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The influence of former land-use on vegetation and biodiversity in the boreo-nemoral zone of Sweden

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Pollen analyses were carried out at two sites with contrasting land-use histories (in-field and out-land) within a single estate. The aim was to distinguish the relative importance of natural processes and cultural influence on the development of vegetation and biodiversity. The estate lies in the boreo-nemoral zone of southern Sweden, and attention is focused on the distribution of coniferous and deciduous trees. The in-fields, which lie close to the estate buildings, are currently dominated by deciduous trees, and have a documented history as fields and hay meadows. The more distant out-lands were primarily used as grazing land in the past, and support coniferous forest at present. The study covers the last 4000 yr. 2000–1000 BC: the out-lands site supported natural, dense forests consisting of *Quercus*, *Betula*, *Tilia*, *Alnus* and *Corylus*. 1000 BC–AD 1100: several events are best interpreted as an increased cultural activity in the area. Agriculture was based on animal husbandry and the recorded cereals probably originate from a kind of shifting cultivation. AD 1000–1800: agriculture intensified on the in-fields with cereal cultivation of increased importance, while the out-fields were used for slash-and-burn agriculture and forest grazing. The forests became more open in structure but the composition remained unchanged. An increase in *Calluna* was a possible consequence of over-exploitation. AD 1800 onwards: the out-field deciduous forests were rapidly replaced by *Picea-Pinus* coniferous forests during the 1800's. The in-fields retained deciduous forest with a continuity of *Quercus* and other species.
There is a close, positive relationship between floristic diversity and cultural influence during the last 4000 yr. A comparison is made with a similar investigation on another estate in the region, revealing small differences between the estates, but striking similarities in the effects of land-use types on the development of vegetation. The significance of former in-fields for nature conservation is discussed, particularly as a potential source for increasing the deciduous component in commercial forestry practice.

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Human activities have been a major controlling factor in many European vegetational successions during the past few hundred years, and must be given due consideration in ecological research, nature conservation and nature-based forestry (Peterken 1996). Human influence has been more pronounced over longer time periods in central and western Europe than in much of Scandinavia, and as a consequence Swedish conservation policy has largely focused on the preservation of unmanaged systems. Little is known about the former extent of human intervention in these systems, and some recent studies have suggested that this has been underestimated (Segerström et al. 1994, Hörnberg 1995). Several of the most valuable unmanaged ecosystems in Sweden occur in National Parks, yet almost no detailed investigations of vegetation history have been undertaken in these areas. Thus, the potential human impact on Swedish National Parks is largely unknown (Lagerås 1995) even though the IUCN (The World Conservation Union) recommend that "National Parks

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should comprise ecosystems that have not been significantly altered by human activities". Nature conservation is also concerned with ecosystems where traditional management (e.g. hay meadows or grazing) has created a rich biodiversity. However even in these cases where human influence has itself contributed to the biological value, land-use history is often poorly documented.

Palaeoecological methods can contribute to fill this gap in knowledge. They can describe vegetational development and trace human influence on ecosystems further back in time than can historical studies, and the results can help establish the "baseline" conditions prior to major human intervention (Davis 1989), and thus for example make valuable contributions to nature conservation (Birks 1996). The data must be interpreted with due regard to the balance between human factors (elucidated from historical records) and natural (including climatic) factors in driving the observed changes in vegetation. Former land-use must be taken into consideration during site selection.

This study comprises pollen analyses of two sites (in-field and out-land) from the same estate, Osaby, which is in the boreo-nemoral zone of southern Sweden. The investigation was carried out as a palynological study of small hollows (sensu Bradshaw 1988). The sites were chosen with help from historical documents and maps, and the information from these documents was used as a complement to the palynological analysis. The sites are only 400 m apart from each other but have a documented difference in land-use since the beginning of the 1700's, a difference that probably extends much further back in time. As is the normal custom, the Osaby in-fields, which lie closest to the estate buildings, have been used for cultivation and as hay meadows, while the out-lands were mostly forested and primarily used as grazing land. Division of the land in this way was widespread in southern Sweden until the beginning of the twentieth century.

The aim of this study is to establish the relative influence of land-use history on the development of vegetation and biodiversity since the onset of human influence on the landscape. I focus on the current distribution of deciduous and coniferous forest on the estate (deciduous confined to the in-fields and coniferous to the out-lands). I hypothesise that the present distribution of forest types is a result of former land-use, and that the deciduous forest, despite a more apparently intensive exploitation, has closer links to the baseline conditions than does the coniferous forest.

A comparison is drawn with a comparable investigation from Råshult, ca 50 km southwest of Osaby (Lindbladh and Bradshaw 1995, 1998), which was not colonised until the early Middle Ages. Osaby is thought to have been colonised earlier than Råshult based on the archaeological record (Larsson 1975), and this ought to be expressed in the development of the vegetation. I hypothesise that Osaby will have been more intensively utilised and therefore further displaced from "natural" conditions than Råshult.

Material and methods

Site description

The estate of Osaby is 10 km south of the town of Växjö, southern Sweden (56°46′N; 14°47′E 165 m a.s.l.), (Fig. 1). The bedrock consists of granite and the soil is dominated by till but there are also glaciofluvial deposits in the area (Anon. 1994). The area lies within the boreo-nemoral zone of southern Sweden (Sjörs 1965). Mean precipitation is 700 mm yr^{-1} and the mean annual temperature is ca 6°C, the July mean 15–16°C and the January mean between −3°C and −4°C (Anon. 1995).

The in-field was sampled in the central part (Fig. 1). The sampling site is located ca 200 m from the lake. The top 76 cm was sampled and the monolith consisted of peat mixed with woody fragments. The site is entirely covered with young *Betula* sp. individuals not more than one metre in height. Numerous stumps show that the species was also common before this recent regeneration phase. A few individuals of *Pinus sylvestris*, *Frangula alnus* and *Vaccinium uliginosum* are also present and the field- and ground-layer consists mainly of *Vaccinium vitis-idaea*, *Vaccinium myrtillus* and *Sphagnum* spp. Traditionally managed meadows and pastures with many *Quercus robur* individuals several hundred years old, lie to the north of the sample site. The map (Fig. 1) shows the land-use in AD 1919 and is drawn from documents made in connection with a redistribution of land to disperse ownership patterns. The distribution of in-field and out-land was the same as today but all arable land has since then been transformed into pastures or meadows. The in-fields south of the sample site consist today of a sparse forest of *Pinus* and *Betula*.

