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Abandonment, agricultural change and ecology

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A palaeoecological approach to a societal crisis

The medieval landscape in Sweden as in much of Europe was a cultural landscape. It was shaped by agriculture and most of the ecosystems were greatly influenced by human activities. When the human population was drastically reduced after the Black Death, and also when those who survived developed new strategies, we may expect environmental consequences. In fact, any large-scale change in society during the Middle Ages is likely to have resulted in changes in the environment, particularly in the vegetation.

Because of this strong relationship between vegetation and agriculture, studies on vegetation change may contribute to our understanding of the late-medieval crisis. However, documentary sources from the Middle Ages give us very little information about the vegetation. This is true for many countries but particularly so for Sweden, which has a rather scanty record of medieval documentary sources. Most preserved documents are of an economical character and tell us about taxes, rents, transactions and expenses, and they rarely give us any direct information on vegetation. Some glimpses may be gained from letters, legal documents (e.g. the landscape laws of the thirteenth and fourteenth centuries) or religious texts (like the visions of Saint Bridget), but they never explicitly describe the vegetation or the agricultural landscape. Preserved wall paintings in medieval churches may, when deciphered from their religious symbolism, provide some information on agricultural tools and practices (Fig. 2 in Chapter 2). But again, they give us glimpses and details and not the large picture. Old maps are perhaps the best documentary sources to past vegetation and to agricultural landscapes in general. Sweden has a wealth of such maps, in particular cadastral maps of hamlets and villages, but the oldest ones are from the seventeenth century, more than two centuries after the Black Death.

Hence, documentary sources give us no direct evidence on vegetation or environmental change in connection with the Black Death and the crisis. But indirectly they point to large-scale and profound changes. In countries with richer documentary sources, changes in rents,

taxes and prices indicate changes in the agricultural production that must have been connected to vegetation change. In Sweden, the many deserted farms and the significant population drop (reflected in *Peter's Pence* and several other sources) in particular indicate a social crisis that must have had major environmental and ecological consequences. In this way, we may use historical evidence of the societal crisis to discuss its possible environmental consequences, but much of the reasoning would be hypothetical.

A different approach is to use pollen analysis or other palaeoecological techniques to study vegetation changes more directly. In the study presented in this chapter pollen data from southern Sweden are used to interpret vegetation and agricultural change in the wake of the Black Death. Pollen analysis is a widely used method for studying vegetation change,



Fig. 4. The basic steps of pollen analysis, from peat coring on a bog, via subsampling to microscoping. The pollen photo is taken at magnification $\times 400$ (photos: Per Lagerås and Henrik Pihl)

but its potential is still rather unexplored in the context of the late-medieval crisis. In general it is used to study long-term vegetation changes of a distant past, in particular of prehistoric periods from which we have no written sources. However, also from later periods, like the Middle Ages and later, pollen analysis and other palaeoecological techniques have the potential to make important contributions.

Some earlier studies, both in Sweden and other countries, have shown that reforestation and other vegetation change in connection to the Black Death may be identified in pollen diagrams.² However, studies are few and usually based on only one or a few sites, which have made it difficult to draw general conclusions. In this study a large set of pollen data based on numerous individual pollen studies is used. The aim is to look beyond local variation to identify possible regional changes in vegetation and land use that may be associated with a large-scale societal crisis.

The method of pollen analysis will be presented below but one principally important difference from the use of written sources should be mentioned here. Pollen data first of all reflect vegetation. But because vegetation in a cultural landscape is much influenced by agricultural land use, pollen data also reflect agriculture. Furthermore, because agriculture and, in particular, crop growing indicates nearby settlement, pollen data may be used to interpret not only vegetation and agriculture, but also settlement dynamics. And when large sets of pollen data are compiled, like in this study, the observed settlement dynamics may even be discussed in terms of population dynamics. Thus, the line of reasoning is from pollen to vegetation, from vegetation to land use, from land use to settlement dynamics, and finally from land-use and settlement dynamics to population dynamics. This is opposite to the line of reasoning offered by written documents. They primarily deal with social and societal matters, which indirectly may provide hints on vegetation change.

Hence, a palaeoecological approach offers new perspectives by taking changes in vegetation and agricultural landscape as starting points for discussion. In so doing it highlights the environmental and ecological dimensions of the social crisis.

Data and methods for this study

Pollen analysis is the most widely used method for studying past vegetation. The method was introduced already a century ago,³ and even though there has been considerable development in data processing, modelling and in dating techniques, the basic principle remains the same (Fig. 4).⁴ Pollen is released during flowering and in particular wind-pollinated plants disperse enormous amounts of pollen, of which the majority does not fulfil its mission of pollination but just falls to the ground. The pollen grains are very robust to decay and if they get embedded in wet, anaerobic environments, like peat or lake mud, they may be preserved for thousands of years. One cubic centimetre of such sediment may contain as many as hundreds of thousands of pollen grains. Since pollen carries information on past vegetation and landscapes, peat bogs and lake-bottom sediments with their microscopic content of pollen are nature's own historical archives.

From cores retrieved from such archives several small samples are taken out at various depths representing different times of deposition. The samples are treated with chemicals to extract and concentrate pollen and thereafter analysed using a high-magnification microscope.

The identification and counting of pollen grains is a time-consuming task and takes skill and patience. Usually between 500 and 1000 pollen grains are identified in each sample to get a statistically significant result. Some characteristic pollen grains can be identified down to species level but most of them only to so-called pollen types, which may include several species, or to plant genera or family. After identification, the raw pollen counts from each sample are transferred to percentage values and usually presented in a diagram with individual graphs for each pollen taxon. The diagram can be used to interpret past vegetation around the site, and the changes in pollen percentages observed throughout the stratigraphic sequence reflect vegetation change through time. Peat or other plant remains from the analysed core are radiocarbon dated to obtain an absolute chronology.

After its introduction, pollen analysis was for long used only to study what was regarded as natural vegetation development, in particular changes in forest composition, and how it may have reflected climate. This was partly due to the limited knowledge on pollen identification at the time, which was much restricted to tree pollen, but partly also to the general opinion during the early twentieth century that past human impact on the vegetation was small and not measurable. However, from the 1940s onwards, with the first identification of pollen from cereals and from plants thriving in pastures, pollen analysis gradually became a method also to study past agriculture.⁵ After an influential paper by Björn E. Berglund,⁶ pollen diagrams in the 1970s and 1980s were frequently used to identify periods of agricultural expansion and decline, which were discussed in relation to Ester Boserup's model of a stepwise societal development and to ideas on carrying capacity in relation to different agricultural techniques.⁷

Until the 1980s pollen analysis was mostly used to study long-term trends over several millennia and the pollen diagrams that were produced had a rather poor time resolution. They also had a poor spatial resolution since they used cores from large lakes and bogs with a large pollen source area, and aimed at describing the regional development rather than the local. This changed in the 1990s. From then onwards there has been an increasing interest in Sweden and in many other countries for more detailed pollen studies of local vegetation development with a shorter time perspective. Some of these local pollen diagrams have been produced within the context of forest ecology, with the aim to answer questions on tree successions and woodland dynamics at stand scale.⁸ Others have been produced in connection with archaeological excavations in order to interpret local vegetation and land use that may be linked to the investigated remains.⁹ In both cases a detailed picture of local conditions with a high temporal resolution is preferred before a more general picture of long-term trends over a large region.

Hand in hand with this development, there has been an increasing awareness of problems connected to radiocarbon dating. Chronologies of most early pollen diagrams were based on radiocarbon dating of bulk lake sediments, which due to the so-called reservoir effect may provide erroneously old dates (the error is usually 100–300 years but occasionally much larger).¹⁰ In modern studies radiocarbon dating of bulk samples from lake sediments is usually avoided. Instead bog moss and other macro-remains (fruits, leaves, etc.) from terrestrial plants are used which has resulted in more accurate chronologies.¹¹ This advance has been facilitated by the AMS technique (Accelerator Mass Spectrometry), by which very small samples can be dated.

Sweden has a long tradition of pollen analysis and a wealth of pollen data, and in particular during the last two decades several high-resolution pollen records have been

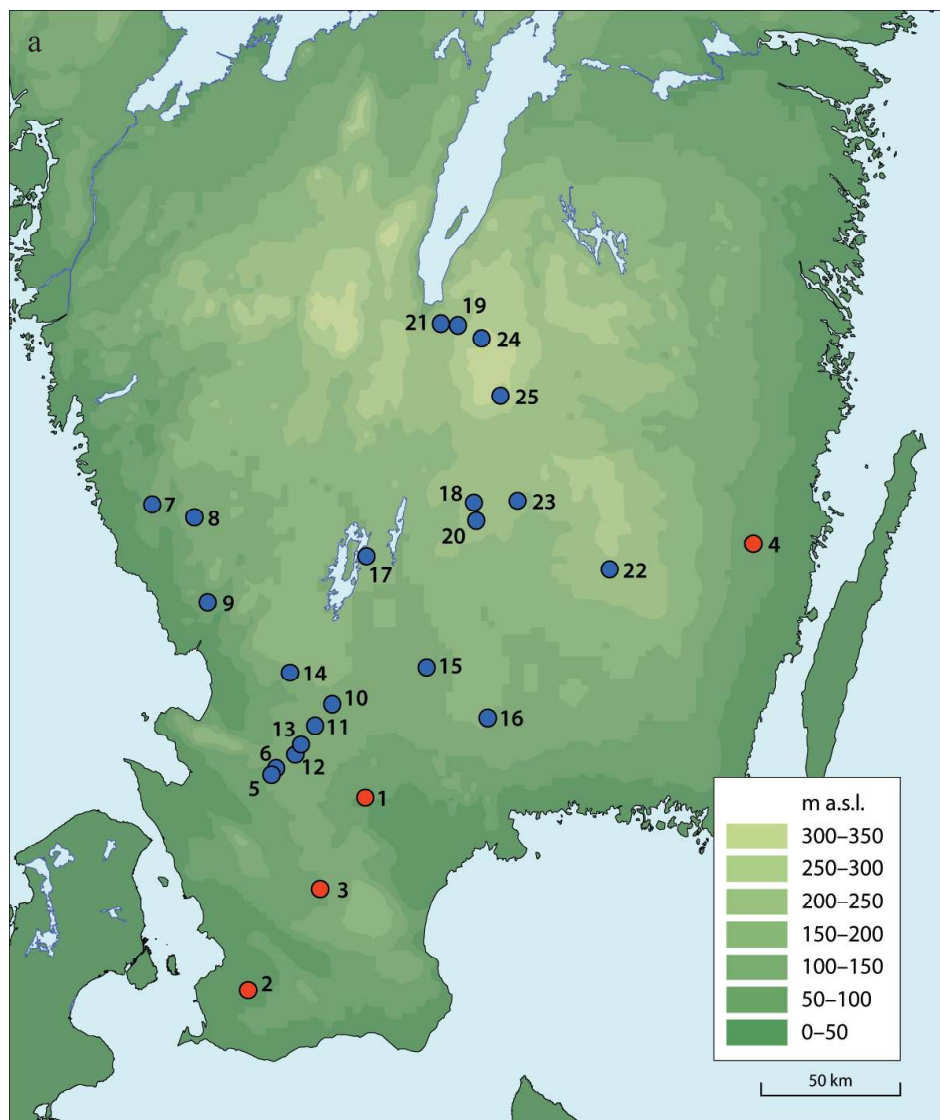


Fig. 5a. Map showing pollen sites in southern Sweden used in the present study. Symbol colours distinguish between lowland sites (< 100 m a.s.l.) (red dots), and upland sites (> 100 m a.s.l.) (blue dots). Sites: 1 Skeakärret, 2 Torup, 3 Häggenäs, 4 Skärsgölarna, 5 Östra Ringarp, 6 Grisavad, 7 Bocksten, 8 Yttra Berg, 9 Trälhultet, 10 Exhult, 11 Köphult, 12 Rosts täppa, 13 Bjärabygget, 14 Baggabygget, 15 Råshult, 16 Siggaboda, 17 Flahult, 18 Lindhultsgöl, 19 Öggestorpsdalen, 20 Åbodasjön, 21 Store mosse, 22 Storasjö, 23 Skärpingegöl, 24 Bråtamossen, 25 Mattarp

published. These detailed, local records are the foundation for the present study. Because the aim is to reveal possible vegetation changes connected to the late-medieval crisis, which in a palaeoecological perspective is a rather sudden and short-lasting event, care has been taken to use pollen records that have a reasonably high resolution (i.e. many pollen-analysed levels) for the last 1000 years and have good and independent chronologies. Pollen records with chronologies based on radiocarbon dating of lake sediments or on pollen-analytical correlation with other sites have been excluded.

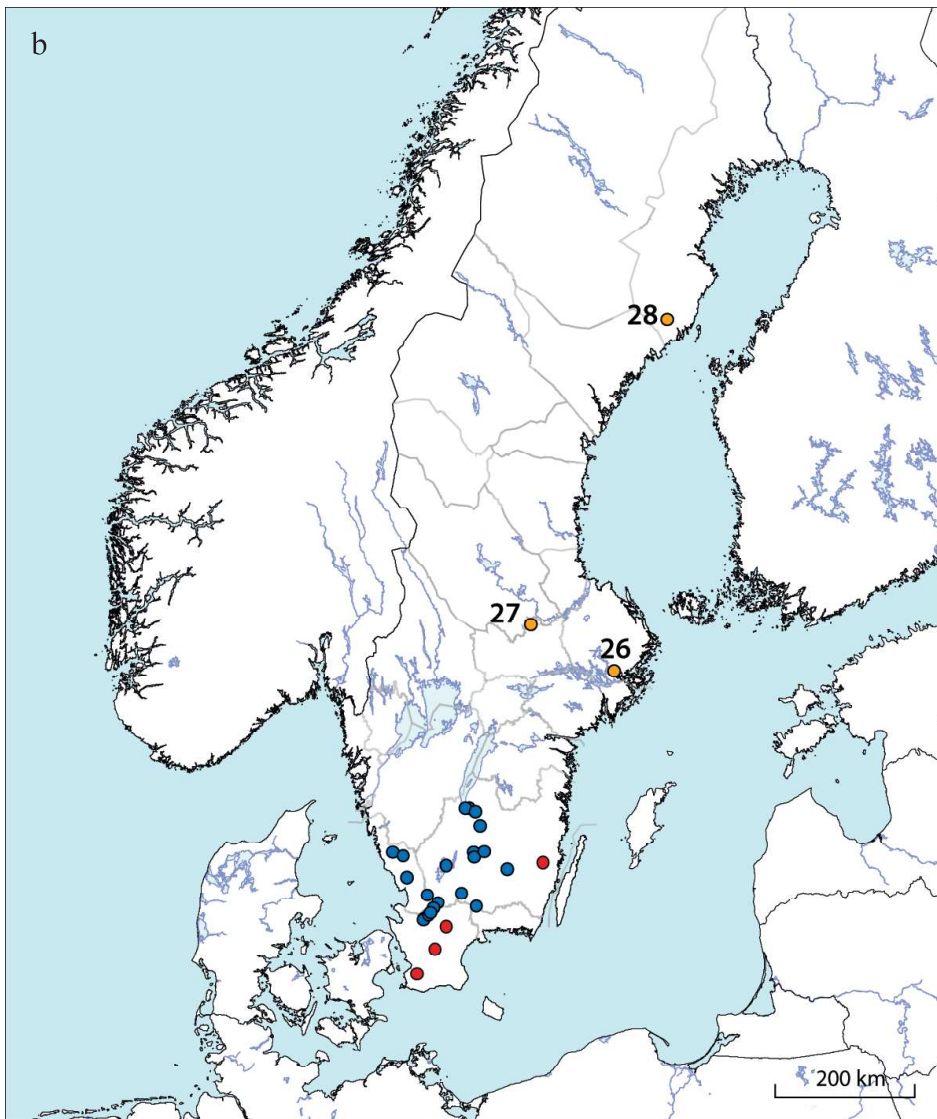


Fig. 5b. Map showing the pollen sites used in the present study including three sites in middle and northern Sweden (yellow dots). Sites: 26 Fjäturen, 27 Kalven, 28 Kassjön. For site descriptions and references to original publications see Appendix 1

Based on the above criteria a set of pollen data from 25 sites from southern Sweden (Fig. 5a) has been established. The vast majority of them (21 sites) are situated in the South-Swedish Uplands (Sw: *Sydsvenska höglandet*), and therefore much of our conclusions and discussions will focus on these uplands. One reason why the uplands have attracted so many pollen-analytical studies is that they are rich in well-preserved peatlands. In contrast, the agricultural plains of the lowlands have very few preserved peatlands, due to cultivation, drainage and peat cutting, and hence there are only a few useful pollen records (four sites) from the lowlands in the data set. In addition to records from the uplands and lowlands of southern Sweden, there are three sites from further north – two of them from middle Sweden and one from the northern part of the country (Fig. 5b) (for details about the pollen sites see Appendix 1).

