Medieval Slash-and-Burn Cultivation: Strategic or Adapted Land Use in the Swedish Mining District?

MARIE EMANUELSSON[1]

Department of Forest Vegetation Ecology
Swedish University of Agricultural Sciences
SE – 901 83 Umeå

ULF SEGERSTRÖM

Department of Forest Vegetation Ecology
Swedish University of Agricultural Sciences
SE – 901 83 Umeå

ABSTRACT

The general view in Swedish historiography of an inherent conflict between iron-making and the practice of slash-and-burn is questioned on the basis of this palaeoecological case study of repeated slash-and-burn cultivation from the fourteenth to the seventeenth centuries in the mining district of central Sweden. An alternative thesis of a mutual association between iron-making and the practice of slash-and-burn is put forward. Deliberately used by the mining peasant, slash-and-burn was a way to turn forest resources into cereals, animal fodder and charcoal for iron-making. However, the initial practice of slash-and-burn ceased after c. 400 years, when competition for forest resources arose due to the scarcity of local forest. The new situation seems to have brought about changes in land use from slash-and-burn cultivation to field cultivation and a meadow-field-rotation system. This study also shows that the practice of slash-and-burn and its relationship to the use of forest resources may be crucial for understanding the historical relationship between iron production and agriculture in the Swedish mining district.

KEYWORDS

Bergslagen, iron, land use, pollen, slash-and-burn, vegetation history

Environment and History **8** (2002): 173–96

INTRODUCTION

In legislation from the seventeenth and eighteenth centuries, the Swedish Crown presented a negative opinion about the practice of slash-and-burn[2] in relation to the iron-making industry.[3] Foresters have strengthened this attitude; slash-and-burn destroyed the forests.[4] Together, these ideas have given significant backing to a more general view of an inherent conflict between iron-making and the practice of slash-and-burn. This viewpoint is mainly based on the following lines of reasoning: The pre-industrial and early industrial production of iron was dependent on large quantities of wood and charcoal.[5] Inferior transportation, e.g. an undeveloped road system, exposed local forest resources to intensive exploitation. Any other activity that was competing for forest resources was seen as a threat to iron production. The practice of slash-and-burn cultivation was one of these activities, since it involved cutting down trees before burning the wood that otherwise could have been used for iron production. In this article, the notion of an in-built conflict is challenged, and in its place we suggest a beneficial relationship between iron-making and the practice of slash-and-burn.

Iron production has been an important part of the Swedish economy for a long time. During the thirteenth to fifteenth centuries, iron-making became concentrated in the Bergslagen[6] forest region in central Sweden, where the required natural resources – iron ore, wood and water power – were found. The production of iron increased gradually from this period and in the seventeenth and eighteenth centuries Sweden became a major producer and exporter of iron in Europe.[7] For example, the export of iron increased from some 11,000 metric tons in 1640s to almost 18,000 metric tons in 1650s, and furthermore to 27,000 metric tons around A.D. 1700. At that time, iron made up about three quarters of the total value of Swedish exports. During the second half of the eighteenth century, the average export of iron was 45,000 metric tons.

Because of its impact on the national economy, the Swedish Crown paid great attention to iron production and supported it through various laws and regulations, especially in the seventeenth century.[8] Many of the regulations were concerned with the rationing of the forest resources, as substantial quantities of wood and charcoal were needed to maintain or increase iron production. For instance, starting in the first half of the seventeenth century, the different steps in the iron-making process were geographically separated to avoid local depletion of the forest.[9] The first two steps – mining and smelting – were located in the mining district Bergslagen, while the third step – the forging of pig iron into bar iron – was designated to ironworks in the regions around Bergslagen. In the same spirit, the Crown regulated the deliberate cutting and burning of the forest. The practice of slash-and-burn, which did not aim at clearance for new, permanent fields, was locally prohibited in parts of the mining district as early as the 1570s.[10] Legislation became more and more rigorous over the course of the following century, and the restrictions did not ease up until the mid-eighteenth century.[11]