The out-land site is a wetland ca 200 m west of the in-field (Fig. 1). The investigated area is marked as out-land on maps dating from both 1798 and 1919, but the major part of the Osaby out-lands lay east of the farm. The wetland has a radius of ca 10 m and is overgrown by small individuals of *Betula*, *Picea abies* and *Frangula alnus*. The fields and ground layers of the wetland are dominated by *Sphagnum* spp. but Cyperaceae spp. and *Lysimachia vulgaris* individuals are also present. The surrounding out-land consists of a dense mature forest of mainly *Picea* but also *Pinus* and to a minor extent *Quercus* and *Betula*. Several individuals are more than one hundred years old and the vegetation besides the trees is rather sparse due to the dark conditions. The field-layer consists mainly of *Vaccinium* spp. A 86 cm peat monolith was extracted from the wetland.

The estate has since 1964 been owned by the Swedish Society for Nature Conservation. It consists of 501 ha land of which 375 ha is forested (27 ha broad-leaves) and 90 ha is arable land or pastures; 225 ha is set aside as a nature reserve. The in-field consists of pastures and restored meadows which are managed in a traditional way and mowed in late July.

Pollen source area

Definition of the pollen source area is of major importance for the interpretation of palynological studies. The pollen source area of small- to medium-sized lakes for major tree taxa has been estimated to be 10–30 km radius in a number of studies (Bradshaw and Webb 1985, Prentice et al. 1987, Schwartz 1989). A much shorter distance has been suggested by Sugita (1994) in simulation experiments. The simulations suggested that the relevant source area would be 300–400 m for a lake

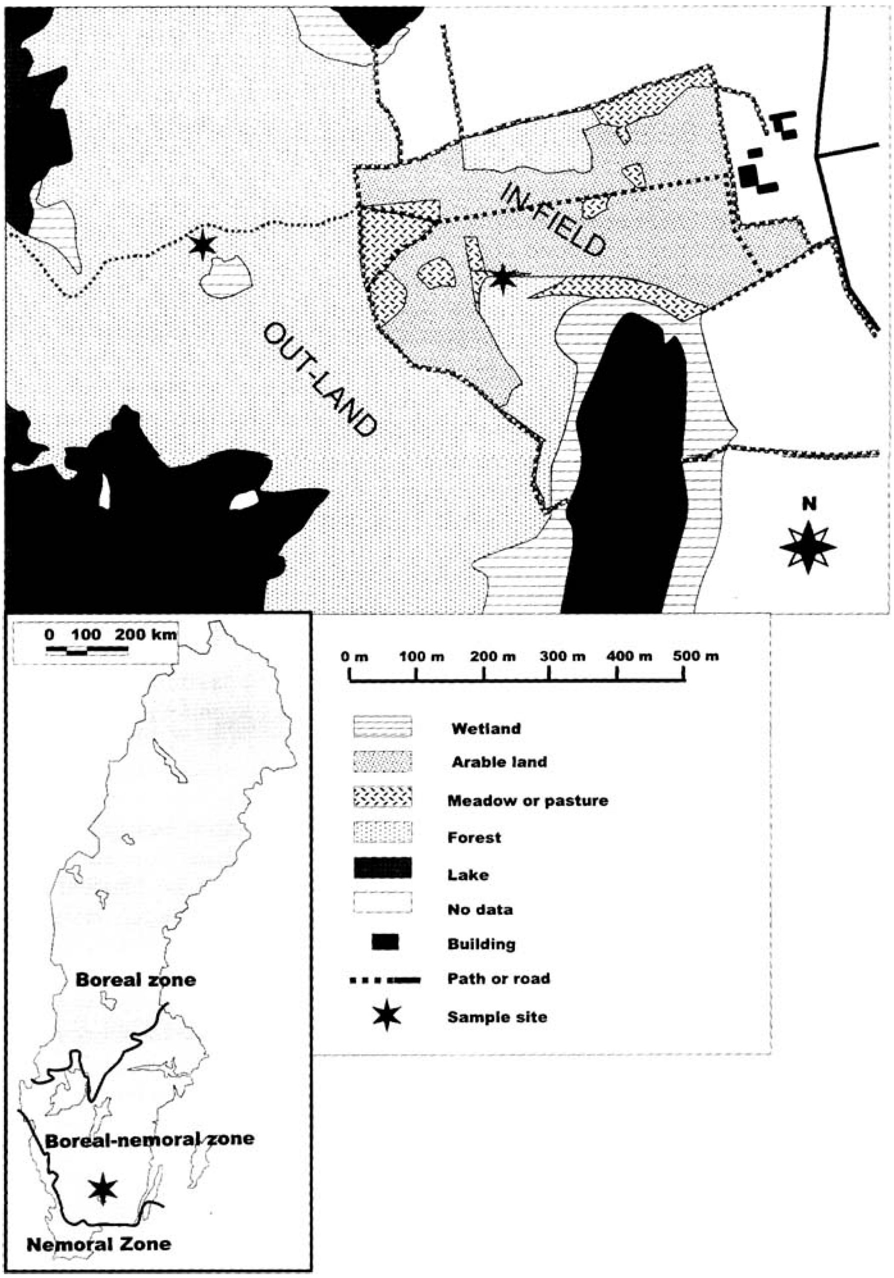

Fig. 1. Map of Sweden showing the location of the study area. The map of Osaby shows the relationship between the in-fields and out-lands. Sample sites are marked by stars. The land-use is based on an AD 1919 map.

radius of 50 m (cf. Jacobson and Bradshaw 1981), and for a forest hollow, with a radius of 2 m, the relevant source area would not exceed 50–100 m. Only 35–45% of the pollen loading was of local origin (i.e. from trees within the relevant source area) in this simulation, but this proportion was sufficient to reflect the surrounding local vegetation since the background signal of pollen from outside the source area was more or less constant. Empirical studies of small forest hollows by Calcote (1995) support Sugita's simulations.

The primary aim of the investigation was to study local vegetation development sensu Bradshaw (1988). In our studies the collecting basin at the Osaby outland site has a radius of ca 10 m and consequently an estimated relevant pollen source area of not more than ca 100–200 m if the surroundings were forested. The majority of pollen from most herbaceous species will have travelled < 20–30 m under a closed canopy (Bradshaw 1981, Prentice 1988), and they will therefore reflect the local vegetation even more strongly.

It is harder to find suitable sites in the in-fields where land-use has been more intensive. In this case I have sampled sediments from a peatland fringing a lake that lay close to the central part of the in-field system (Fig. 1). The site was not ideal as it was not a "small hollow" and lacks the appropriate "relevant source area" sensu Sugita. Nevertheless the site had more small hollow than lake properties. Pollen landing on the peat surface was not transported further, and when trees grew on the peat, the pollen source area was small. When the peat surface lacked trees, the pollen source area would have been larger than the out-field site, and this is given due regard in my interpretation. However pollen from herbaceous species, inclusive of the anthropogenic indicators, would not have travelled much further than at the out-land site. It is therefore likely that signals from open in-field conditions are also to be found in the pollen diagram. The pollen source area for the lowest part of the in-field profile was the most difficult to interpret. The appearance of taxa associated with lakes (e.g. *Nuphar* and *Myriophyllum alterniflorum*) in this part of the profile suggests that the lake covered a greater area at that time and that the site was located close to the lake shore. There are other signs in the pollen diagram, particularly the high pollen percentages of *Pinus*, that indicate that the pollen source area was larger at that time, suggesting that the site was connected to the lake.