The South-Swedish Uplands range *c.* 100–377 m above sea level and today they are, to a large degree, covered by forest, in particular planted spruce and pine forest. The high degree of forestation is due to the relatively poor natural conditions for agriculture. In comparison to the lowlands of Scania in the south, the mean annual temperature of the uplands is *c.* 1–2° lower and the growing season is 10–20 days shorter.¹² The Quaternary deposits are dominated by sandy till, rich in stones and boulder, reflecting the hard gneissic bedrock, whereas the agricultural plains of the lowlands are characterised by more fertile, calcareous clay and silt.

The strong bias in our pollen data to marginal uplands makes it difficult to draw general conclusions on a national scale or to make comparisons between lowlands and uplands. However, because settlements of marginal areas were not isolated, ups and downs in marginal areas in one way or the other reflect changes in central areas too. Furthermore, marginal areas appear to be most suitable for studies of environmental responses to societal change. In comparison to central areas they show a more discontinuous land-use and settlement history, which makes it relatively easy to distinguish periods of agricultural expansion from periods of stagnation and decline. In particular semi-open landscapes characterised by a mosaic of woodlands and agricultural land are suitable for a palaeoecological approach, because in such landscapes changes in human impact are likely to result in vegetation changes that are distinct enough to be detected by pollen analysis. Therefore studies on marginal areas may be used to take the temperature on society as a whole.

In addition to pollen records, conclusions presented in this chapter are drawn from dendrochronological dating. The basic principle of this technique is the counting and measuring of tree rings for comparison with reference tree-ring series of known age.¹³ Trees, timber or any wooden objects that contain tree rings can be dated with very high precision, even down to a single year if the outer tree ring is preserved. In Sweden the construction of reference tree-ring series and systematic dendrochronological dating started in the 1970s.¹⁴ Since then a lot of dating has been performed, in particular of timber from churches and other standing buildings but also of wooden objects from archaeological excavations.

In middle and northern Sweden well-preserved extant log buildings (mostly small barns and storage buildings) have attracted a lot of dating activity, and many of them have turned out to be very old.¹⁵ The oldest ones are from the late thirteenth century and quite a few are from the first half of the fourteenth century. What is most interesting for the scope of this book is that the dates show a gap of about 100 years between the 1360s and the 1460s. The gap obviously reflects a pause in building activities due to stagnation and population decline in connection with the late-medieval crisis.¹⁶ To investigate if building activities also show a similar break in southern Sweden, a large number of dendrochronological dates have been compiled and analysed. Our data set includes all dates from the provinces of Småland and Östergötland performed by the Swedish National Laboratory for Wood Anatomy and Dendrochronology at Lund University (all together 1882 dates). Since southern Sweden has very few standing profane buildings from the Middle Ages the data represent first of all planks, posts and other wooden objects documented during archaeological excavations, but also standing churches.

Dendrochronological data from Småland will be used in this chapter as a complement to pollen data from the same region, first of all to discuss the dating of the late-medieval decline, but also in relation to woodland development.¹⁷

Abandonment of fields and farms

Among the different aspects of the late-medieval crisis, abandoned farms are probably the most acknowledged. In fact the mentioning of abandoned or deserted farms in written records from the centuries after the Black Death is one of the strongest indications of the societal crisis and of the associated drop in population numbers. Also the physical remains of them are sometimes preserved. The archaeological study of deserted farms and villages is a well-established field of research in several countries, particularly in England but also for instance in Germany, where they are referred to as *Wüstungen*. Even though farms may be abandoned for different reasons, and have so been from time to time throughout history, the Late Middle Ages appear to have been a period of unusually extensive abandonment.

In Sweden relatively few have been archaeologically investigated and conclusions on late-medieval farm abandonment are based mainly on documentary evidence.¹⁸ In particular cadastral registers have been extensively studied.¹⁹ However, the earliest of these registers are from the late fifteenth century and most of them are from the sixteenth or seventeenth centuries, i.e. several centuries after the Black Death of 1350. Therefore they do not catch the actual process of abandonment and they do not show the original number of deserted farms. What the cadastral registers do show is that many farms were still deserted one or several centuries after the Black Death.

The reason why abandoned farms are mentioned in these records in the first place is that they were still someone's property. They were uninhabited but owned by other farms in the vicinity or by big landowners and they were regarded as a resource (or a potential resource) with an economical value. When they were registered they were uninhabited and probably had no buildings left, but their land was owned and managed by other farms, usually for pasture or mowing. The term "abandoned farm" (Sw: *ödegård*) in the cadastral registers thus means a piece of land that once belonged to a farm that is now uninhabited. Because the registers are not from the nadir of the societal crisis, but rather from afterwards when there was strong expansion of agriculture and settlement, many once abandoned farms were probably already re-inhabited and therefore no longer deserted. In the records they will appear as ordinary tax paying farms, undistinguishable from farms that were never abandoned. Furthermore, there were probably many abandoned farms in particular in distant areas that were never reclaimed or registered. They were simply deserted, overgrown and forgotten and therefore missing in the historical record.

For these reasons it is not possible to say, based on the historical documents, how many farms that were originally abandoned in the wake of the Black Death and this is why different scholars have arrived at different conclusions. According to the cautious estimation by *The Scandinavian Research Project on Deserted Farms and Villages*, only about 15% or less of the farms in several parts of Sweden were abandoned.²⁰ However, for one study area, situated in the uplands of southern Sweden, they suggested a more extensive desertion, about 25–40%.²¹ Janken Myrdal presented a quite different conclusion. According to him, in many areas of southern Sweden 30–60% of the farms was abandoned and in marginal uplands even more.²²

From this background we will now turn to pollen data and look specifically for indications of farm abandonment. Because crop growing is closely associated with settlement, cereal pollen may be used as an indicator of settlement. In Figure 6 the cereal pollen graph for

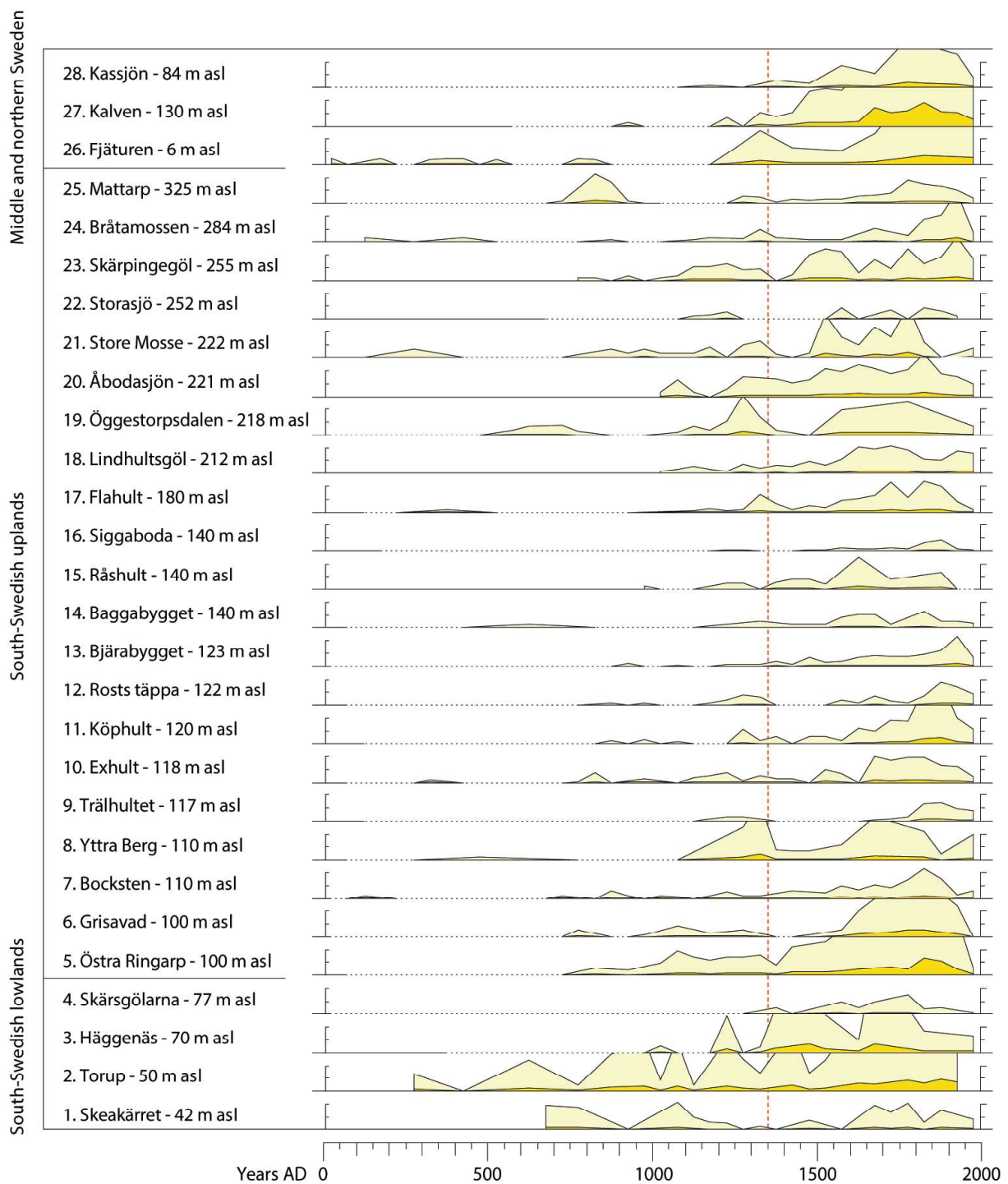


Fig. 6. Graphs showing cereal-pollen percentages from each individual pollen site plotted on a time scale (site numbers refer to Fig. 5 and Appendix 1). Dark-yellow graphs show percentages of the pollen sum (the length of the vertical scales is 10%), whereas light-yellow graphs show an exaggeration by $\times 10$. The year 1350 is indicated by a red line

each individual site in the data set is presented. Except for the three sites from middle and northern Sweden, presented at the top the diagram, the sites are presented in order of altitude, starting with the lowermost site at the bottom. The graphs are plotted on a time scale and

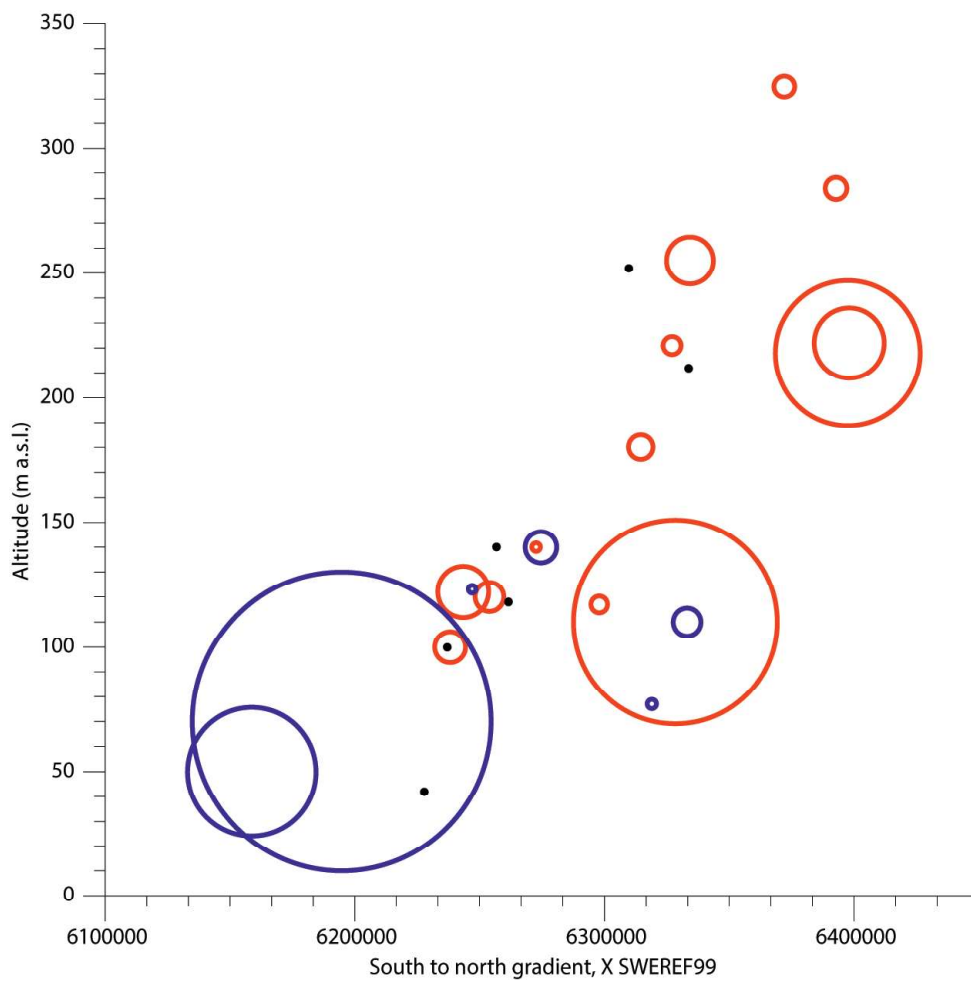


Fig. 7. Bubble graph showing the change in cereal-pollen percentages around 1350, based on a comparison between the two periods 1250–1350 and 1350–1450. Each site is represented by a circle or a dot, plotted against altitude (vertical axis) and south-to-north position (horizontal axis). Blue circles represent sites that show an increase in cereal-pollen percentages from 1250–1350 to 1350–1450, and red circles represent sites that show a decrease. The sizes of the circles are proportional to the size of the increase or decrease, respectively. Black dots represent sites with no change

most of them cover the last 2000 years. Because cereals do not survive in the wild, cereal pollen is the best pollen indicator of crop growing and indirectly of agricultural settlement. With the exception of rye, all cereals are poor pollen producers, and even though the pollen grains are dispersed by wind, they are relatively large and heavy and do not travel long distances. Consequently, cereal pollen in most pollen diagrams reach only low percentages of the pollen sum (i.e. of the total number of identified pollen grains in the sample), but even low percentages may be used as indications of arable fields in the vicinity.

In some of the original diagrams, different types of cereal pollen have been distinguished. However, with the exception of rye, the distinction between different cereal-pollen types is difficult and sometimes arbitrary, and different analysts may use different identification criteria. Therefore, to enable comparison between the sites and calculations of mean values, they are all put together here into one common graph including all types of cereal pollen from each site.

