only as a historical peculiarity, but also in the future management of the forest. However, despite a long history of human interference, the area around my study site has an unbroken continuity as forested land during the past 6000 years. This is particularly remarkable since Torup is close to the densely populated Scanian plains which are believed to have lost their forests during the Middle Ages or even earlier.

Despite possible errors, pollen analysis has proven to be very useful. It can show us what species were definitely present, when they established and expanded, as well as patterns (when a certain taxa increased, decreased or was replaced by another one). On top of this, it permits us to go far back in time, using the fossilised pollen as our time warp. Vegetation history is, as most history research, exciting in itself, but it is also useful for understanding the present day vegetation, as well as the conditions our ancestors lived under. How can we understand the placing of settlements without knowing an areas’ “green” history? And how can we re-establish past times landscapes without knowing what they looked like?

Although the new information obtained from individual surveys might be minor, every single work carried out in vegetation history should be seen as a piece of a larger jigsaw puzzle. If not crucial in itself, it contributes to the understanding of the history of southern Scandinavia. The more we know about different areas, the easier it will be to understand what the area really looked like and how the land was used. Even vegetation- or forest history should not be seen as an isolated event, but as a part of something bigger; a wish to know what really took place in the past. Thus it is important not only to involve knowledge from other disciplines, but also to spread the findings of forest history to a larger audience, in order to create a common knowledge about the landscape of past times.

But even single surveys could be of importance, for instance when creating nature reserves, teaching about an areas past, or in order to re-establish forest on former arable land or in urban areas, to have something to connect it to. In Torup, my hope is that the forest history will be considered in the future management, as well as complete the picture of the past Scania in an area were very few palynological surveys have been carried out.

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