In conclusion, in spite of the relatively short distance between the sites is it probable that the pollen diagrams, apart from the first part of the in-field profile, satisfactorily reflect the vegetation of each site. The more complex "pollen source area" at the in-field site will be taken into consideration when interpreting the results.

Macroscopic charcoal fragments in peat are appropriate for reconstructing local fires, although studies of charcoal dispersal have been neglected. Theoretical models of dispersal predict that the dispersal distance is related to particle size (Patterson III et al. 1987). Wein et al. (1987) found in an experiment that macroscopic charcoal did not travel > 1 km from the fire.

Field and laboratory methods

The peat monoliths were sampled with a Wardenaar corer (Wardenaar 1987) and subsequently treated in a similar way: they were stored at −20°C, divided into two, with one part reserved for pollen and charcoal analysis and the other for radiocarbon dating. The central sections of the frozen monoliths were extracted using a hand saw, and cut into thin subsamples (3–4 mm thick) using a slicing machine with a serrated rotating blade. Small samples (0.4–0.9 cm^3 for pollen and 0.8–1.5 cm^3 for charcoal) were taken from the centre of these subsamples, the volume being measured by water displacement. *Lycopodium* tablets were added to the pollen samples and they were prepared for analysis in a standard manner (Berglund and Ralska-Jasiewiczowa 1986). Microscope slides were prepared from the residues and scored for pollen. The median pollen sum for all samples was 612 ranging between 280 and 1533. The charcoal samples were dissolved in NaOH (10%) and macroscopic charcoal that would not pass through a 250-μm mesh was counted from a known volume of sediment. Sections (1–2 cm thick) of the frozen monolith were submitted for conventional radiocarbon dating, whereas three smaller samples were submitted for AMS dating.

Dating

Eight radiocarbon dates were obtained from the in-field profile and six from the out-land (Table 1). The 76 cm of peat from the in-field developed during approximately the last 3600 radiocarbon yr, and the 86 cm from the out-field covered the last 6000 radiocarbon yr. The age scale is calibrated to calendar years using OxCal (Stuvier et al. 1993). The three uppermost samples from the in-land profile and the uppermost from the out-field were dated as "modern", indicating the carbon analysed included atmospheric "bomb carbon" generated within the last 50 yr (Table 1). The three modern dates of the in-field site were not included when creating the age-curve as they gave an unrealistic result. If included these dates give the age-depth curve an implausible sudden change of slope with a preposterous increase by a factor 100 from one pollen-sample (12.7 cm) to the next (11.2 cm) in the influx values alone (grains cm^{-2} yr^{-1}), that is not

Table 1. Radiocarbon dating.

Sample	Depth (cm)	Radiometric method	Conventional ^{14}C age	Calibrated calendar age
Osaby in-field				
Beta-105492	8–9.5	AMS, bulk	Modern	
Beta-102278	9.5–11	Radiometric-standard	Modern	
AAR-3821	12.5–14	AMS, insects	Modern	
Beta-099285	14–15.5	Radiometric-standard	890 ± 60 BP	AD 1020–1270
Beta-107282	24.5–26	Radiometric-standard	2040 ± 60 BP	185 BC–AD 90
Beta-102277	40–41.5	AMS, bulk	2520 ± 50 BP	800–415 BC
Beta-107283	51–52.5	Radiometric-standard	3000 ± 60 BP	1400–1020 BC
Beta-099287	75.5–77	Radiometric-standard	3530 ± 70 BP	2025–1675 BC
Osaby out-land				
Beta-105492	9.5–11	AMS, bulk	Modern	
AAR-3822	16–17.5	AMS, plants (*Betula*, *Carex*)	130 ± 35 BP	AD 1695–1955
Beta-103236	19–20.5	Radiometric-standard	650 ± 60 BP	AD 1270–1420
Beta-102279	26.5–28	Radiometric-standard	870 ± 60 BP	AD 1025–1275
Beta-102281	58–59.5	Radiometric-standard	3080 ± 60 BP	1440–1145 BC
Beta-102280	83–84	Radiometric-standard	5930 ± 80 BP	4965–4605 BC

observed in the concentration data (grains cm^{-2}). This behaviour of the influx data alone suggests that a hiatus is unlikely. The smooth forms of the age-depth curves gives however no cause to suspect the reliability of the other dates (Fig. 2), and the lack of dates from the uppermost 15 cm of the in-field profile is taken into consideration when interpreting the last few hundred years.

Data analysis

The data are presented in pollen percentage diagrams (Figs 3a, b). A common time-scale beginning at 2000 BC is used in order to facilitate the comparisons between the pollen diagrams. Pollen concentration and accumulation rates were also estimated and the values for the latter are presented for selected species together with the percentages values (Figs 4–7). The selection of anthropogenic indicators is based on the interpretation of Behre (1981) and Gaillard et al. (1992). It is important to keep in mind that several of the indicators are also common in natural communities. For that reason Gramineae, Cyperaceae and *Calluna* pollen grains are not included in the anthropogenic indicators sum. The identification of cereal pollen was based on measurements of pollen and annulus diameter (Andersen 1979). Due to different mounting media (Andersen; silicone oil: this study; glycerine) a correction factor was established based on the measurements of *Corylus* pollen (Lagerås 1996a). The taxonomic nomenclature follows Tutin et al. (1964–76). Rarefaction analysis was calculated for each sample (Birks and Line 1992). It estimates the number of different taxa that would be expected if all the pollen counts had been the same size. It is a simple measure of palynological richness of a pollen sample but as an estimation of floristic richness it is somewhat more complicated, but still useful (Odgaard 1999). The data were standardised to a basic sum of 280.

Historical documents

Several unpublished historical documents were consulted at the Land Survey Office (Appendix 1), the oldest dating from the early eighteenth century. Other written sources were taken from the research department of the National Land Survey at Gävle (AD 1705), Vadstena landsarkiv (AD 1693), and from the National Archive, Stockholm (AD 1845). Literature of interest concerning the estate and region is contained in Larsson, L. O. (1980) and Almquist (1976).