The first impression from Figure 6 is that all the graphs look different. The differences reflect differences in the history of cereal growing between the sites, but that is not the whole truth. The pollen percentages are also influenced by other factors, like the size of the sampled basin (i.e. the peatland or lake) and the distance between the basin and the past cereal growing. Furthermore, the cereal-pollen percentages are affected by vegetation structure, which may have differed from site to site and also through time.

Hence, the graphs all look different, partly because of differences in their local agriculture and settlement histories and partly because of pollen-dispersal factors. Still it is possible to find patterns beyond the site-to-site variation. For instance, all sites show higher cereal-pollen percentages from the last millennium than from the previous one. Furthermore, most of the sites show a decrease during the last one or two centuries, reflecting the farm abandonment and forest plantation that characterised the uplands in the late nineteenth and twentieth centuries. Hence, the comparison of cereal graphs from different sites reveals both local variations and common regional trends. Also a closer look at the time of the Black Death and the late-medieval crisis, indicates great variation between the sites, but some important conclusions can be made. Of the 25 sites from southern Sweden, 11 show decreasing cereal-pollen percentages around 1350 (Grisavad, Östra Ringarp, Yttra Berg, Trälhultet, Rosts täppa, Flahult, Öggestorp, Store mosse, Skärpingegöl, Bråtamossen and Mattarp), others show little change, whereas only five sites show increasing values (Torup, Häggenäs, Skärsgölarna, Bocksten and Råshult). Thus, the number of sites showing decreasing cereal-pollen percentages around 1350 is higher than the number of sites showing increasing values.

Furthermore, from the same figure it can be concluded that the few sites that show increasing cereal-pollen percentages around 1350 are situated at relatively low elevation. This relationship is also evident from the bubble graph in Figure 7. The graph reveals clearly that two sites at low altitudes (Torup and Häggenäs) deviate strongly from the others by showing significantly increasing cereal-pollen percentages. These two sites are also the two southernmost sites, situated not far from the agricultural plains of Scania (sites 2 and 3 in Figs 5 and 6).

To summarise the evidence so far, pollen sites that show decreasing cereal-pollen percentages around 1350 are common in the South-Swedish Uplands, whereas two lowland sites in southernmost Sweden, on the contrary, show a distinct increase. The difference between lowland and upland sites is intriguing, but because of the low number of lowland sites any interpretations regarding the development in the lowlands have to be tentative and do not allow for any detailed analysis.

The same is true for much of middle and northern Sweden. Only three sites with detailed chronologies were available for the present study, and they represent rather different ecological and climatic zones. They are here used only as examples of agricultural development in different regions. Site Fjäturen, which is situated in a low-lying agricultural area north of Stockholm, has a cereal-pollen graph similar to many sites in the South-Swedish Uplands. It shows an increase in cereal-pollen percentages in the thirteenth century followed by a decrease in the fourteenth century. The latter indicates a late-medieval agricultural decline. It was followed by a second expansion in the seventeenth century. Lake Kalven is situated in an upland forest region and mining district of middle Sweden. It shows an increase in cereal-pollen percentages immediately before 1350, reflecting the first agricultural expansion in the area. The expansion was soon followed by stagnation and possibly decline after 1350.

A renewed expansion started in the fifteenth century, later followed by a much stronger expansion in the seventeenth century. Lake Kassjön is the northernmost site, situated outside Umeå in northern Sweden. A continuous cereal-pollen graph begins in the fourteenth century. There is no clear indication of decline but rather a slow step-wise increase in cereal pollen, reflecting expansion periods in the sixteenth and eighteenth centuries.

The two sites from middle Sweden – Fjäturen and Kalven – show indications of late-medieval agricultural decline. In particular Lake Fjäturen is interesting, since it is the only lowland site in the data set that shows strong indication of agricultural decline in connection to the Black Death. Lake Kassjön in northern Sweden shows no such decline, but rather indicates an establishment of continuous crop growing at the same time. Written records are scarce and it is still an open question if the Black Death reached that far north.

Similar to lowland sites from southern Sweden, the sites from middle and northern Sweden provide interesting examples but are too few to allow for any representative analysis. In contrast, the South-Swedish Uplands are very well represented. As many as 21 pollen sites in the data set are from this relatively homogeneous upland region, which makes a solid basis for interpretation. Therefore the rest of this chapter will focus on the uplands. (Hopefully future research will provide more pollen sites from lowland areas as well as from regions further north.)²³

We may now look at the average development in the South-Swedish Uplands by calculating mean cereal-pollen percentages for all the 21 upland sites together. This was done for 50-year time slices and the result is presented in Figure 8a. As evident from the diagram mean cereal-pollen percentages from upland sites are very low during much of the first millennium after Christ. Following an initial increase in the late eighth and early ninth centuries a significant increase starts in the late eleventh century and continues to the early fourteenth century. This increase reflects medieval colonisation and expansion, which is well known from other sources, like settlement remains, written documents, place names, etc. The expansion was part of a general agricultural expansion over much of Europe.²⁴ The upward trend in the graph is broken in the mid-fourteenth century by an abrupt decrease in mean cereal-pollen percentages. There can be no doubt that this decrease reflects a significant decrease in cereal growing in the uplands after the Black Death. After the decline, values remain low for at least a century, until they start to increase slowly during the late fifteenth century onwards. In the sixteenth century they reach the same level as before the decline. Except for a possible stagnation in the early eighteenth century they continue to rise until the early nineteenth century. From the late nineteenth century onwards, cereal-pollen percentages decline, which reflects depopulation of the countryside and large-scale introduction of modern forest plantations in the uplands.

The fact that the mean cereal-pollen percentages for the upland sites drop sharply in connection to the Black Death is a strong and independent indication of agricultural decline. It shows that in spite of the site-to-site variation, and in spite of the very low cereal-pollen percentages in general from upland sites, the regional trend is clear. The mean value decreases from 0.4% to 0.2% of the pollen sum, i.e. a halving.²⁵

In order to estimate what this change in mean pollen-percentage values represents in the landscape, past vegetation cover for each 50-year time slice has been modelled using the so-called Landscape Reconstruction Algorithm.²⁶ This modelling technique uses pollen counts, pollen-dispersal characteristics (pollen production and fall speed of pollen grains)

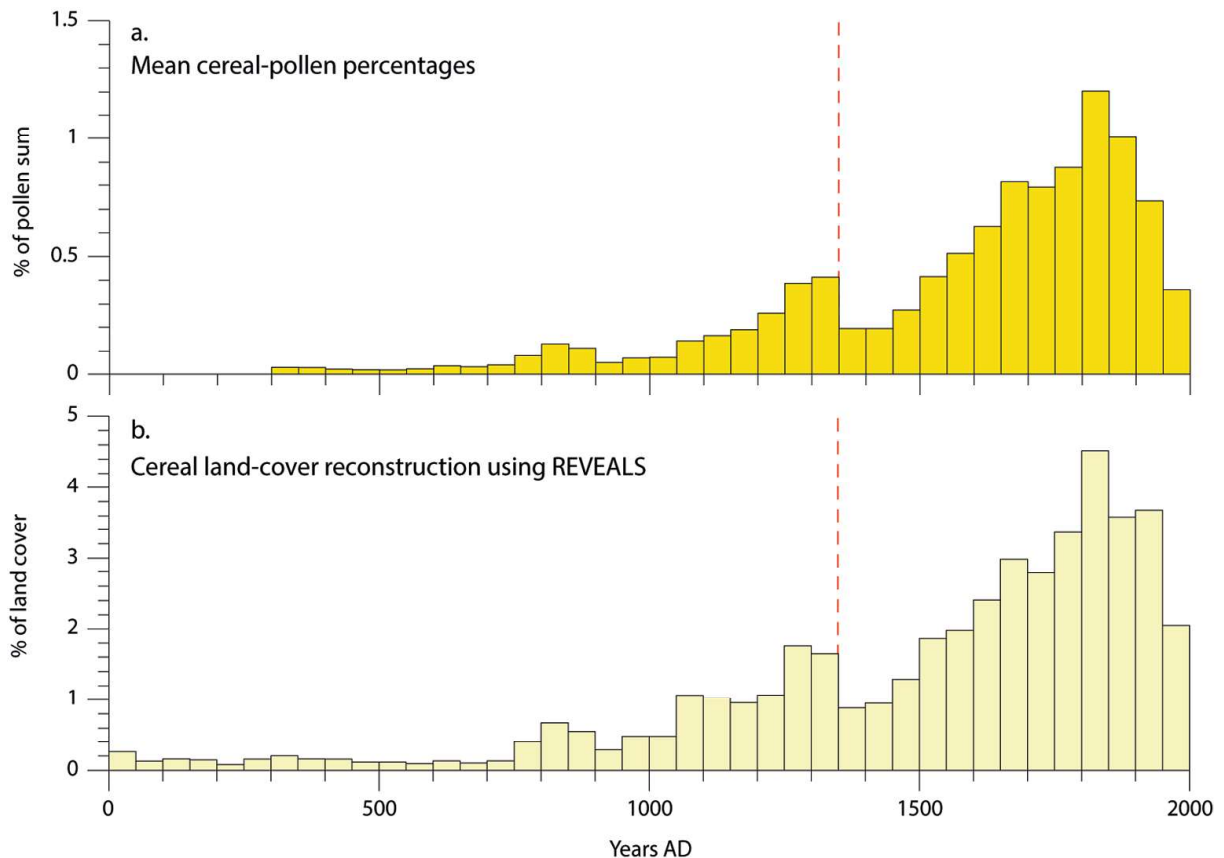


Fig. 8. Bar charts showing (a) the mean cereal-pollen percentages for each 50-year time slice based on all the 21 upland sites, and (b) the corresponding cereal land-cover reconstruction using the Landscape Reconstruction Algorithm, submodel REVEALS. The year 1350 is indicated by a red line

and site characteristics (basin size) to translate the fossil pollen record to vegetation cover. Thus, the model enables us to describe the actual extent of cultivated fields, pastures and woodland. The model corrects for over- and under-representation of strong and weak pollen producers, respectively (for instance, most trees are over-represented in the pollen record and most herbs under-represented). Some of the problems connected with the interpretation of pollen percentages, for instance the over-representation of plants growing on the sampled peatland, also affects the model output, but the technique is the best available to reconstruct vegetation cover from pollen data. For this study pollen data and site characteristics for all the 21 upland sites have been used.²⁷

The graph in Figure 8b shows the reconstructed land cover of cereal vegetation in the upland region for each 50-year time slice.²⁸ The shape of the graph is similar to the one for cereal-pollen percentages, with only small differences. Most important in this context is that the reconstruction allows us to tentatively discuss not only pollen percentages but also the land cover of arable fields. According to the reconstruction, cultivated arable fields (excluding fallows) covered approximately 2% of the upland region in the late thirteenth and early fourteenth centuries. After a drop around 1350 they covered approximately 1% in the late fourteenth and early fifteenth centuries. After the late-medieval nadir they expanded to reach the maximum distribution of all time in the nineteenth century, when they covered

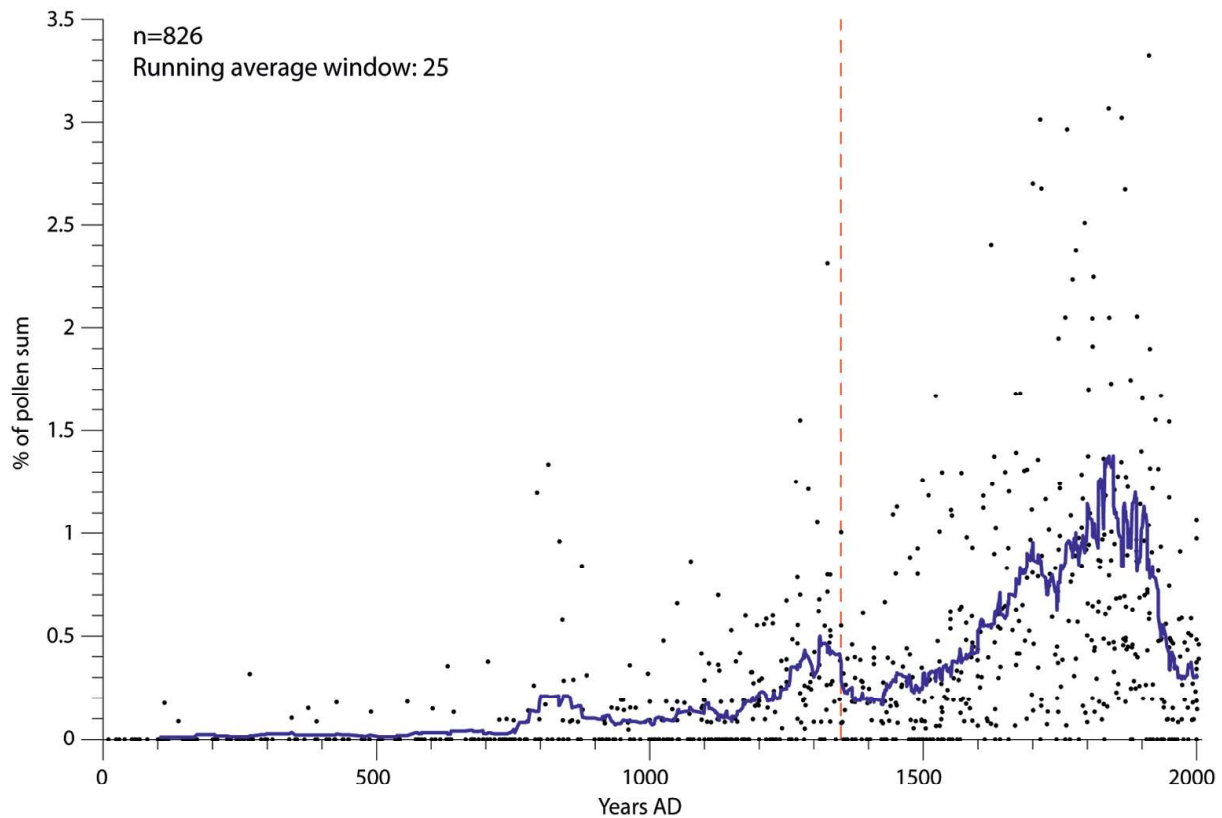


Fig. 9. Cereal-pollen percentages from all the 21 upland sites. Each dot represents an original pollen sample with its corresponding cereal-pollen percentage (vertical axis) and original dating (horizontal axis). The samples were sorted chronologically and a running average was calculated (blue line). Four dots with very high values from the nineteenth century were excluded from the picture but included in the running-average. The year 1350 is indicated by a red line

4–5% of the landscape. Thereafter they decreased and in the late twentieth century they covered approximately 2%.

Based on historical documents, the average land cover of arable fields for southern Sweden during the early eighteenth century has been estimated to approximately 5%, and for forested uplands to approximately 2%.²⁹ The latter figure fits reasonably well with the land cover reconstruction based on pollen records presented here. According to the reconstruction, cereal cultivation covered approximately 3% of the uplands in the eighteenth century (Fig. 8b). The good agreement for the eighteenth century, from which there is plenty of documentary evidence, indicates that the pollen-based reconstruction is reliable enough also for earlier periods.

Regarding the drop around 1350, the reconstruction shows a halving of cereal cropland, from *c.* 2% to 1% of the land cover. Thus the pollen record – both pollen percentages and pollen-based land-cover reconstructions – gives support to earlier interpretations of historical records that suggest extensive farm abandonment in upland areas during the late-medieval crisis. Even though a halving of cereal production, as indicated by the pollen record, does not necessarily reflect a farm-desertion frequency of 50% (farms may have survived but reduced their acreage), it indicates that a desertion frequency of that size is not at all unlikely.