Results

Historical documents

The first mention of Osaby in a historical document is dated to AD 1402 (Larsson, L. O. 1980) and the estate was noted as a "säteri", a farmstead exempt from land

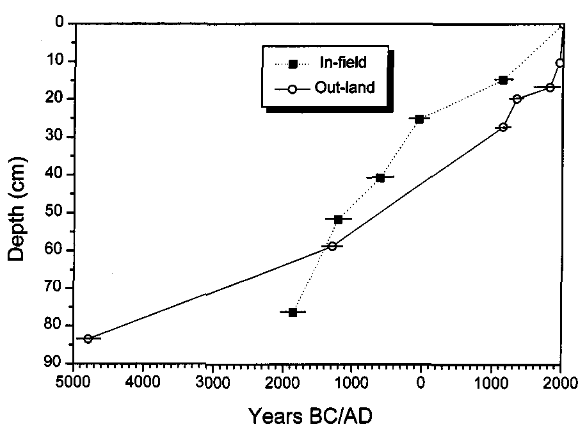

Fig. 2. The relationships between depth in the peat and calibrated calendar age for the sites. The circles and squares represent the calibrated ^{14}C dates, four from the out-field and five from the in-field site. The age range for each sample represents a 95.4% confidence interval.

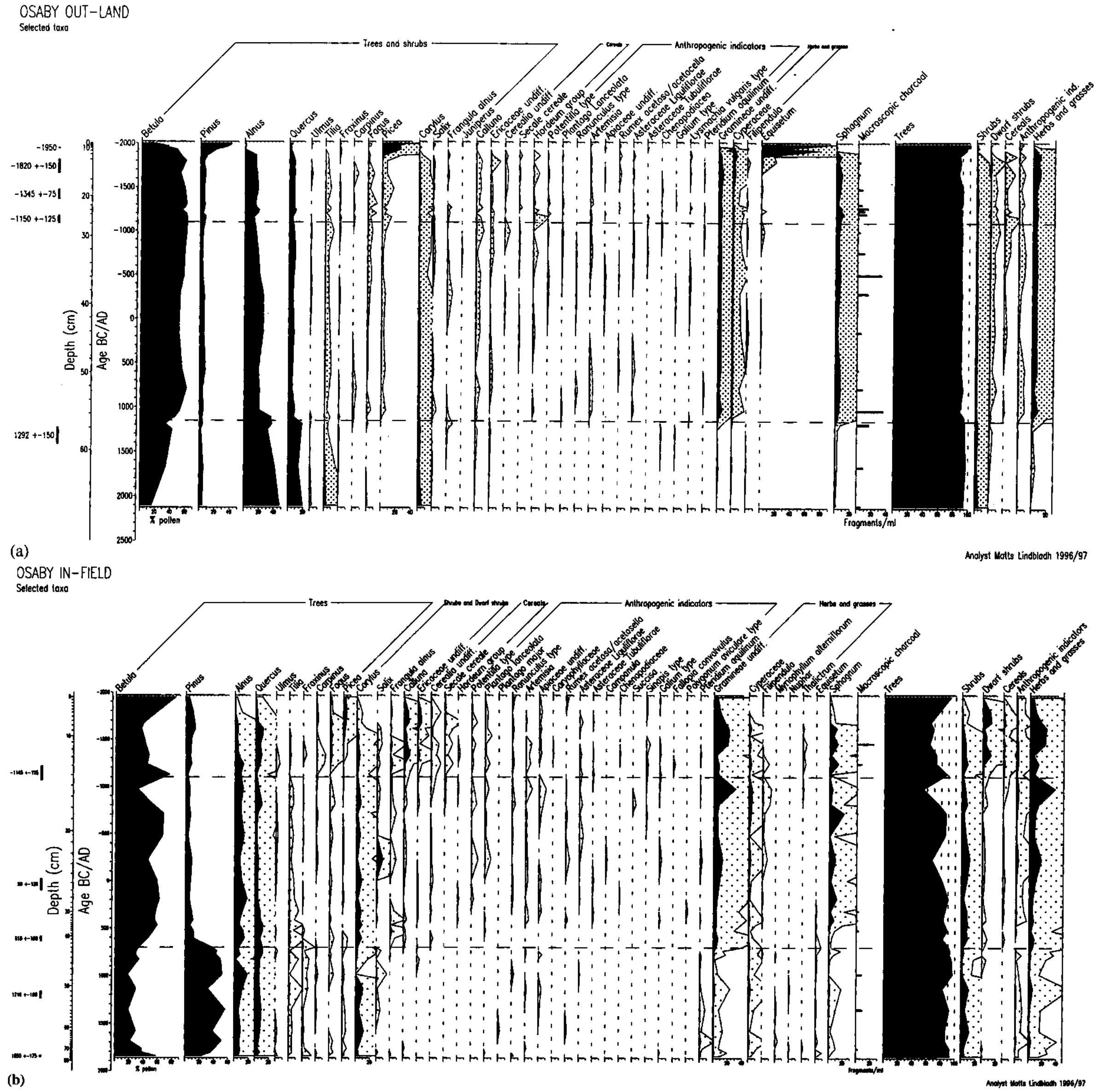

Fig. 3. Summary percentages pollen diagram from a) out-land and b) in-field. The calculation sum comprises all seed plants. The shaded portion of the graphs is 10 × of the true value. The y-axis scale is calibrated ^{14}C years.

dues, in the sixteenth century (Almquist 1976). Valuable information is obtained from the maps dated to AD 1705 and 1706 (Appendix 1). They show that the present division of the in-field and out-land was also valid at least at that point in time, but it was probably established much earlier. The majority of the numerous documents merely concern legal and economic matters. Relatively comprehensive documents exist from the eighteenth and nineteenth centuries. From the beginning of the twentieth century is it possible to obtain a reliable picture of the entire vegetation (Fig. 1). No complete analysis of the historical documents is made here. They will be discussed together with the results from the pollen analysis from each respective time period.

Natural forest (2000–1000 BC)

Out-land

The out-field site was dominated by a dense, natural forest until ca 1000 BC. Humans have been present in this part of Sweden for 5000–6000 yr (Larsson 1975), but the few signs of human activity (no cereal grains and only a few grains of anthropogenic indicators) seen in the pollen diagram suggest an insignificant level of human impact at Osaby during the period (Figs 3a and 4). The vegetation at this site was heavily dominated by trees and shrubs, and pollen from the field layer never reached more than a few percent in the pollen diagram. *Quercus*, *Betula*, *Tilia*, *Alnus* (probably in association with the wetland) and *Corylus* were the dominating species at the site. *Betula* was an important species at the site even though this taxon is over-represented in the pollen diagram. It is a pioneer species and produces large numbers of pollen grains (Andersen 1970, Björse et al. 1996). *Pinus* is also a good pollen producer, and its pollen are also well dispersed (Andersen 1970, Björse et al. 1996). The relatively low values of *Pinus* pollen at the out-land until the recent past suggests that the species was not locally abundant. *Tilia* shows the opposite relationship to that of *Betula* and *Pinus* (Andersen 1970, Björse et al. 1996). It is pollinated by insects and produces few pollen grains, which furthermore are heavy and are not able to be dispersed over long distances. The relatively high pollen percentage values of *Tilia* particularly at the beginning of the period therefore indicate that *Tilia* formed a rather significant part of the vegetation.