Some earlier pollen studies have similarly shown a decrease in cereal-pollen percentages after the Black Death. Evidence comes from several parts of northern and western Europe, for instance from Sweden, Norway, Denmark, Estonia, France, Netherlands, England and Ireland.³⁰ Many of these studies are of high quality, with high-resolution analysis and detailed chronologies, but most of them are based on single pollen sites or occasionally a few sites. Dan Yeloff and Bas van Geel reviewed pollen-analytical evidence on late-medieval farm abandonment in Europe.³¹ Their review considers only positive evidence of abandonment and they emphasise that there are also many other pollen diagrams from Europe that instead show continuity. They arrived at the conclusion that the effect on the European rural landscape of the Black Death varied geographically. They also concluded that abandonment in some areas started already before the Black Death, for instance in France and England.

In spite of these earlier studies, it is difficult to draw any general conclusion on the late-medieval decline based on pollen data, in particular on a European scale but also on national and regional scales. However, the method used in this study – to combine a large number of local pollen studies from one region at such high time resolution – is a step forward. With this approach it has been possible to interpret the regional development and at the same time reveal local variation within the region.³² Also, the technique of landscape reconstruction modelling used here enables us to discuss the actual extent of arable and how it has varied through time.

Sudden impact of the Black Death

The late-medieval crisis was a complex and multifaceted process that lasted for more than a century and several different factors may have contributed to the circle of events. The Black Death of 1347–52 was certainly a major factor, but in some parts of Europe there was stagnation and even farm abandonment already before that period, in particular after the harvest failures leading to the Great Famine of 1315–22. There is no evidence of the latter from Sweden but that may very well be due to a paucity of documentary records.³³ If the harvest failures struck Sweden, farm abandonment might be expected, not only connected to the Black Death, but also before.

Furthermore, abandonment may have continued long after the Black Death. Based on documentary evidence, Janken Myrdal suggested that widespread farm abandonment did not begin until the 1360s and 1370s. Before that time, vacant farms were probably taken over by the many landless and poor. Abandonment started when this reserve of the labour force was used up and it continued well into the fifteenth century. It was most extensive in the 1420s or somewhat later. According to Myrdal the prolonged process of abandonment was due to recurring outbreaks of plague in combination with social oppression and conflicts.³⁴

The pollen data presented here may contribute to the discussion of timing. In the diagram for upland sites in Figure 8a, mean cereal-pollen percentages decrease exactly at 1350, but this is partly due to the construction of the diagram. To enable the calculation of mean values, the original samples from the different pollen sites were adjusted by interpolation to 50-year time slices.³⁵ Therefore changes in the diagram are restricted to 50-year intervals. All that can be concluded from the diagram, regarding the time of the Black Death, is that

the mean cereal-pollen percentages decrease significantly from the 1300–1350 time slice to the 1350–1400 time slice.

In an attempt to obtain a finer resolution than 50 years, a different type of diagram is presented in Figure 9. This diagram is also based on all the 21 upland sites, but instead of showing calculated mean values based on time slices, it shows all the original pollen samples from the different sites. In large measure the curve of the running average resembles the graph of mean values in Figure 8a. The important difference is that this one is not limited by the 50-year intervals of the time slices. Therefore it is interesting to note that it falls sharply exactly at 1350.

The chronologies of the different pollen diagrams included in the data set are all based on radiocarbon dating. Even though only pollen diagrams with chronologies that are regarded as sufficiently reliable have been included, radiocarbon dating is still a rather blunt technique in this context. Even if the radiocarbon dates are correct themselves they have a statistical error. Furthermore, the construction of the time/depth models used to calculate sample ages in the original studies include errors connected to interpolation.³⁶ In spite of these possible chronological errors, which probably blur the picture, the mean cereal-pollen graph shows a distinct decline around 1350 (Fig. 8a) and, more important, the running-average curve for the original samples falls steeply at exactly 1350 (Fig. 9). Hypothetically, the fall in the latter would be even more concentrated to 1350 if the underlying chronologies were perfectly correct.

In conclusion, pollen data from the uplands indicate an immediate effect of the Black Death, which we know from other sources ravaged Sweden in the year 1350. They do not indicate a delayed effect, as suggested by Myrdal based on documentary evidence. However, the running-average curve seems to support his conclusion that abandonment continued into the early fifteenth century. Regarding the Great Famine in the early fourteenth century, the curve shows a slight decline from approximately 1320, but perhaps not strong enough to prove abandonment already at that time.

This conclusion of the timing of the decline based on pollen data may be compared with an entirely different type of source material, namely the dating of wood by dendrochronology. This dating method is very precise. If the outermost tree ring is preserved, the very year when the tree was cut down can be identified. If the outer tree rings are not preserved, the felling year may be estimated. The precision of this estimation varies, and depends on how much of the tree trunk that is preserved, but it is usually higher than for radiocarbon dating.

In Figure 10, a compilation is presented of all the dendrochronological dates from the Province of Småland performed by the National Laboratory for Wood Anatomy and Dendrochronology at Lund University (dates later than 1800 were not included). Småland covers most of the upland region that is covered by the pollen data. The diagram is based on 702 individual dates, representing 96 dating projects in 47 different parishes (Fig. 11). The dated objects were standing buildings (in particular churches) as well as posts, planks and other construction details revealed by archaeological excavations. They represent both churches (142 dates) and profane contexts (560 dates).

The diagram (Fig. 10) shows a more-or-less gradual increase in the number of dates per 50 year slice from 1100 to 1350, which reflects medieval settlement expansion, and, in connection to that, the establishment of numerous churches.³⁷ Around 1350 the number of dates decreases distinctly, and from 1350 to 1600 there are very few dates per 50 years. The

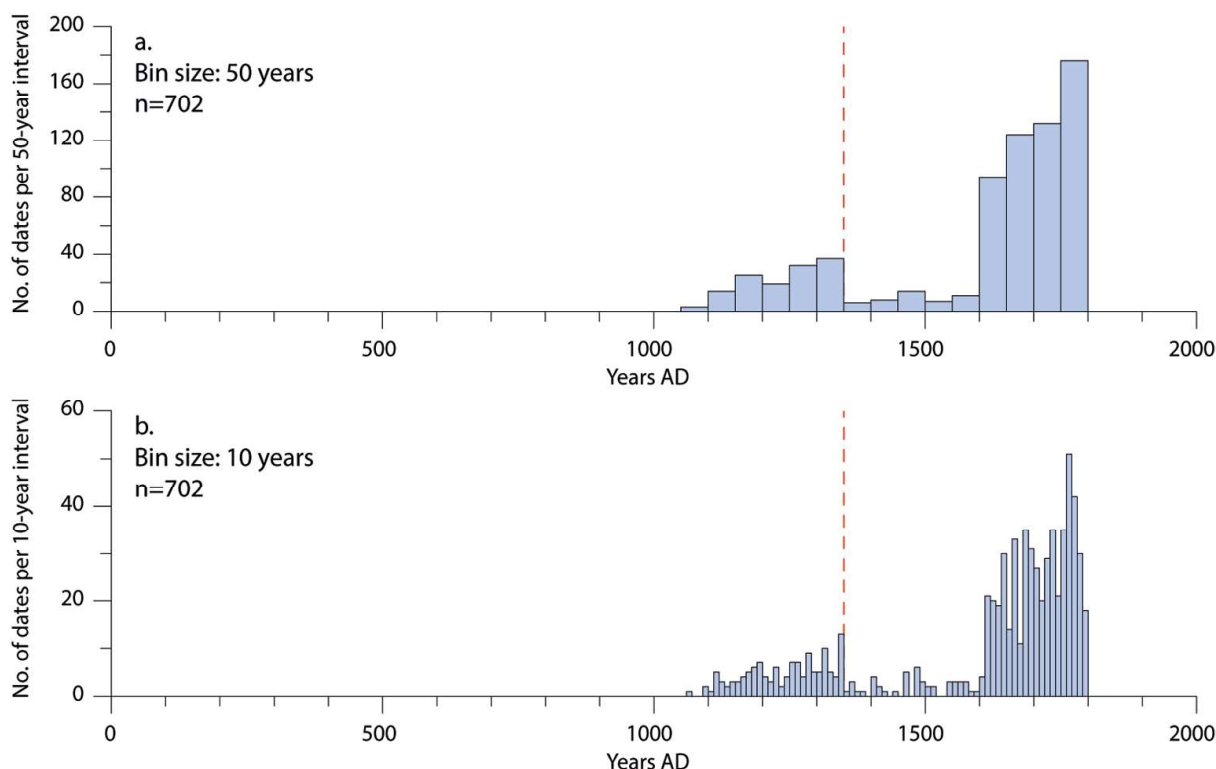


Fig. 10. A compilation of all dendrochronological dates (felling years) from Småland performed by the National Laboratory for Wood Anatomy and Dendrochronology at Lund University. Bars show the number of dates per (a) 50-year and (b) 10-year time slices, respectively. Dates later than 1800 are not included. The year 1350 is indicated by a red line

low number of dates after 1350 indicates a distinct drop in building activity in connection with the late-medieval crisis. At 1600 the number of dates increases sharply. The sharp increase in the number of dates in the early seventeenth century is partly due to a bias in the dating activity. Whereas very few post-medieval rural settlements have been investigated, there have been intense archaeological investigations in the early-modern towns of Jönköping and Kalmar, which have well-preserved timber constructions from the sixteenth century onwards.

Also, in some earlier studies a decrease in building activity in connection with the late-medieval crisis has been inferred from dendrochronological data. In middle and northern Sweden a compilation of dates from standing log buildings showed a gap of about 100 years starting in the 1360s, interpreted as reflecting a pause in building activity.³⁸ Similarly, a compilation of dendrochronological dates from Norway showed that the Black Death of 1349–50 more or less halted the building activity in Norway for 60 years.³⁹ The data from Småland fits into this picture by indicating a marked decrease in building activity after the Black Death. Also a new compilation from the province of Östergötland shows a similar pattern (see Chap. 5).

The temporal distribution of dendrochronological dates from Småland may be compared with the pollen record of the uplands presented above. A comparison of Figure 10 with Figure 8 reveals striking similarities. The gradual increase in the number of dendrochronological dates from 1100 to 1350 corresponds with a similar increase in the cereal-pollen percentages during the same time period. The two different types of data thus provide independent

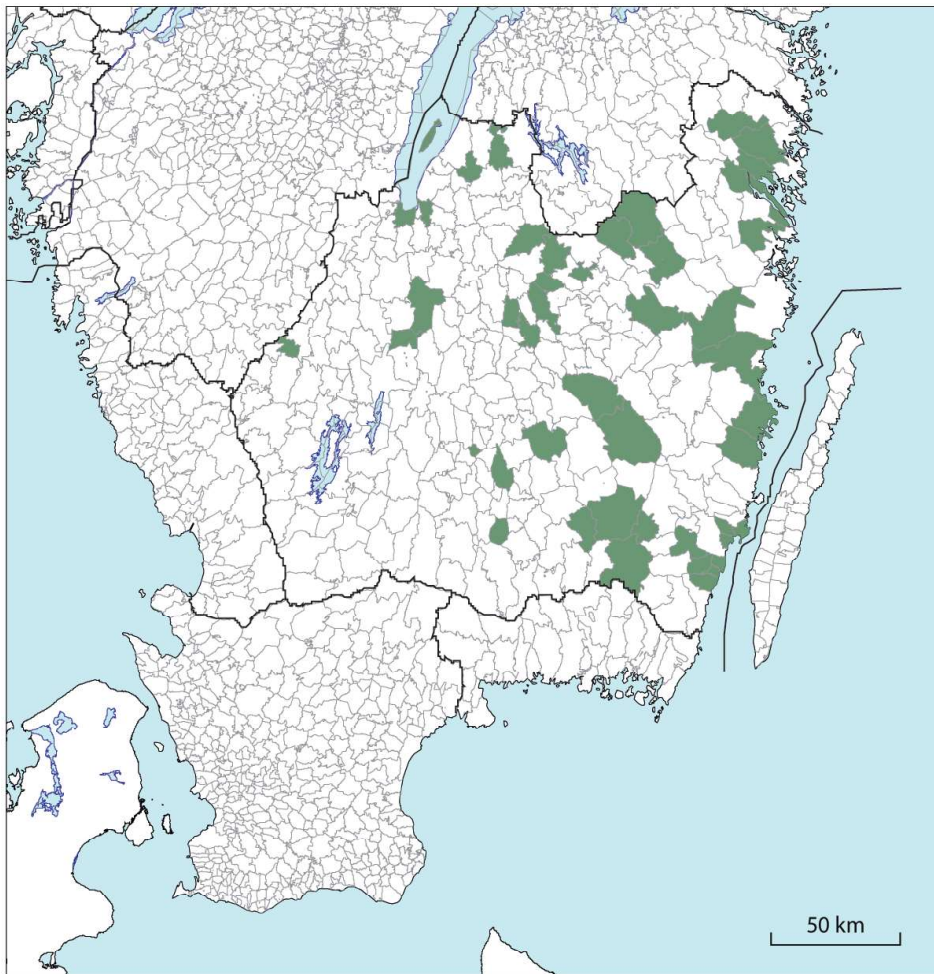


Fig. 11. Map of southern Sweden with parishes. Green indicates parishes in Småland from which we have dendrochronological dates

evidence of the medieval expansion in the uplands, reflecting construction activity and cereal growing, respectively. Both types of data also show a decrease around 1350, providing independent evidence of the severe effect of the late-medieval crisis in the uplands. It is fascinating how similar are the pictures obtained of the medieval development from these two completely different types of data.

In Figure 10a the dendrochronological dates are grouped in 50-year intervals for easy comparison with the cereal-pollen percentages. To get a higher resolution the same dendrochronological dates are grouped in 10-year intervals in Figure 10b. Although the diagram shows considerable variation from one decade to the other, it indicates that the most marked decrease in building activity followed directly upon the first struck of the plague in 1350. Even though a larger number of dates may change the picture in the future, at present dendrochronological data from Småland support the interpretation of a sudden decline in close connection to the Black Death.

To sum up the discussion on timing, both cereal-pollen percentages and the compilation of dendrochronological dates show a clear drop from the period 1300–1350 to the period 1350–1400. They provide independent evidence of a distinct decrease in crop growing

and building activity in the South-Swedish Uplands in the mid-fourteenth century. It is not possible from these two data sets to prove or disprove a smaller decline already in connection to the Great Famine of the early fourteenth century. And, likewise, it is difficult to judge the effect of later plague outbreaks, during the late fourteenth and early fifteenth centuries. However, the high-resolution diagrams in Figures 9 and 10b strongly indicate that the major decline was close to the year 1350. The conclusion that can be made is that the first struck of the plague – the Black Death *sensu stricto* – had a significant and immediate effect on upland settlements.

Plague victims or lucky emigrants?

The data presented above suggest that the uplands of southern Sweden were hit hard by the late-medieval crisis. It may be concluded that there was a population decline and that population numbers remained low for more than a century. Furthermore, the decline seems to have been very sudden – as far as can be judged from our chronologies the decline happened in close connection to the year 1350. The timing and the suddenness point to the Black Death as the major factor behind the decline. If for instance climatic deterioration were the driving force a more gradual process would have been expected.

Our conclusion is in line with some earlier studies that have suggested extensive farm abandonment particularly in upland areas. Janken Myrdal suggested that farm abandonment was extensive (more than two-thirds) in the South-Swedish Upland.⁴⁰ Also *The Scandinavian Research Project on Deserted Farms and Villages* came to the conclusion that farm abandonment was most extensive in the uplands,⁴¹ and studies from England, Germany and other countries have come to similar conclusions.⁴²

Obviously, population numbers in the uplands dropped in the mid-fourteenth century and the strong temporal correlation with the year 1350 indicates that the Black Death was the major underlying cause. But were the upland people directly hit by the plague? Several authors explain the extensive abandonment in uplands not as a direct effect of the plague, but rather as an indirect effect through migration.⁴³ According to this line of reasoning, the plague may have ravished the lowlands harder than the uplands, but farms on good soil were not abandoned for long. When lowland farmers on good holdings died there were always those who were eager to take over. This was the rare moment when landless and farmers of poor holdings got the opportunity to improve their living conditions and probably did not hesitate to do so. Also the large landowners had to adapt to the dwindling labour force by redirecting their tenants to the most productive farms.