In-field

The grains of taxa associated with lake biotopes (*Nuphar* and *Myriophyllum alterniflorum*) found at the in-field diagram suggest that the site was connected to the lake at the time (Fig. 3b). There are also regional signals in the pollen diagram that suggest that the pollen source area was much bigger and that the entire lake surface was the collecting basin. Most obvious are the high values of *Pinus* (40–50%) that are not seen in other "local sites" in south-central or south western Sweden during this period (Björkman 1996, Lindbladh and Bradshaw 1998). *Pinus* trees are good pollen producers and *Pinus* pollen can be transported over large distances. The out-land site of Osaby has *Pinus* values of not more than ca 5% during the period and a comparison of the two Osaby sites illustrates the difference in pollen loading features between local and regional sites. It also suggests that the abundance of *Pinus* probably will be somewhat overestimated in parts of southern Sweden if based on regional pollen sites alone (Lindbladh et al. unpubl.).

The pollen percentage values for *Pinus* decreased sharply ca 700–600 BC, simultaneous with the cessation of grains from lake taxa. These events suggest that the site was no longer connected to the lake, and a transformation from reflection of regional to more local conditions probably occurred. The decrease of *Pinus* pollen percentages was accompanied by an increase of *Betula* and Gramineae pollen percentages.

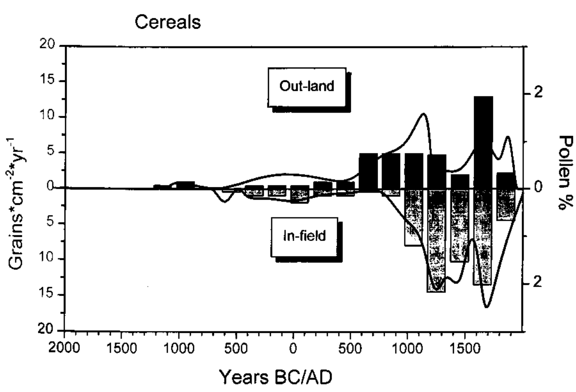

Fig. 4. Percentages (curve) and influx values (histogram) for cereals from the two sites. Spline interpolation (third degree) has been used to smooth the pollen percentage curves. Every column of influx value represents the mean of a 200 yr period.

Shifting cultivation (1000 BC–AD 1100)

Several events between 1000 and 500 BC are best interpreted as an increased cultural activity in the area. The pollen values of light-demanding herbs and grasses became a significant part of the pollen diagrams at that point of time (Figs 3a, b). The anthropogenic indicators became rather common and furthermore signs of cultivation occur with the first cereals being found during this period (Figs 3a, b and 4). The forests were probably initially opened up to improve the grazing, and cultivation subsequently became more important. The more open conditions may also explain the increase of the spore percentages for *Sphagnum* at both sites that coincided with the increased human activity.

Several of the common tree species at the out-land site showed a rather sudden decrease at 1000 BC; the pollen percentage values for *Alnus*, *Quercus*, *Tilia* and to a minor extent *Corylus*, decreased (Fig. 3a). *Betula*, a possible human indicator, was the only former common tree species that increased. The late immigrants *Carpinus*, *Fagus* and *Picea* appear at this time. *Pinus* was still likely to have been uncommon at the site.

The forest composition at the in-field site was rather similar to that of the out-land site with *Betula*, *Alnus*, *Quercus*, *Corylus* and initially also *Tilia* as the dominant species (Fig. 3b). The human impact increased by the end of the period and the forest became more open. *Tilia* became rare after a few centuries. This study is another example of the coincidence of the disappearance of *Tilia* and forest openings, suggesting that human activity plays a part in the event (Turner 1962, Andersen 1984, Björse and Bradshaw 1998).

The relatively low values of cereals do not, however, suggest an intensive agricultural system with permanent, fertilised arable fields. The results may rather be interpreted as reflecting an agricultural system based on live-stock raising, as several indicators of grazing became frequent in the pollen diagrams, e.g. *Potentilla* type and *Rumex* spp. The recorded cereals perhaps originate from a kind of shifting cultivation where new land was continuously cleared, used for cultivation for a few years and then grazed by domestic animals. That cereals were found at both sites is an argument for cultivation not being solely confined to the in-fields but possibly being more evenly scattered through the area.

Clearance cairns of the so-called hackerör type (hoe-cairns) have been found a few hundred metres north of the estate (Tollin pers. comm.). This type of clearance cairns is very common in southern Sweden and a general opinion is that most of them are remains of cultivation during Late Bronze Age and the early Iron Age, 1000 BC–AD 400 (Lagerås 1996b and references therein). It is also accepted that areas with hackerör reflect shifting cultivation with non-manured arable fields and long fallow periods (Gren 1989). There is most likely a connection at Osaby between the prehistoric remains and the agricultural activities recorded by the pollen data.

The values for anthropogenic indicators and "herbs and grasses" did gradually increase at the in-field site compared to the out-land. But however do the data suggest that the focus of human activities did not shift entirely towards the in-field area until the beginning of the Middle Ages.

Medieval agricultural system (AD 1000–1800)

The agricultural activities at the in-field became more intensive at the beginning of the Middle Ages. A peak of Gramineae occurred AD 1000, with a pollen percentages value of > 30% and some hundred years later the values for cereals increased considerably (Figs 3b and 4). The cereals also increased at the out-land site, but to a lesser extent, and no corresponding increase of Gramineae and herbs occurred (Figs 3a and 4). The ending "by" of Osaby means "village" and the common opinion is that these place names reflect settlements that were permanent by AD 1000 (Hallberg 1983). From the Viking age onwards (beginning AD 800) human influence is considered to have increased dramatically in southern Sweden (Callmer 1991). The system of villages (and the in-field/out-land system) is thought to have become established during the Viking age, AD 800–1000 (Lindquist 1968), or at the beginning of the Middle Ages, AD 1000 and onwards (Ambrosiani 1994). At Osaby the establishment of the in-field/out-land system seems to have occurred during the latter period.

Cereals and "slash and burn"

The large numbers of pollen grains from cereals recorded at both sites, but particularly at the in-field, are striking and probably mark the transition from an agricultural system based on livestock-raising to a system more dependent on cultivation of cereals. *Secale cereale*, rye, was the most frequent cereal pollen type at the in-field site, whereas grains from the *Hordeum* group, most likely barley (although certain other Gramineae species, e.g. *Elytrigia repens* or *Glyceria fluitans*, cannot be entirely excluded), dominated at the out-land. The first findings of *Secale cereale* in southern Scandinavia are dated > 500 yr earlier (Behre 1992). The species is wind-pollinated and is it not surprising to find pollen grains from the species at the in-field site. It is furthermore not surprising that several grains of *Secale cereale* were also found in the out-land profile, as generally this species is considered to have been the most common cereal in the former widespread "slash and burn cultivation" in the out-lands of Sweden (Kardell et al. 1980, Engelmark 1995). However the more frequent occurrence of pollen from the *Hordeum* group at the out-land site is surprising. *Hordeum* is naturally a poor pollen disperser (Vuorela 1973) and provided that the grains originated from this species, the relatively large amount of grains found throughout the period must reflect a rather extensive cultivation. The large amount of tree pollen and the relatively few anthropogenic indicators apart from the cereals do indicate "slash and burn cultivation", and charcoal fragments were found in every sample throughout the period (Fig. 3a). The pollen record for *Potentilla* type is almost confined to this period, and it has a positive relationship with fire and to forest grazing (Gaillard et al. 1992). Several Chenopodiaceae pollen grains were also found at this part of the profile, and species of this family were the dominating weed in fields of "slash and burn" according to archaeological findings (Engelmark 1995).