Pollen records from lowlands are unfortunately few, and therefore it is difficult to make comparisons between lowlands and uplands. In the data set used for this study there are only four records from southern Sweden that represent sites situated below 100 m above sea level. It is interesting to note, however, that the lowland records deviate from the picture revealed by the much more numerous upland sites. Of these four lowland sites, three show increasing cereal-pollen percentages around 1350 and in particular two of them – Torup and Håggenäs – show a strong increase. These two sites are also the two southernmost sites in the data set. Even though they may not be representative for the lowlands, they do indicate

that parts of the lowlands of southern Sweden did not witness agricultural decline during the fourteenth century but rather expansion. If the migration hypothesis were correct a decline in crop growing in the uplands and no decline, or at least a smaller decline, in the lowlands would be expected. The pollen records of Torup and Häggenäs give some support to this hypothesis by indicating no decline in crop growing. However, the fact that they indicate an increase in crop growing is difficult to explain.

Turning to the uplands again, it is likely that the decline in cereal growing to some extent was due to migration. But the possibility that upland people were also directly hit by the plague should not be ruled out. No farm was completely isolated. Also inhabitants of the most remote settlements belonged to social networks and gathered for instance in church and at market places. Even though question marks remain regarding the dissemination mechanisms, the fast spread of the Black Death through Europe – where only a minority lived in Urban areas – shows that it spread effectively also in the countryside. Even sparsely populated countries witnessed a dramatic population drop, like Norway in connection with the Black Death of 1349–50 and Iceland in connection to the plague outbreak of 1402–04.⁴⁴ Certainly the plague knocked on the door also of farmsteads in the South-Swedish Uplands.

Trade connections were important for the spread of the plague, and, as Dick Harrison has emphasised, settlements depending on imported grain may have been particularly vulnerable.⁴⁵ This is because grain was usually accompanied by rats and their fleas. Possibly parts of the uplands depended on such trade. At least this was the case later, from the sixteenth century onwards, when grain was imported to the uplands in exchange for animal products.⁴⁶

The very suddenness of the decline, indicated by both cereal-pollen percentages and dendrochronological dates (Figs 9 and 10b), is interesting in this context. It may indicate that the upland settlements were hit directly by the plague, or, alternatively, that the process of migration started immediately after the plague, with no measurable delay. Regardless of which interpretation is correct (most likely it was a combination of both), it is noteworthy that the Black Death had an immediate impact on upland societies. If the Black Death of 1350 is regarded as the starting point for the late-medieval crisis in Sweden, it can be concluded that marginal uplands were immediately affected by the crisis. There is no indication of any delay from centre to periphery, and, thus, no indication that upland societies were more sustainable or resistant to change. When the Black Death hit southern Sweden it had an instant impact on the entire society, from towns and agricultural plains to remote woodlands.

A turn to animal husbandry

So far the discussion in this chapter has focused on crop growing and been based primarily on cereal pollen. An advantage with such an approach is that crop growing is closely connected to settlement and the results may be compared with previous studies on farm abandonment. Another advantage is that cereals do not grow in the wild and they disappear quickly when cultivation stops. Cereal pollen is therefore the best pollen indicator of crop growing and indirectly of settlement, and it shows an immediate response both to the beginning and end of cultivation.

Although less straightforward, pollen records may also be used to study animal husbandry.

This is because certain plants thrive in pastures and meadows.⁴⁷ Humans do not intentionally grow these plants, and many of them are part of the natural flora. But because they are light demanding and well adapted to withstand grazing, they are competitive and dominating in pastures and also in hay meadows. Vegetation changes related to the introduction or cessation of grazing are more gradual than the ones related to crop growing, but they may still appear relatively sudden in a historical perspective. If grazing or mowing stops, a natural succession would lead to overgrowing by shrubs and trees, and shade-intolerant species like heather, grasses and other herbaceous plants would decrease and eventually disappear. Apart from temporary glades, most dry ground in southern Sweden would be forested if it were not for grazing and other agricultural land uses, which hold back the forest. In this respect grazing and mowing (and also crop growing) keeps the vegetation at an early phase of succession.

Consequently, landscape openness as reflected in the pollen record may be used as a measure of agricultural impact on the landscape and in particular of the impact of animal husbandry. Land used for animal production – in particular pastures but also hay meadows – in most pre-industrial agricultural systems was much larger than the one used for crop growing.⁴⁸ Landscape openness is therefore strongly related to the impact of grazing and mowing and ultimately to the number of grazing animals. In the uplands of southern Sweden domestic grazers would have been cows, oxen, sheep and goats and to a smaller extent horses.⁴⁹

To quantify landscape openness and how it changed through time we return to the Landscape Reconstruction Algorithm, which was used in a previous section to recalculate pollen percentages to land cover. Figure 12 shows the model output based on all the 21 upland sites. For cereals it is the same output as in Figure 8b, but here all the vegetation types estimated by the model are presented.

Starting from the bottom of the diagram, the lowermost field shows the relative land cover of cereals, which was discussed above. The next field, named Mixed herbaceous, shows the land cover of all herbaceous plants excluding cereals, grasses and sedges. Most of the mixed herbaceous plants grew in pastures and meadows, while some may have grown for instance as weeds in arable fields.⁵⁰ Next follow grasses and then sedges and heather. Grasses to a large degree reflect pastures and meadows, even though some species of grass may grow in woodland, at lakeshores (reed), in naturally open wetlands or in mowed wetlands. Sedges are largely restricted to wetlands, mowed as well as natural. Heather thrives in poor pastures (heathland), usually characterised by high grazing pressure and acidic soils, but may also grow in peat bogs. After heather in the diagram follow shrubs (juniper, hazel) and different types of trees. Juniper and hazel may have grown in half-open pastures and meadows. Also birch, which is a shade-intolerant tree, may have grown in wooded pastures. However, it is also an early-succession tree that quickly expands on abandoned land when land use ceases or grazing pressure decreases. After birch in the diagram (as well as in a natural succession) follow the more shade-tolerant trees.

The diagram presents groups of plants separately that in the landscape were often mixed together. For instance, wet meadows may have contained a mix of sedges, grasses and several different herbaceous plants, whereas dry pastures had a mix of grasses, herbaceous plants and heather. Also, arable fields did certainly not contain only cereals, but also different weeds represented in the diagram by mixed herbaceous plants. In the same way most woodland before the introduction of modern forest plantations was a mix of several different tree species. Important to note is also that the transition between open land and

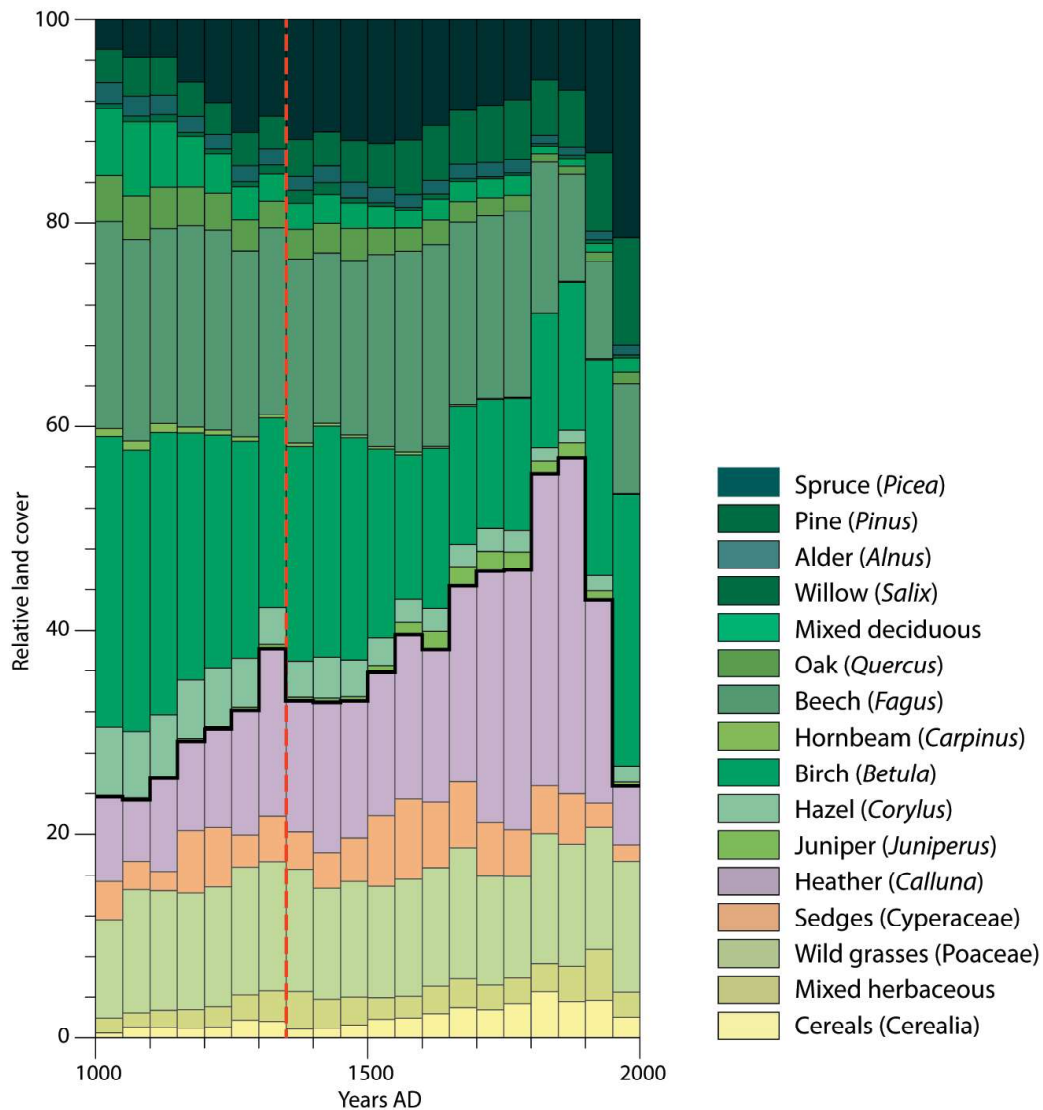


Fig. 12. Vegetation land-cover reconstruction based on pollen data from the 21 upland sites using the Landscape Reconstruction Algorithm, submodel REVEALS. The bold line between heather and juniper marks the boundary between open-land vegetation below that line and the vegetation of shrubs and trees above it. Mixed deciduous include *Ulmus* (elm), *Tilia* (lime tree) and *Fraxinus* (ash). Mixed herbaceous plants include *Compositae* SF. *Cichorioideae* (dandelions, hawk's-beards, etc.), *Filipendula* (dropwort, meadowsweet), *Plantago lanceolata* (ribwort plantain), *Potentilla* type (tormentil, cinquefoil), *Ranunculus acris* type (buttercups), *Rubiaceae* (bedstraw), and *Rumex acetosa* type (sorrel). Cereals include *Secale cereale* (rye) and *Cerealina* type (unspec. cereals). The year 1350 is indicated by a red line

woodland in the pre-industrial agricultural landscape was often diffuse and gradual. There was a range from open pastures, meadows and fields, via half-open pastures and meadows with scattered shrubs and trees, to wood pastures and dense woods. Landscape openness usually decreased by the distance to settlement.

Even though the details of these vegetation patterns are not known nor how different plant groups were mixed together, the total land cover of open-land vegetation can be used as a measure of landscape openness. In the diagram the upper limit of heather (bold line)

marks the relationship between all the open-land plants below that line and the shrubs and trees above it. It represents a summary of the land cover of all open-land vegetation and gives us a quantitative estimate of landscape openness and how it has changed through time.

The model output based on the 21 upland sites shows that open-land vegetation in the uplands expanded gradually from the eleventh century, when it covered approximately 24% of the landscape, to the early fourteenth century, when it covered 38%. Some open-land vegetation belonged to naturally open wetlands, but the strong expansion of the open landscape at the regional scale was certainly due to agricultural clearance, establishment of new settlements and increasing numbers of grazing animals.

Similar to the expansion of cereal growing, the expansion of open-land vegetation came to a halt in the fourteenth century. The gradual deforestation that had been going on for centuries stopped and from the early to the late fourteenth century landscape openness decreased from 38% to 33%. Although a relatively small decrease, it is the most marked decrease of landscape openness recorded during the last 1000 years, except for the decrease during the twentieth century. After the reforestation in the fourteenth century, landscape openness remained at the same level, about 33%, for a century and a half. In the sixteenth century open land started to expand again and apart for some short-term stagnation periods it continued to expand all the way up to the nineteenth century, when landscape openness peaked at 57%. Finally, during the twentieth century, the extent of open landscape was dramatically reduced, and during the second half of that century landscape openness was only 25%. Hence, landscape openness today in the uplands is back at the same level as by the onset of the medieval expansion one millennium ago. However, it has a very different character because of woodland species composition and how the open land is managed.

The landscape development of the last century is interesting because it gives us an opportunity to test the reliability of the landscape reconstruction. According to the reconstruction in Figure 12, the reduction of open land in the twentieth century was characterised most of all by a strong decrease in heather vegetation. Also the land cover of cereals, mixed herbaceous plants and sedges decreased at the same time. The parallel reforestation was characterised by a strong expansion of spruce, but also of pine and birch. These changes, suggested by the pollen-based reconstruction, fit nicely with the well-known landscape development based on various sources:⁵¹ Much agricultural land in the uplands was abandoned during the twentieth century and in the same process modern forestry was introduced with large-scale forest plantation. In particular heathland and other poor pastures were planted with spruce and, to some degree, with pine.⁵² Pastures left for natural succession were colonised by birch and later by coniferous trees. By the turn of the century 1900 open heathlands were still common and widespread, in particular in the western part of the uplands, but today they are all gone.

The good agreement between the land-cover reconstructions based on pollen data and the well-documented landscape development for the last century increases the credibility of the reconstruction also for earlier periods. Furthermore, the fact that modelled land cover of heather vegetation shows a sharp decrease in the twentieth century, when grazed heathland disappeared but natural peat bogs in the uplands changed very little, indicates that most of the heather vegetation, according to the diagram, belonged to pastures.

We may now return to the decrease in landscape openness that took place in the fourteenth century. Apart from cereals, particularly heather decreased whereas birch and some other

trees expanded. It reflects how pastures on poor soils were abandoned and gradually became overgrown particularly by birch in a natural succession. Also sedges and grasses show a slight decrease. The only open-land vegetation that increased at this time, according to the reconstruction, was mixed herbaceous plants. It may reflect an expansion of weeds and other plants in abandoned arable fields when crop growing stopped and they were turned into pastures or meadows.

An interesting observation is that the decrease of open-land vegetation from the early to the late fourteenth century was proportionally much smaller than the decrease in crop growing. Whereas the total land cover of open-land vegetation decreased from 38% to 33% (a decrease of 13%), the land cover of cereals was halved. Obviously landscape openness did not decrease as dramatically in the wake of the plague as the extent of arable fields. Even though some of the open-land vegetation grow in natural wetlands that were not affected by agricultural change, the much smaller relative decrease in landscape openness than in cereals indicates that grazing (and possibly mowing) did not decrease as much as crop growing during the crisis.

Hence, in addition to the change in landscape openness, there was also a change in the proportional relationship between different types of agricultural land. In the traditional agricultural landscape of southern Sweden, areas connected to animal husbandry (pastures and meadows) usually covered much larger areas than areas used for crop growing. The relationship between arable fields, meadows and pastures differed between regions and also changed through time, but everywhere, except for in the most densely populated plains, pastures and meadows dominated the agricultural landscape. In the uplands, where animal husbandry played a more important role than in the lowlands, arable fields represented only a minor part of the productive land. The hamlet Lönsboda in the southern part of the uplands is a typical example.⁵³ According to a map from 1696, it consisted of two households with 2.5 hectares of arable each. The total arable made up less than 2% of the land belonging to the hamlet, whereas the rest consisted of meadows, pastures, woods with clearings, swidden land and bogs. The meadows were more than ten times larger than the arable.

To conclude, animal husbandry has always been important in the uplands, but it became even more so after the Black Death. Population drop and farm abandonment resulted in a distinct and sudden decrease in crop cultivation, whereas land associated with animal husbandry decreased much less. The pollen record thus indicates that animal husbandry gained in relative importance after the Black Death. The same conclusion has been put forward by several authors based on the historical record.⁵⁴ In Sweden indications are found in cadastral registers from the fifteenth century onwards. According to them, many deserted farms were used as pastures and meadows.⁵⁵ Another indication is the increased production of butter, reflected in declining prices of butter relative to grain prices.⁵⁶ Even though it is difficult to quantify the increased importance of animal husbandry, the landscape reconstruction shows that this change of the agricultural system resulted in vegetation changes that were distinct enough to show up in the pollen record on a regional scale. Because animal farming is more land demanding but less labour intensive than crop growing, this relative increase in animal husbandry at the expense of arable appears to have been a strategic, labour-saving change in a time of land excess but shortage of manpower.⁵⁷

It is not possible from the pollen-based landscape reconstruction to distinguish hay meadows for fodder production from pastures. Even though animal husbandry in general

was less labour intensive than crop growing, the collection of winter fodder by mowing was rather labour intensive. At the time of hay harvest, mainly in late July to early August, the size of the workforce was a limiting factor. The development during the Late Middle Ages of longer scythes and better rakes made hay mowing more efficient and less time consuming, but fodder production still remained a bottleneck in the animal production.⁵⁸ Cadastral registers mention deserted farms used for hay mowing, at least during the late fifteenth century and later, but probably the landscape was kept open first of all by grazing. Fenced-in meadows and arable were grazed after harvest but for most of the grazing season animals roamed freely in the outlands, watched over by herders. The shift from male herders to children and women, which started in the fifteenth century, probably reflects an adaptation to the shortage of manpower after the Black Death, and helped to keep a larger livestock in relation to the number of people.⁵⁹

In the wake of population drop and abandonment, arable fields were turned to meadows and pastures, and some meadows were turned to pastures as well. At the same time, the decrease in land cover of heather vegetation after 1350 indicates that poor, less productive heathlands were completely abandoned and left to reforestation. The only open-land vegetation that increased was the one represented in Figure 12 by mixed herbaceous plants, which increased in the late fourteenth century from 3% to 4% of land cover. It probably reflects an expansion of weeds and other open-land plants when cereal growing stopped and arable fields were turned to meadows or pastures. Such an expansion of grazing indicators at some sites in the fourteenth century has been shown earlier in a few individual pollen diagrams. Examples of plants that expanded were ribwort plantain, cow-wheat, goosefoot, sorrel and grasses.⁶⁰ The reconstruction presented here shows that the increase of this type of vegetation is detectable also at a regional scale.

The decrease in land cover of heather and the increase in mixed herbaceous plants indicate that the average quality of pastures and meadows increased. It was the combined effect of two processes – the reforestation of the poorest heathland and the establishment of rich herbaceous vegetation on abandoned arable fields. This appears to have been the result of strategic decisions. By turning arable to pastures and meadows and by leaving the poorest pastures to natural succession, peasants took the opportunity to increase the land productivity of their stock farming.

The changes discussed so far happened in the fourteenth century and were connected to the Black Death and the associated population drop. Eventually, after more than a century, the first signs of agricultural expansion and recolonisation are visible. Both crop growing and animal husbandry (as reflected in landscape openness) started to expand again, but there appears to have been a time lag between the two. According to the landscape reconstruction, cropland reached a nadir in the late fourteenth century (Figs 8b and 12). In the first half of the fifteenth century it remained almost the same with only a slight increase, but for the second half of that century it shows a relatively distinct increase. It marks the beginning of an expansion of arable land that continued more or less uninterrupted to the early nineteenth century. The total land cover of open-land vegetation (Fig. 12) shows a similar development but slightly delayed. After the decrease in the mid-fourteenth century landscape openness remained the same throughout the fifteenth century, and the first marked increase according to the reconstruction was not until the first half of the sixteenth century. From then on, open land expanded to reach maximum openness in the late nineteenth century.

A plausible interpretation of this time lag is that the first agricultural effort, when population numbers had recovered enough to enable expansion, was to increase crop production. Arable fields once abandoned were now put under the plough again. On the stony ground that characterises much of the uplands, it was an obvious advantage to return to old fields that had already been cleared from stones. In this way the great effort once invested in stone clearance was not wasted.⁶¹ The re-establishment of previously abandoned fields is indicated by the pollen-based reconstruction. The increase in cereal cultivation in the late fifteenth and early sixteenth centuries is matched by a decrease of mixed herbaceous plants. This group of open-land plants was the only one to expand in the late fourteenth century (interpreted above as the turn of arable land to pastures and meadows), and it was the first to decrease its land cover when arable started to expand again.

The pollen record from the uplands thus indicates that agricultural expansion after the crisis started by the re-establishment of arable land. By doing so crop production and the total land productivity increased. In other words, more people could be fed on the same land. The introduction of crop growing on the deserted farms was probably associated with the establishment of new buildings and, of course, the moving in of people. Slightly later, in a second step of the expansion, forest clearing begun. This two-step process reflects a difference in the labour input required. To gradually expand pastures in the woods by girdling and fire, for instance by grazing of swidden land, may not have been a very labour intensive task, but to turn woodland to permanent arable certainly was. The felling of trees and clearing of roots to prepare the soil for cultivation was hard work. In contrast, abandoned fields that in the meantime had been used for grazing and mowing would have been relatively easy to put under the plough.

An interesting question in connection to this is to what degree vegetation and land-use during the late-medieval crisis had any influence on the duration of the crisis. As evident from the historical record and further supported by the pollen record, many deserted farms were used for pastures and meadows by other farms. In this way surviving farms got the opportunity to expand their land and in particular their animal production in the wake of the population drop. It is interesting to note that deserted farms used for pasture were frequently registered even though no rent had to be paid.⁶² Probably they were not seen only as pastures, but also as land that could be put under the plough in better times. In other words they were a resource for future expansion. Hence, the grazing and mowing of deserted farms did not only provide valuable pastures and fodder – by holding the forest back the threshold for future expansion was lowered. Regardless if this was an intentional strategy or not, it was a land use that facilitated the expansion and recolonisation that followed. If all deserted farms had been left for natural succession and reforestation, the threshold for clearance would have been higher and the recolonisation of the uplands delayed.

Expanding woodlands

Reforestation on abandoned land is frequently associated with social crisis and depopulation in the same way as its opposite – forest clearing and deforestation – is associated with agricultural expansion and population growth. Many of the most famous and well-studied examples of social collapse were followed by reforestation, for instance in Central America

after the Maya decline in the tenth century, in North America in the sixteenth century, and in Amazonia after the sixteenth century.⁶³ Also the late-medieval crisis in Europe is frequently associated with reforestation.⁶⁴ According to a much-debated hypothesis by William Ruddiman, reforestation in Europe after the Black Death and in the Americas in the sixteenth and seventeenth centuries was significant enough to result in a reversed greenhouse effect and climatic cooling.⁶⁵ Although the hypothesis has been questioned, the possible effect of past land-use changes on the climate has received increased attention during the last decade. However, few empirical studies have focused on environmental changes after the Black Death and we still know very little about the degree of reforestation. Several pollen studies provide individual examples of forest expansion, but there have been no attempts to quantify late-medieval reforestation for larger areas.⁶⁶ Here pollen-based reconstructions using LRA, like the one used in the present study, have great potential.⁶⁷

Reforestation throughout most of history – in Sweden before the last two centuries – was not by planting but by secondary succession. It was a natural process of woodland re-growth on abandoned land. The forest was held back by agricultural land use and as soon as the impact of this land use stopped or decreased a secondary succession of shrubs and trees would begin. In the traditional agricultural landscape of Sweden, there were sometimes pollards among settlement and in the meadows (Fig. 2 in Chap. 2), but most trees and woodland were to be found in the outlands. Woodland was the natural vegetation and grazing and continuous clearing was needed to keep the vegetation open and to hold the woodland back. Natural seeding of trees occurred also in open pastures but saplings were bitten off by grazing animals, and in the meadows mowing effectively stopped any sprouting of unwanted tree vegetation. Still, tree saplings that germinated in pastures and meadows could survive for many years even if browsed or cut down, ready to sprout whenever they got the opportunity.⁶⁸

As soon as the impact of people and their animals decreased or stopped, trees would invade the open vegetation by sprouting and seed dispersal. In the uplands the first trees to establish would be birch and rowan.⁶⁹ (Rowan is insect-pollinated and therefore poorly represented in pollen records.) Also oak and hazel may be quick to expand, as well as goat willow. Of these early succession trees birch was the most important. It is a typical pioneer tree, which quickly occupies cleared surfaces.⁷⁰ It is also fast growing and will soon produce a dense canopy that covers lower vegetation. The process would be quick on barren soil and slower on a well-developed grass sward, but generally it would take 20–50 years for a canopy to develop.⁷¹ Birch and other pioneer trees dominate the first phase of succession. They are, however, shade-intolerant and after a while they will be outcompeted by more shade-tolerant and usually more slow-growing trees. Typical such late-successional trees in the uplands are beech and spruce.

Turning to the result of the pollen-based landscape reconstruction, which was based on all the 21 upland sites, the diagrams in Figure 13 shows the regional land cover for a selection of tree taxa. Of the different trees to expand in the late fourteenth century, birch shows the most distinct increase. It started to expand in connection to farm abandonment in the late fourteenth century and reached a temporary peak in the early fifteenth century. The expansion of birch was a temporary interlude in a long-term declining trend of birch woodland. Oak displays a similar development. A long-term gradual decrease of oak woodland was interrupted by a temporary expansion in the late fourteenth century.

Another tree that shows an increase in land cover in the late fourteenth century is spruce. However, in contrast to birch and oak, the long-term trend of spruce during the Middle Ages was expansion. Spruce is the latest tree immigrant in southern Sweden and the only one to have expanded from north to south.⁷² Its slow but steady conquest of the uplands started in the northern parts in eighth century and by the nineteenth century it had reached also the southern parts.⁷³ The increase in the late fourteenth century appears to have been part of this long-term development, but locally the establishment of spruce forest may have been facilitated by agricultural abandonment.

An expansion of birch in connection to late-medieval farm abandonment, which is evident from the landscape reconstruction presented here, is a distinct feature also of several individual pollen diagrams.⁷⁴ In at least one of them, the peak in birch-pollen percentages is followed by an increase of pollen from more shade-tolerant trees, reflecting a gradual transition from early to late-successional woodland.⁷⁵ Such a complete succession from open land to woodland of shade-tolerant trees certainly occurred locally, but is not evident from the regional landscape reconstruction presented here. Probably the time between abandonment and re-expansion was not always long enough for a complete succession. However, it is interesting to note that oak, which similar to birch starts to expand already in the late fourteenth century, peaks somewhat later. The land cover of birch woodland peaks in the early fifteenth century, 50–100 years after the Black Death, whereas oak peaks in the next 50 years period, in the late fifteenth century. It may reflect the difference in life span and growth rate between the two species. Oak as well as birch quickly colonises abandoned land, but because oak is more slowly growing, birch dominates in the first phase and soon establishes a canopy. However, birch is a short-lived tree that does not usually exceed 100 years.⁷⁶ Its short life span together with its inability to regenerate under a closed canopy explains why the birch phase of a natural succession is only temporary. Oak trees grow much older and are more shade-tolerant. Therefore the reforestation of oak woodland is a longer process that continues after the first generation of birch trees has died off.

The strength of the landscape reconstruction presented in Figure 12 is that it is based on a large number of sites from a relatively homogenous region – the South-Swedish Uplands above 100 m above sea level. From the perspective of woodland development, however, this region is not so homogeneous. An important difference within the uplands during the last 1000 years was the different spatial distribution of spruce and beech, respectively. Both species are competitive and shade tolerant, but with different climatic preferences. As mentioned above, spruce is a late immigrant from north to south and did not reach the southern and western parts of the uplands until a century ago.⁷⁷ During much of the last 1000 years it was restricted to the northeastern parts of the uplands. Beech is also a late immigrant in a Holocene perspective but expanded from south to north. It reached the southernmost parts of the uplands in the fifth to tenth centuries and slowly expanded northward. Even today beech woodland is much restricted to the southern and western parts of the uplands with only scattered stands further north.⁷⁸

Because of this difference, the pollen sites in the data set were divided into two groups – one for the southwestern parts of the uplands and one for the northeastern (Fig. 14) – and the two subsets were run separately using the LRA. The results are presented in Figure 15. The two reconstructions do not only represent a SW–NE gradient, but also different elevation since the northeastern parts of the uplands are higher. The sites in the southwestern group

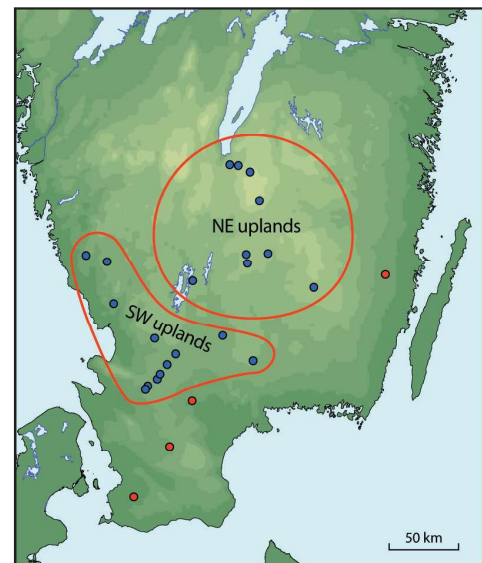
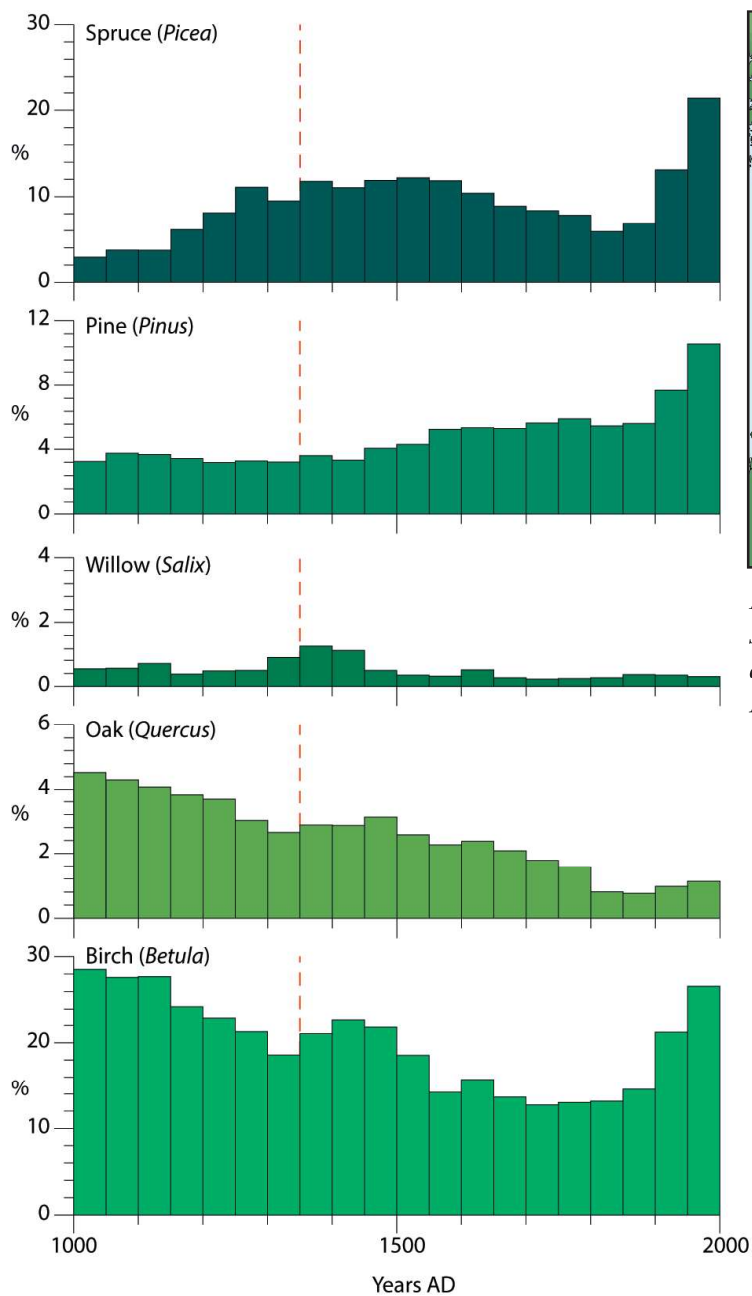