Calluna vulgaris *and soil impoverishment*

Calluna vulgaris pollen is also correlated with human impact and with a heavy grazing pressure from domestic animals (Behre 1981, Gaillard et al. 1992), even if it also is common in natural communities. It is a major component of the heath moors, common in coastal areas over north-western Europe, promoted by humid climate but primarily caused by human activity (Behre 1988). At Osaby out-lands the *Calluna* pollen percentages and influx values were low until AD 1000, while it was almost absent at the in-field site (Fig. 5). From that time onwards it became more abundant at the in-field site compared to the out-lands. The pollen percentages at the in-field, confirmed by the influx values, probably reflect a relatively large population, and long-distance transport of this low-growing plant is unlikely. The values for *Calluna* are possibly underestimated as a considerable number of probable *Calluna* grains had to be defined as "Ericaceae undiff." due to degradation. The *Calluna* population also increased at the in-fields of Råshult during these centuries (Lindbladh and Bradshaw 1995, 1998), but to an even greater extent. A recent macrofossil investigation of that site (Hannon pers. comm.) excludes the possibility that the grains originate from *Calluna* plants that grew on the fen itself (Lindbladh and Nilsson in press).

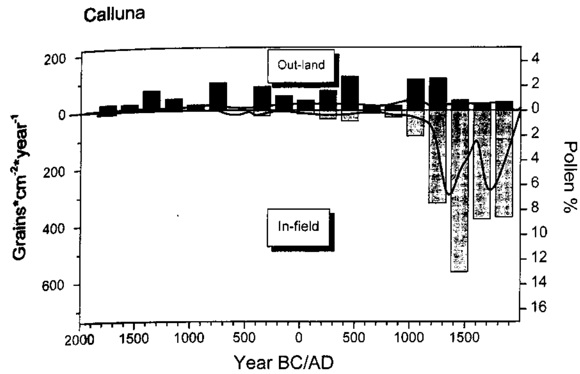

Fig. 5. Pollen percentages (curve) and influx values (histogram) for *Calluna* from the two sites together with Gramineae from the in-field site. Spline interpolation (third degree) has been used to smooth the pollen percentage curves. Each column of influx value represents the mean of a 200 yr period.

Even if *Calluna* was favoured by the gradually opening conditions, it is remarkable that the in-fields held the largest populations. The species is traditionally considered to be associated with the strong grazing-pressure of the out-lands that prevailed at these areas in the recent past (Sjöbeck 1927, Emanuelsson 1987). I suggest that a heavy utilisation of the meadows of the in-fields for winter-fodder production, followed by grazing after haymaking, could also favour an expanding *Calluna* population. Malmström (1939) found this development described in historical sources in the neighbouring province of Halland. He found many examples of meadows with a marked decrease in grass production in favour of *Calluna* vegetation as Sjöbeck (1931) did. At both the Råshult and Osaby (Fig. 5) in-field sites, *Calluna* pollen percentages show a negative correlation with those of Gramineae. This further supports the hypothesis of *Calluna* as an indicator of not only an open landscape and grazing pressure, but also of soil impoverishment as a result of intensive winter-fodder production.

Forest composition

The changes in the field-layer of both sites are not matched in the tree-layer. The forest composition was rather stable although the forest constantly got a more open structure. Human-initiated fires and grazing pressure by domestic animals probably contributed to the open structure of the out-lands. Several taxa that indicate forest grazing appeared frequently during this period; *Pteridium aquilinum*, Asteraceae Liguliflorae, Apiaceae undiff. (Behre 1981), *Rumex* sp. and *Potentilla* (Gaillard et al. 1992).

Betula, *Alnus* and *Quercus* dominated the forests at both sites, and *Corylus* was also rather abundant. *Tilia* was still present at the out-field site. There were almost no coniferous trees present, even if the percentage and influx values for *Picea abies*, an immigrant from the north, began to increase by the end of the period (Fig. 6). The immigrant from the south, *Fagus sylvatica*, was established at Osaby in-field at the thirteen century. *Fagus* never became a dominant species it this vegetational zone, as it did in the nemoral zone of Scandinavia, but it was by this time more widespread than today (Björse and Bradshaw 1998).

Coniferous and deciduous forests (AD 1800–)

At the out-land the deciduous forest was abruptly replaced by a dense coniferous forest of mainly *Picea*, but also *Pinus*. It probably occurred during the nineteenth century (Figs 3a and 6), but the radiocarbon chronology is rather insecure during the last few hundred years. The migrational pattern of *Picea* is considered to be under broad climatic control (Huntley and Webb 1989), and its establishment at a stand level is considered not to be as closely correlated to local disturbances compared with *Fagus* (Björkman 1996). According to regional analyses (Björse and Bradshaw 1998) the southern limit of *Picea* moved over this region of south Sweden between AD 1000 and 1500, but most likely with some local variation. A historical document tells that coniferous forest must have been present at the estate also prior to the nineteenth century. A tax assessment from AD 1693 (Appendix 1) states that old coniferous forests existed at the Osaby out-fields although much had been destroyed by fire.

Even if *Picea* is not dependent on disturbances for its establishment, the rapidity of the transition from deciduous to coniferous forest suggests human intervention (Fig. 6), supporting the hypothesis for the role of human land-use in the vegetational development. Intensive exploitation by burning and forest grazing, as described above, probably formed the basis for the

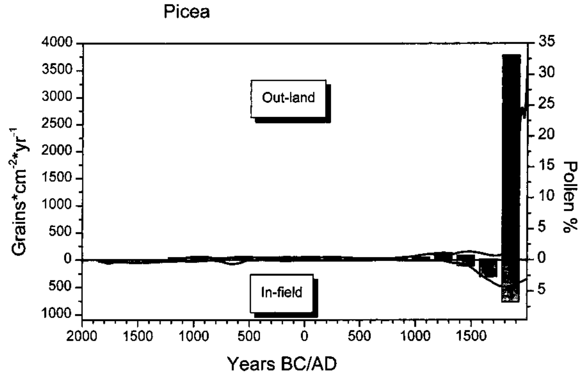

Fig. 6. Pollen percentages (curve) and influx values (histogram) for *Picea* from the two sites. Spline interpolation (third degree) has been used to smooth the pollen percentage curves. Each column of influx value represents the mean of a 200 yr period.

transformation. The invaded forest was perhaps rather open with young stands of *Betula* on slashed and burnt land, few scattered *Quercus* individuals and *Alnus* in connection with the wetlands. Perhaps the very fast invasion of *Picea* was a result of both passive and active human activity. The first planting of coniferous forests in Sweden is known from the nineteenth century according to historical documents (Eliasson pers. comm.). Spores of *Equisetum* in the diagram from Osaby out-field increased markedly at the same time as the coniferous forest (Fig. 3a), and perhaps species of this taxa are favoured by the rapid transition to darker conditions.