Fig. 14. The subdivision of upland sites into one south-western group and one north-eastern group used in Fig. 15

Fig. 13. Vegetation land-cover reconstruction for selected tree taxa. Based on the same model output as in Fig. 12. The year 1350 is indicated by a red line

range 100–140 m above sea level, whereas those in the northeastern group range 180–325 m. An obvious drawback with this approach is the smaller number of sites underlying each reconstruction, 12 sites in the southeastern group and nine in the northeastern. It leads to a stronger influence of individual sites, and, therefore, a larger variation in the estimated vegetation cover. The subset reconstructions will therefore not be used here to interpret subtle details, but only the major and most apparent differences between the two.

The different distribution of beech and spruce is evident from the reconstructions. Beech woodland had an average land cover of *c.* 25–30% in the southwestern parts during much of the last millennium, but never reached more than 10% in the northeast. Spruce showed a different development. It played a minor role before the eleventh century, but from then



Fig. 15. Vegetation land-cover reconstruction for the lower south-western parts of the uplands, based on 12 sites, and for the higher north-eastern parts of the uplands, based on 9 sites. Cf. Fig. 14. For further details and legend see Fig. 12

on it expanded strongly in the northeastern parts, where it reached a land cover of 25% by the sixteenth century. Spruce forest and other woodlands reached a nadir in the nineteenth century, but they increased strongly again in connection to the reforestation of the twentieth century. In the southwestern parts spruce played a much smaller role, reaching less than 5% of land cover for most of the period. Not until the twentieth century did it expand strongly to reach a land cover of almost 20%. The strong expansion of spruce all over the uplands in the twentieth century was associated with the introduction of modern forestry and spruce planting.

Even though beech and spruce woodlands showed very different development and distribution in different parts of the uplands, none of them seems to have been affected by the late-medieval decline in agricultural activity. Spruce did expand, but this expansion seems to have been part of a long-term expansion that lasted from the eleventh to the sixteenth

century. It may be concluded that the land cover of dense, climax woodland did not change in the wake of the population drop, regardless if the dominating tree species was beech or spruce. None of them were able to compete with birch and other early-successional species on abandoned land.

If we now turn to the degree of landscape openness in the uplands, the two diagrams reveal an interesting difference between the northeastern and southwestern parts. In the northeast, there was a very marked decrease in landscape openness after the Black Death. Total land cover of open-land vegetation decreased by one fourth. All types of open-land vegetation decreased, but heather most of all. At the same time, birch woodland expanded strongly. In contrast, the southwestern parts of the uplands show no signs of reforestation. Although some individual diagrams in the southwestern parts do reflect reforestation, the reconstruction presented here based on 12 sites does not.⁷⁹ It may be concluded that woodland expansion in the wake of the Black Death was more common in the higher, northeastern parts of the uplands. In the southern and western parts, grazing and possibly mowing to a greater extent kept the landscape open. This difference may reflect the harsher climate of high altitudes, leading to more widespread abandonment and depopulation. On the other hand, land cover of cereal growing shows a smaller decrease after 1350 in the northeast than it does in the southwest. Hence, the results are contradicting. Future studies will hopefully provide a better basis for interpretations of differences within the uplands. At present, what can be said with any certainty, based on the comparison presented here, is that reforestation after the Black Death was more common and widespread in the higher parts of the uplands.

Pollen records provide the best basis for studies of medieval woodland development but interesting information may be gained also from dendrochronology. The most important underlying cause to woodland expansion in some areas in the wake of the Black Death was certainly decreased agricultural impact. However, with dwindling population numbers there was also a reduced demand for fuel, timber and other woodland products. As discussed above, compilations of dendrochronological dates from Småland as well as from other regions show that there was a marked decrease in building activities during the late-medieval crisis.⁸⁰ The building of castles and fortifications continued or even increased, probably due to increased repression and riots,⁸¹ but the need for new ordinary buildings and in particular farm buildings was much reduced. Also, there was no need for new churches during the crisis and there were little resources for renovation.⁸² On the contrary, many churches decayed during the crisis and some were abandoned.⁸³

Compilations of dendrochronological dates, like the one presented here for Småland, clearly reflect the decline in building activities after the Black Death, but they may also provide some insights into the woodland development. It is a routine in dendrochronological dating not only to date the last tree ring, which of course is the one of interest for trying to date the construction of the building, but also when possible to date the innermost tree ring to estimate the year of germination. The latter may provide information on woodland establishment and reforestation. Furthermore, wood dated by dendrochronology is routinely also identified to tree species.

Dated wood from Småland and the rest of Sweden is almost entirely of oak and pine. These two tree species were by far the most important timber trees for building and they are also the ones for which there are long reference tree-ring series.⁸⁴ The diagram in Figure 16 shows the temporal distribution of the dates (estimated felling years) from Småland. It is the

same data as in Figure 10 but now with oak, pine and spruce separated. The diagram shows that oak was an important building timber during the Middle Ages before the crisis. It was particularly important for large buildings, and much of the dated oak is from churches, but it was also frequently used for profane buildings in towns. No oak has been dated to the period between 1360 and 1464. Some oak timber was used in the late fifteenth and early sixteenth centuries, but after that almost none was used until the eighteenth century. Also pine was used in churches as well as in profane buildings in towns during the Middle Ages (very few profane buildings in the countryside have been dated). Both pine and oak were important as building timber before the crisis. Later, in connection to the very strong expansion of several towns (Jönköping, Kalmar, Eksjö, etc.) in the sixteenth century, only pine timber was used. The regular use of spruce timber started very late, in the eighteenth century.

The shift from oak and pine to a strong dominance of pine may to some degree reflect a change in the composition of woodlands – from the sixteenth century onwards the land cover of oak woodland had decreased whereas pine woodland had increased (Fig. 13). However, the change in woodland composition appears to have been very slow and gradual. More important was probably the fact that all oaks in Sweden were declared royal property (*regale*) in the mid-sixteenth century. Because of their value as mast trees and timber trees for royal shipbuilding, no oak trees wherever they grew were allowed to be felled or cut in any way by peasants.⁸⁵

We may now look not only at the years of tree felling, but also at woodland regeneration as reflected in the dating of the innermost tree ring of each tree. In Figure 17 the temporal distribution of all the estimated germination years is presented. The diagram shows several peaks but one of the strongest is at 1350–1360. It indicates that several of the trees that were later cut and used for building had germinated around the time of the Black Death. Later and stronger peaks are found at 1480–1500 (possibly associated with the plague years 1484 and 1495)⁸⁶ and 1670–1690.

More details are revealed by the presentation in Figure 18. In this diagram all the individual dates from Småland are presented. For each of the identified tree species – pine, spruce and oak – the dates are in chronological order based on their estimated felling years (blue dots). In the cases where also the germination year has been possible to estimate (usually with an error of within ± 20 years), the life span of the tree is indicated by a black line. Most interesting for the discussion here are the germination years of trees that were cut during and after the late-medieval crisis. Of pine very few were cut during the late fourteenth and fifteenth centuries, and most of them had germinated before the crisis. In the mid-sixteenth century some pines that had germinated soon after the Black Death of 1350 were cut, probably in connection to clearings of secondary woodland on abandoned land. However, not all pines that germinated in association with the Black Death were cut during the sixteenth century – several survived much longer. Still throughout the seventeenth century, pine trees that germinated soon after 1350 were occasionally cut and used for building timber. The last ‘Black Death-pines’ according to the diagram were actually cut down as late as in the early eighteenth century. In 1704, a pine tree was cut that had germinated approx. 1355. It was by then 350 years old. A little later, in 1712, a few pines were cut that had germinated approx. 1380 (Fig. 19). They were the last reminders of the woodland regeneration of the late fourteenth century.⁸⁷ Later on, all trees used for building were much younger.

Oak tells a somewhat different story than pine. Due to the *regale*, very few oak trees

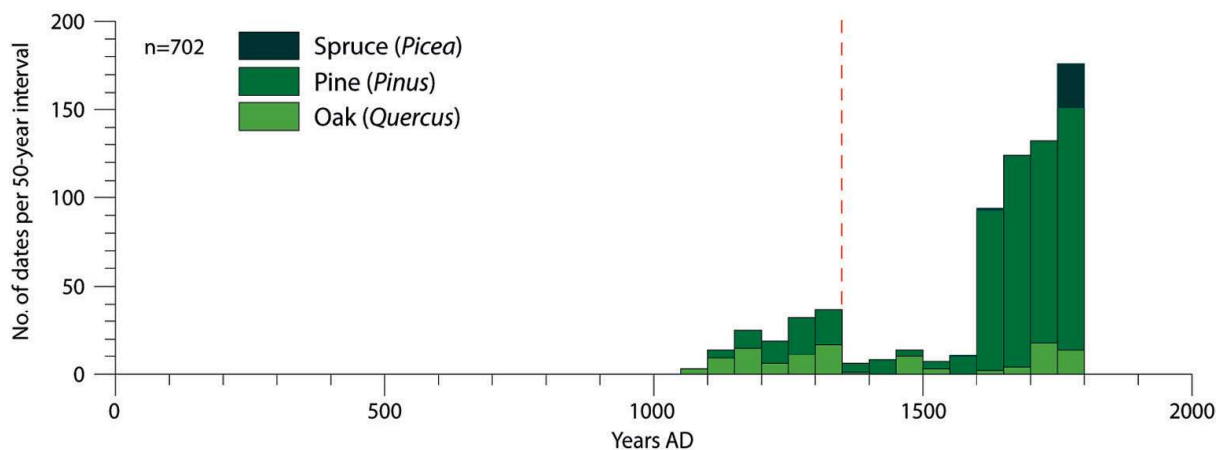


Fig. 16. The same dendrochronological dates (felling years) from Småland as in Fig. 10, but here with tree species distinguished

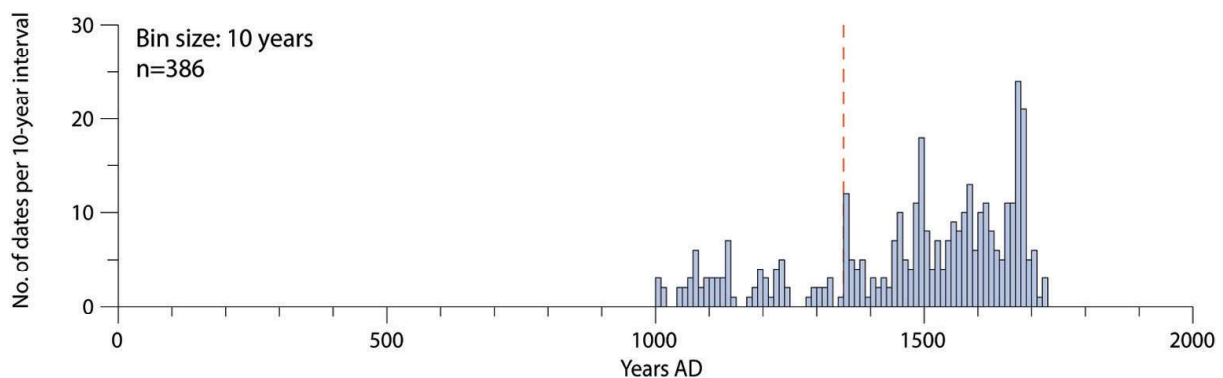


Fig. 17. A compilation of all the dated germination years in the dendrochronological record from Småland. Bars show the number of dates per 10-year time slices

were cut and used for building constructions during the seventeenth century. There may very well have been old oak trees growing in the landscape, of which some had their roots in the Black Death, but since they were not cut and used for building constructions, they do not show up in the data presented here. However, a number of oaks were cut down in 1464–1509, before the regale, in connection to the building of two churches.⁸⁸ As shown by the diagram the majority of these oaks germinated in connection to 1350. A plausible interpretation is that secondary oak woodland that once got established on abandoned land in connection to the Black Death, now a century and a half later was cut down. The timber was obviously used for construction but a purpose of the clearing may at the same time have been to re-establish agricultural land. The dendrochronological data thus supports the interpretation of the pollen based land-cover reconstructions, according to which there was a slight expansion of oak woodland in the uplands after the Black Death.

Spruce was not used regularly as building timber until the eighteenth century, and there are only two older samples in the data set. Interestingly, one of them was a very old tree that was cut in 1624 to be used in a house foundation in the town of Jönköping. It had germinated almost 300 years earlier, in approximately 1355.