According to a historical document from the mid-nineteenth century the dense forest of the Osaby out-land was not representative for the parish. In an assessment of the forests of Sweden in 1846 (Appendix 1), the parish of Tävelsås was judged as "although not totally lacking forests, the stock of suitable trees is insignificant". In the same assessment the estate of Osaby is, however, considered to have "the most substantial forest of the parish".

The transformation of the out-land not only involved the establishment of the coniferous forest but also the total disappearance of almost every other species. No pollen grains of cereals are recorded after the establishment of the coniferous forest and very few other species of the field layer. It is, however, noteworthy that among the few field-layer species recorded were several anthropogenic indicators, e.g. *Artemisia* and *Rumex* spp., showing that the human impact had not ceased. The pollen percentages values for *Betula* decreased gradually from 60 to <20%, a level which implies that the species was almost lacking at the site. The pollen percentage of *Alnus* also decreased to a very low level, either in response to increased shading from conifers, but felling by humans is further possibility. *Tilia*, *Fagus* and *Carpinus* all disappeared. *Quercus* pollen percentages decreased but not to a level that implies extinction, as confirmed by the pollen and influx diagram (Fig. 7). In spite of the dramatic overall change of the vegetation at the out-land site there is a continuity of *Quercus* individuals. A compilation of historical sources concerning *Quercus* supports the pollen data, in that the species became rare in the parish at this time (Eliasson pers. comm.). It reveals that the number of *Quercus* individuals decreased from 7007 individuals in AD 1732 to 538 in AD 1832.

The influx of charcoal fragments ceased just prior the establishment of the coniferous forest. According to historical data "slash and burn cultivation" was common in this part of the region during these centuries (Larsson, L. J. 1980) even if it had been opposed by the authorities since AD 1647 (Schmedeman 1706).

No such dramatic vegetation change occurred at the in-field, and it continued to be rather open until the recent past. The uppermost two samples are heavily

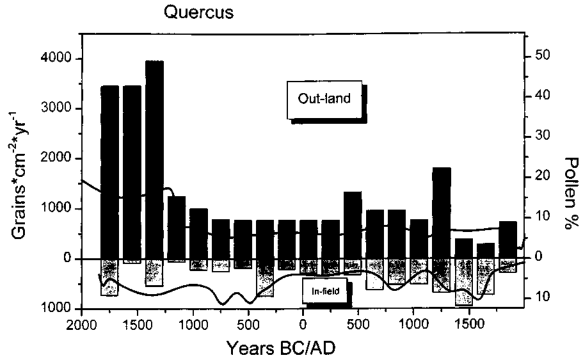

Fig. 7. Pollen percentages (curve) and influx values (histogram) for *Quercus* from the two sites. Spline interpolation (third degree) has been used to smooth the pollen percentage curves. Each column of influx value represents the mean of a 200 yr period.

dominated by *Betula*, reflecting the grove of *Betula* trees at the site of today and suppressing the percentage values of the other taxa. The pollen percentages of *Alnus*, *Quercus*, *Fagus* and *Corylus* all decreased during the last centuries, and it is not entirely an effect of the increased values for *Betula*. The percentages and influx values for *Quercus* (Fig. 7) reveal, however, a continuity of that taxon also at this site, yielding the few old individuals that can be seen at the in-fields of today. *Picea* showed a slight increase of the pollen percentages value and a more noticeable increase in the influx values (Fig. 6), probably reflecting the coniferous establishment of the nearby out-lands. Grains of anthropogenic indicators, cereals and "herbs and grasses" were recorded continuously until the present century, confirming that the pollen diagram reflects the in-field (Fig. 3b).

Diversity and cultural influence

The human impact on the vegetational development was significant, particularly in the upper parts of the profiles, and this impact seems to be related to the degree of biodiversity. To investigate this the "floristic diversity" (rarefaction analysis) is plotted against "cultural influence" (Fig. 8), the latter being defined as the total percentage of all anthropogenic indicators including cereals, but excluding pollen of Gramineae, *Calluna* and Cyperaceae from the sum. These three pollen types are so frequent that they would conceal the rarer indicators, and these taxa are also common in natural communities (Behre 1981). Each point on the diagram represents an interval of 500 yr and is the mean value of all samples within the interval. The in-field values for the periods of 2000–1500 BC and 1500–1000 BC are excluded as the samples from these periods most likely reflect regional conditions (see under Results/Natural forest/in-field).

The diagram confirms that cultural influence has a decisive role in influencing diversity. An increase or decrease of the pollen percentages for the anthropogenic indicators is in most cases followed by a corresponding change in the number of taxa recorded. At the beginning of the profile, 2000 BC, there were no anthropogenic indicators recorded at the out-field site. The human impact at the site must therefore have been negligible, even if it cannot be entirely excluded, and this time ought therefore to represent a "baseline condition". The low number of taxa recorded is therefore noteworthy and emphasises that a "natural" vegetation or "baseline condition" is not correlated with high diversity.

Increasing human activity at the out-land site ca 1000 BC can be noticed in the diagram. It results in comparable positions in the diagram for the two sites during the C and D periods, 1000 BC–0 BC, suggesting a similar human utilisation of the sites. Both "no. of taxa" and "% anthropogenic indicators" increase sharply at the in-field site during period E, probably marking the transition to more intense agricultural activity at that site. The values gradually increase at the in-field site with a peak at AD 1000–1500; the time of "Medieval agricultural system" (Lindbladh and Bradshaw 1995) is thus easily identified. The connection between diversity and cultural influence is well documented in the contemporary vegetation, e.g. in restored forest meadows (Jonsson 1995), or in-field and out-land areas (Berglund 1963–64). Forest meadows are among the most species-rich vegetation types in northern and central Europe (Kull and Zobel 1991).