Hence, the dendrochronological record indicates that there was woodland regeneration

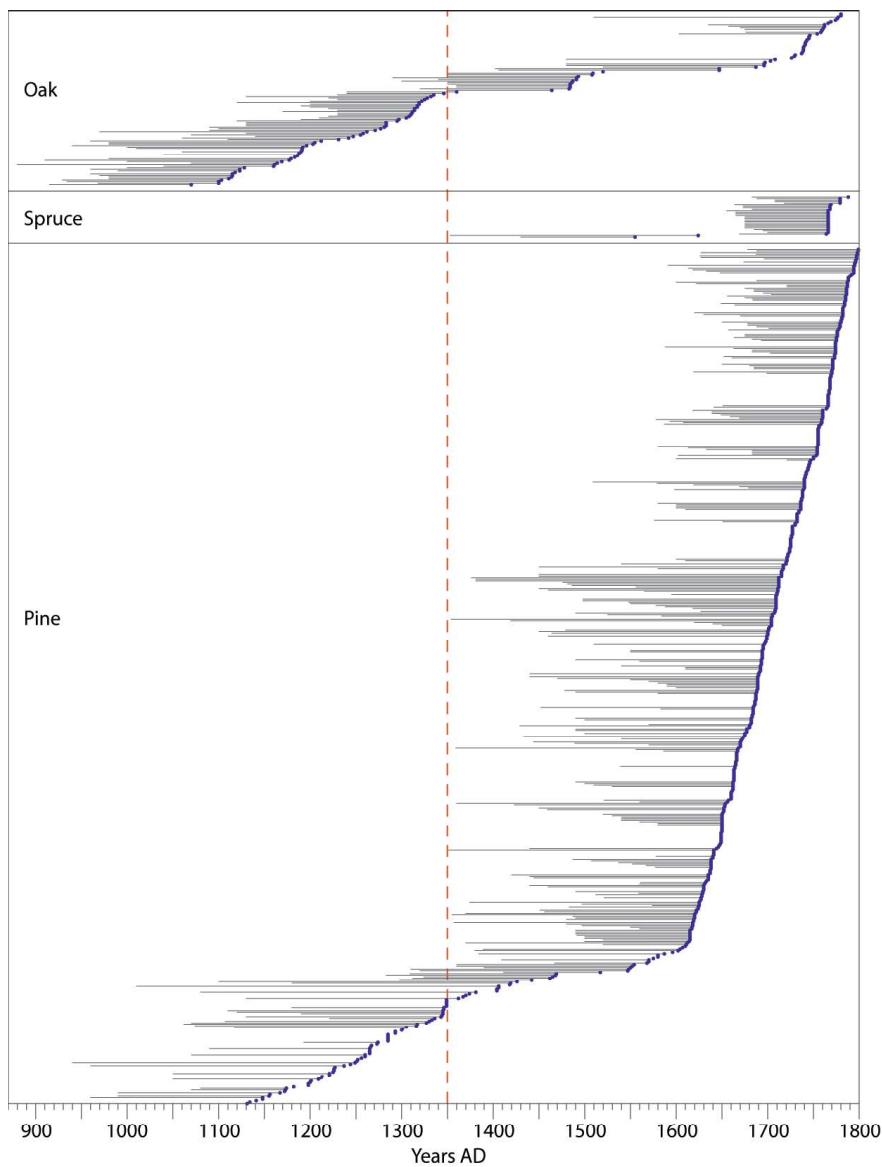


Fig. 18. All the 702 dendrochronological dates from Småland separated into tree species and presented in chronological order based on felling years (blue dots). In those 386 cases where also the germination year has been determined, the life-span of the individual tree is marked by a black line. The year 1350 is indicated by a red line

Fig. 19. Uranäsboden on display at the Kulturen Museum in Lund. It was originally situated in Älgåhult Parish, Småland, in the eastern part of the uplands. According to dendrochronological dating of the timber, parts of the building originate from the early sixteenth century but it was re-built and enlarged in the early eighteenth century. Some of the timber that was cut and used in the early eighteenth century was from very old pine trees that had once germinated on abandoned land in the wake of the Black Death (photo: Per Lagerås)



during the late-medieval crisis. Furthermore, it shows that this reforestation started already in close connection with the Black Death of 1350. This result is in line with earlier studies from middle and northern Sweden and from Norway.⁸⁹ Whereas the pollen record indicates particularly birch but also oak regeneration, dendrochronology gives examples of oak and pine regeneration. The total absence of birch in the dendrochronological record is due to the fact that birch was not used for building timber. However, it is more difficult to explain why an expansion of pine after 1350 stands out stronger in dendrochronological data than in the pollen record. Probably, large pine trees were valuable for building timber and particularly sought for, leading to over-representation in the dendrochronological record. Even though the dendrochronological record does not allow for any quantification of woodland regeneration, it indicates that there was increased germination of both oak and pine immediately after the Black Death. Much of the secondary woodland of birch, oak and pine was cleared in connection to the recovery and agricultural expansion that followed upon the crisis, but still after three centuries there were old pine trees growing in the woods that originated in the Black Death.

Summary of conclusions

The pollen and dendrochronological records presented in this chapter have provided new insights into the late-medieval crisis. The most important conclusion, which is also fundamental for a broader discussion, is that societal changes in connection to the crisis resulted in environmental changes. These changes were distinct and far-reaching enough to show up in the palaeoecological records on a regional scale. The conclusion is not surprising, because in a cultural landscape there is always interdependence between vegetation and human activities. Still, high-resolution palaeoecological records with good chronologies are needed to detect these changes. The uplands are suitable in this respect because of the numerous lakes and well-preserved peatlands and the large number of high-quality pollen diagrams available. Furthermore, the half-open landscape of the South-Swedish Uplands – characterised by a mosaic of open agricultural land and woodland – may be particularly suitable for this type of study. Trees and woodland were never far away and reforestation after abandonment was less delayed than it would have been in a more tree-less landscape. Also the mixed agriculture with a large element of pastures and hay meadows enabled swift changes, for instance from arable to pastures.

The aim of this chapter has been not only to interpret vegetation changes as such, but to discuss how these changes may reflect several important aspects of the late-medieval crisis, like population drop and settlement abandonment, agricultural strategies developed during the crisis, and also the recovery afterwards. These are the major conclusions:

During the fourteenth century there was a halving of arable in the uplands, which indicates extensive farm abandonment and population drop. From the lowlands, sites are too few to allow any certain conclusions, but two lowland sites, which are also the most southernmost sites in the data set, deviate from all the upland sites by indicating an increase in cereal growing in the late-fourteenth century.

The decline in arable in the uplands during the fourteenth century started already in 1350 or soon afterwards. The conclusion is based on both the pollen record and the compilation of

dendrochronological dates. Hence the first struck of the plague – the Black Death *sensu stricto* – had an immediate effect on upland societies. If this was a direct effect of the plague or an indirect effect through migration, is not possible to tell from the palaeoecological records.

Abandonment of agricultural land resulted in woodland expansion, but to some extent the landscape was still kept open by grazing. The decrease in pastures and meadows appears to have been proportionally smaller than the decrease in arable, which indicates that animal husbandry in relation to crop growing gained in relative importance during the crisis.

Land left for reforestation was in particular poor, heath-like pastures characterised by heather vegetation. At the same time, abandoned arable was in many cases transferred to pastures and meadows with herbs and grasses. The reforestation of poor pastures and the establishment of new, probably more productive ones on abandoned arable, suggest that the average productivity of land used for animal husbandry increased during the crisis.

Reforestation by natural succession on abandoned pastures was more common in the higher, northeastern parts of the uplands. In the southern and western parts, grazing was more successful in holding the forest back. Where reforestation occurred, particularly birch but also oak, pine and spruce colonised the abandoned land. Dendrochronological dates show that such woodland regeneration in some cases started immediately after the Black Death of 1350. Due to different ecological preferences and life spans of the different tree species, a fast and strong expansion of birch woodland was followed by a slower and subtler expansion of oak and pine.

In association with societal recovery and agricultural expansion after the crisis, abandoned arable fields were put under the plough again. The landscape reconstruction indicates that there was a slight time lag between the reestablishment of arable and the clearing of secondary woodland. The expansion of arable started in the late fifteenth century and the deforestation in the early sixteenth century. This was the beginning of a strong agricultural expansion and deforestation that continued more or less to the nineteenth century, when landscape openness in the uplands peaked. Today, after substantial reforestation during the twentieth century, forest cover is back at the same level as before the medieval expansion.

Notes

- 1 Lagerås is main author. Broström and Fredh performed landscape reconstruction modelling based on pollen data. Berg, Björkman, Fredh, Hultberg, Karlsson, Lagerås, Lindbladh, Mazier, Segerström and Sköld contributed with pollen data. Linderson contributed with dendrochronological data
- 2 Moe 1991; Stebich *et al.* 2005; van Hoof *et al.* 2006; Lagerås 2007; Yeloff & van Geel 2007; Sköld *et al.* 2010; Poska *et al.* 2014
- 3 The method was introduced by Lennart von Post in a lecture in 1916, which was later published in English (von Post 1967)
- 4 For a thorough introduction see Moore *et al.* (1991).
- 5 Iversen 1941 (in English 1949)
- 6 Berglund 1969
- 7 Boserup 1965; Berglund 1991, 14
- 8 Bradshaw 1988; Björkman 1996; Lindbladh 1998
- 9 E.g. Edwards 1991; Lagerås *et al.* 1995; Lagerås 2007
- 10 Olsson 1991
- 11 To avoid the reservoir effect when radiocarbon dating, the important thing is to use remains of plants that, during photosynthesis, get their carbon dioxide directly from the atmosphere (like

- most terrestrial plants), and not from lake water (like green algae, which make up the bulk of most lake sediments)
- 12 Based on instrumental data for the period 1961–90 (Raab & Vedin 1995). Growing season is the part of the year when average temperature exceeds 5°C
 - 13 Cf. Eckstein (1984) for a thorough introduction
 - 14 Bartholin 1987
 - 15 E.g. Bartholin 1989; Raihle 1990; Hovanta 1994
 - 16 Bartholin 1989, 125
 - 17 Dendro data are also presented in Chap.5
 - 18 E.g. Gauffin 1981; Hansson *et al.* 2005; Åstrand 2006. See also discussion in Chap. 5
 - 19 E.g. Larsson 1970; Österberg 1977; Bååth 1983; Myrdal 2003
 - 20 Sandnes 1981, 103
 - 21 Sandnes 1981, 103; Bååth 1983, 199
 - 22 Myrdal 2012a, 226
 - 23 To make a simple and clear definition, all sites above 100 m a.s.l. were regarded as upland sites. Consequently, all sites situated below 100 m a.s.l. were excluded, even though one of them, Skärsgölarna, was situated in a rather poor environment of upland character
 - 24 Cf. Chap. 2 for further background
 - 25 An unpaired *t* test shows that the difference in mean cereal-pollen percentages between 1250–1350 and 1350–1450 is very statistically significant (two-tailed P value equals 0.0099)
 - 26 Broström *et al.* 2004; 2008; Sugita 2007; Gaillard *et al.* 2010; Fredh *et al.* 2012; Mazier *et al.* 2015. Of the Landscape Reconstruction Algorithm we use the submodel REVEALS (Regional Estimates of Vegetation Abundance from Large Sites) presented by Sugita (2007), with the application on small sites tested by Mazier *et al.* (2015)
 - 27 The model has been validated for southern Sweden (Hellman *et al.* 2007; 2008; Mazier *et al.* 2015; Trondman *et al.* 2014)
 - 28 Because of the different pollen-dispersal characteristics of rye and other cereals, respectively, they were calculated separately and then put together into one graph
 - 29 Gadd 2011, 124
 - 30 Moe 1991 (Norway); Hall 2003 (Ireland); Stebich *et al.* 2005 (France); van Hoof *et al.* 2006 (Netherlands); Yeloff & van Geel 2007 (Denmark and review of published data from several countries); Yeloff *et al.* 2007 (England); Sköld *et al.* 2010 (Sweden); Poska *et al.* 2014 (Estonia)
 - 31 Yeloff & van Geel 2007
 - 32 The strength in combining local pollen studies to regional synthesis has been emphasized for instance by Lagerås (2007) and Woodbridge *et al.* (2012)
 - 33 Cf. Chapter 2 for background and further discussion
 - 34 Myrdal 2012b, 227, 234–235
 - 35 The use of a resolution of 50 years is a compromise – a coarser resolution would reveal too few details while a finer resolution would give a more irregular graph due to a smaller number of samples within each time slice.
 - 36 Based on a number of radiocarbon-dated levels, the ages of the pollen-analysed levels in a stratigraphic sequence are calculated by interpolation. Most studies use linear interpolation but also other methods (like cubic spline) are occasionally used. The present study relies on the chronologies of the original publications, with no changes or adjustments
 - 37 Note, however, that the total absence of dates from before the eleventh century does not mean a total absence of settlement. Traces of long houses and other buildings from the first millennium AD have been archaeologically documented in the uplands, but they are too poorly preserved for dendrochronological dating.
 - 38 Bartholin 1989, 125; see Fig. 21a in Chap. 5

- 39 Thun 2005, 73
- 40 Myrdal 2012a, 226
- 41 Gissel *et al.* 1981, 103, 107
- 42 Abel 1980, 88–89
- 43 Abel 1980, 88–89; Dyers 2002, 352; Benedictow 2004, 261; Myrdal 2011, 80; 2012a, 225, 227
- 44 Karlsson 1996; Livi Bacci 2000, 84; Myrdal 2012a, 227
- 45 Harrison 2000, 33
- 46 Myrdal & Söderberg 1991, 133
- 47 E.g. Behre 1981; Gaillard *et al.* 1994
- 48 Gadd 2011, 123ff
- 49 Myrdal 2011, 93
- 50 Mixed herbaceous plants include the following pollen types: Compositeae SF. Cichorioideae (dandelions, hawk's-beards, etc.), *Filipendula* (dropwort, meadowsweet), *Plantago lanceolata* (ribwort plantain), *Potentilla* type (tormentil, cinquefoil), *Ranunculus acris* type (buttercups), Rubiaceae (bedstraw), and *Rumex acetosa* type (sorrel)
- 51 E.g. Eriksson *et al.* 2002; Bernes 2011, 49ff; Morell 2011, 179ff; Fredh *et al.* 2012
- 52 Large-scale forest plantations took off after the Forestry Act of 1903 (Bernes 2011, 50)
- 53 Weimarck 1953; Gadd 2011, 128
- 54 E.g. Abel 1980, 70; Campbell 2006, 185; 2012, 124; Myrdal 2012, 221
- 55 Myrdal 2006, 169
- 56 Söderberg 2007, 143–144
- 57 See Chap.5 for examples of additional strategies developed during the crisis interpreted from the archaeological record
- 58 Myrdal 2012a, 221
- 59 Myrdal 2012a, 217; 2012b, 222; cf. Chap. 2
- 60 Lagerås 1996; 2007, 73; 2013b, 86
- 61 Cf. Widgren (2007) for a discussion on the landesque capital.
- 62 Myrdal 2006, 169–170
- 63 Redman 1999, 197–199, 202
- 64 E.g. Williams 2006, 117
- 65 Ruddiman 2003, 2005, 115–146
- 66 For pollen diagrams showing late-medieval reforestation in Europe, see for instance Moe 1991; Stebich *et al.* 2005; van Hoof *et al.* 2006; Lagerås 2007; Yeloff & van Geel 2007; Sköld *et al.* 2010; Poska *et al.* 2014.
- 67 Gaillard *et al.* 2010; Trondman *et al.* 2014
- 68 Kinnaird 1974, 470
- 69 Götmark & Kiffer 2014
- 70 Atkinson 1992; Hynynen *et al.* 2010
- 71 Götmark & Kiffer 2014
- 72 Bradshaw *et al.* 2000
- 73 Björkman 1996a, 13; Giesecke & Bennett 2004; Lagerås 2007
- 74 E.g. Björkman 1997b, 2003c; Sköld *et al.* 2010
- 75 Sköld *et al.* 2010
- 76 Atkinson 1992, 848
- 77 Björkman 1996a; Lagerås 2007
- 78 Björkman 1996b; Lindbladh *et al.* 2008
- 79 Lagerås 2007; Sköld *et al.* 2010
- 80 Bartholin 1989, 125; Thun 2005, 73
- 81 Lovén 1996; Myrdal 2012a, 230

- 82 It cannot be excluded that some old timber was reused for small-scale building and renovation
83 Nyborg 2009
84 Bartholin 1987
85 Proclaimed by King Gustav Vasa in 1558 (Eliasson & Hamilton 1999, 53)
86 Myrdal 2012a, 223
87 The Black-Death-pines cut in the early eighteenth century were found in Uranäsboden (see Fig.
19), whereas Black-Death-pines cut in the seventeenth century are from Yxenhaga Gammelstuga
(Svenarum Parish) and from different constructions in the towns of Eksjö and Jönköping
88 The dated samples are from the church of Hakarp and the campanile at the church of Härlöv
89 Bartholin 1989, 127; Thun 2005, 66. A similar conclusion can be drawn from a study in Scotland,
in which imported building timber from Scandinavia and the Baltic countries was identified (Mills
& Crone 2012). Many of the logs that were imported during the late fifteenth century and the
sixteenth century were from trees that had started to grow soon after 1350