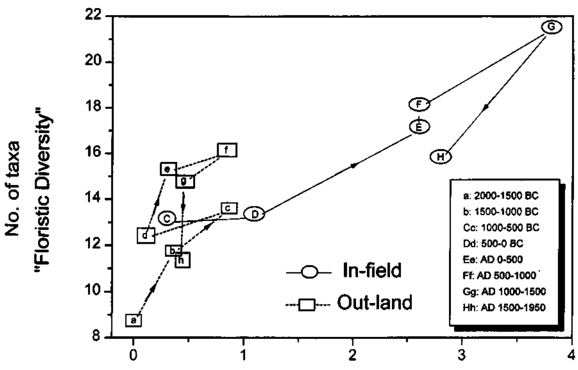

Fig. 8. "No. of taxa" is the estimated number of taxa that would be expected if all the pollen counts had been the same size. "% anthropogenic indicators" is the total percentages of all anthropogenic indicators according to Behre (1981) and Gaillard (1992) including cereals. Excluded from the sum are pollen of Gramineae, *Calluna* and Cyperaceae. Each symbol represents the mean value for a 500 yr period. The in-field values for the periods of 2000–1500 BC and 1500–1000 BC are excluded as the samples from these periods most likely reflect regional conditions.

The values for the out-land site decrease and end up during the last centuries at about the same levels as at the beginning of the profile, at the time of "baseline condition". But the species composition was by this time completely exchanged, from deciduous to coniferous forest.

Discussion

Forest properties and cultural influence

The archaeological conclusion of an earlier colonisation of the Osaby area compared to the more remote and inaccessible area of Råshult is supported by the pollen analysis. Human impact at Osaby increased continuously from 1000 to 700 BC onwards as shown by the cereal pollen record. An opening up of the forests at Osaby from that time is evident as the total tree pollen percentages constantly decreased and several light-dependent species of the ground flora became common.

Scattered anthropogenic indicators were found throughout the Råshult profile, e.g. *Plantago lanceolata* and *Rumex* spp., but there was no obvious increase in human impact until AD 1000. More importantly, none of the common tree species, *Quercus*, *Tilia*, *Alnus* and *Corylus*, decreased in the pollen diagram until that date, suggesting that the forest was more or less unaffected. This is further indicated by the pollen percentage values for "herbs and grasses" which never exceed a few percent. Humans were present at Råshult but not in such numbers as to dictate the forest composition until AD 1100.

However, the markedly increased human impact during the Early Middle Ages is a very obvious and dominating feature in the pollen diagrams of both Osaby and Råshult, and suggests a development at a regional or national scale. Apart from the early human impact at Osaby, the long-term forest development for the two estates is rather similar. The overall pattern is declining frequencies of deciduous trees, except for the late immigrant *Fagus*, followed by an increase of coniferous species. The early signs of human activity influencing forest composition found at the Osaby out-land at 1000 BC did not alter the direction of the forest development, but merely accelerated it.

The hypothesis of Osaby being more intensively utilised and therefore further displaced from "natural" conditions is not upheld. The major differences are not seen between the two areas of Råshult and Osaby but are seen within the estates. The vegetational succession at the estates was dictated by land-use history as human impact was consolidated ca AD 1000. There were several important similarities between the out-land sites of Osaby and Råshult: 1) prior to AD 1000 the out-land forests consisted mainly of *Quercus*, *Alnus*, *Betula*, *Tilia* and *Corylus*. 2) In spite of the increased human impact reflected by cereals, anthropogenic indicators and increased open conditions, this forest type survived at both estates until the last centuries of this millennium. 3) From AD 1500 onwards a dense coniferous forest of *Picea* and *Pinus* replaced the deciduous forest.

The similar development and the rapid vegetational change of the out-lands on the two estates are strong evidence for the importance of human influence on this development.

The in-fields of the two estates also have many similarities: 1) both sites have a continuity of broad-leaved trees, mainly *Quercus*, but also *Fagus* at Råshult. 2) The increasing human impact during the last millennia created uniquely high floristic diversity that is very noticeable at the in-field sites. 3) The human impact culminated during the last part of the millennium when *Calluna* became a significant part of the vegetation at both in-field sites, probably as a result of over-exploitation. 4) The immigration of *Picea* to the areas can be noted in the diagrams but not to an extent that implies that it was established on the in-fields themselves. 5) The establishment of *Fagus* seems, however, to be largely confined to the in-fields. 6) The in-fields of both estates were abandoned in the twentieth century and overgrown, not by coniferous trees, but mainly by *Betula*.

Implications for nature conservation

This study clearly shows the role of land-use in the vegetational development during the last millennia, with totally different results for the in- and out-lands. It has created a characteristic pattern of the contemporary boreo-nemoral zone in Sweden with remnants of deciduous forests close to villages and coniferous forests in between the villages. It is tempting to believe that a cessation of active forestry in the former out-fields would lead to forests returning to more natural conditions. This study shows that in the case of diversity of vascular plant and agricultural impact, current coniferous forests have some similarities with the former natural forest, but differences clearly dominate. The studies of Osaby and Råshult, as well as other small-hollow studies in the southern part of the boreo-nemoral zone of Sweden (Björkman 1996, Eriksson 1996), show that the ecosystem of coniferous forests is not more than 200–500 yr old. They would probably have been younger, or perhaps not even existed yet, if humans had not interfered. During the last hundred years the impact has been intensified and the forests have developed in response to a totally human controlled system. A "free development" of these impoverished forests would not lead to desirable goals but to forests lacking a natural species composition and structure.

Sweden ought to have an international responsibility for the boreo-nemoral zone as the greater part of this biome in western Europe lies within its borders. Mixed stands of mature forests of coniferous and deciduous species would probably be naturally common in this zone if human impact had been milder. Today only fragments of these forests type exist in southern Sweden, often on small areas of isolated or infertile land not suitable for agriculture.

My study shows that the in-fields of the southern part of the boreo-nemoral zone in Sweden also supported significant amounts of deciduous trees in the highly exploited recent centuries. These ecosystems of high diversity supported not only light-demanding species of vascular plants but also groups of organisms adapted to the virgin deciduous forest from which the meadows were derived. Several lichens and wood-living insects dependent on long forest continuity have been found at the in-fields of Råshult (Nilsson et al. 1994), and the forest-meadow system with old and sun-exposed trees has been a place of refuge for these species. My study further emphasises the relationship of the current in-fields with the former virgin deciduous forests. In spite of intensive human impact during the last centuries, no replacement of the dominating tree species has occurred in contrast to the out-land situation. Parts of many in-fields have continuously carried a tree layer and deciduous trees were able to colonise the pastures and arable fields that were abandoned during the last century. The meadows of the in-fields are today regarded as "hot-spots" by nature conservationists because of their high diversity of mainly vascular plants, and significant efforts are made to protect and restore this diversity by maintaining old-fashion management. But the most important role in the future for the wooded in-field remnants ought to be for maintaining tree continuity and as a "source" of deciduous tree species in a more nature-based forestry.

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Appendix 1. Unpublished historical documents concerning the estate or parish.

Swedish National Land Survey, Gävle. (Lantmäteriets forskningsavd, Gävle)

Map of Tofta parish with description, AD 1705. (Karta och "Geopgraphisk delinclation afmätning Tofta socken").

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