In Bergslagen, iron production was mainly carried out by mining peasants. In addition to iron-making, they worked with agriculture, including both cereal cultivation and animal husbandry. A few palaeoecological studies from the region show how the cultivation of cereals (barley and rye, probably on permanent fields) together with forest grazing was initiated around the ninth to thirteenth centuries,[12] a timing which coincides with that suggested for the start of mining.[13] The anthropogenic impact on the forest vegetation was intensified successively, especially during the seventeenth and eighteenth centuries, but no major land use alterations are implied from the palaeoecological studies. The same development is seen in archaeological investigations.[14] Together the palaeoecological and archaeological studies suggest that iron-making was a fundamental factor behind the colonisation of the region. Although the historical bond between iron-making and the agrarian economy is often recognised[15] and even said to be fundamental for the socio-economic stability of the region,[16] hardly anything is known about the relationship between the two.[17] Could the practice of slash-and-burn, even though considered to be negatively connected with iron-making, be one of the keys to understanding this relationship? The great concern of the Crown about the consequences of slash-and-burn on iron-making implies an extensive practice of this type of agrarian land use. Although some historical records exist about burning the slash for rye cultivation after the production of charcoal,[18] there are no clear indications in the palaeoecological studies from the region that slash-and-burn has been practised.[19]

The aim of this article is to examine local agrarian land use and its relation to iron-making in a long-term perspective. While the importance of iron-making is well established through archaeological and historical records, the use of local pollen analysis is the most beneficial method to investigate early agricultural development. On the basis of a case study of repeated slash-and-burn cultivation from the fourteenth to the seventeenth centuries in the Swedish mining district, we want to question the general view of an inherent conflict between iron-making and the practice of slash-and-burn. We put forward an alternative thesis about a mutual association between the two. Furthermore, the following questions are discussed: Was slash-and-burn practised in a way that would have restricted the forest resources used for charcoal production and thereby endangered the production of iron? What agrarian land use was practised in combination with slash-and-burn cultivation? What was the state of the forest when the Crown prohibited the practice of slash-and-burn in the seventeenth century; was it overexploited or was it well preserved? What agricultural changes, if any, took place when the practice of slash-and-burn was forbidden?

STUDY AREA AND METHODS

The village Persbo is situated in the parish of Ludvika in the north-western part of the mining district Bergslagen (Figure 1). The landscape is characterised by a hilly topography and numerous lakes. Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) Karst.) are the most important tree species, but deciduous trees, such as alder (*Alnus* spp.), aspen (*Populus tremula* L.) and birch (*Betula* spp.), are also present. Persbo is mentioned for the first time in A.D. 1539 when two farms are recorded in the taxation book of Dalarna; no older documentation about Persbo exists.[20] Iron-making from the sixteenth to eighteenth centuries is well manifested in historical documents, and is also seen

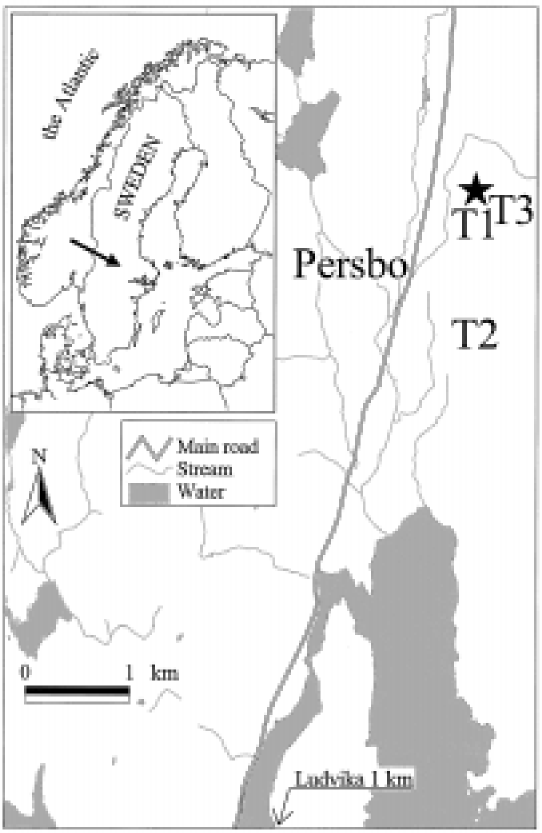


FIGURE 1. Location of Persbo in Ludvika parish, central Sweden. The sampling site of the peat profile (★) and the three transects (T1, T2, T3) are marked.

through archaeological remains in the landscape.[21] Together they confirm the importance of iron-making in Persbo. However, agrarian remains, especially from the seventeenth to nineteenth centuries, are also common. A few, among them a stone wall or fence dated to the thirteenth to fifteenth centuries, have been subjected to archaeological investigation.[22]

For a palaeoecological study of the agricultural land use history of Persbo, pollen analysis was performed on a peat profile from a small mire on the border of the in-fields and the forest (60°12'N, 15°15'E; Figure 2). Pollen analysis is one

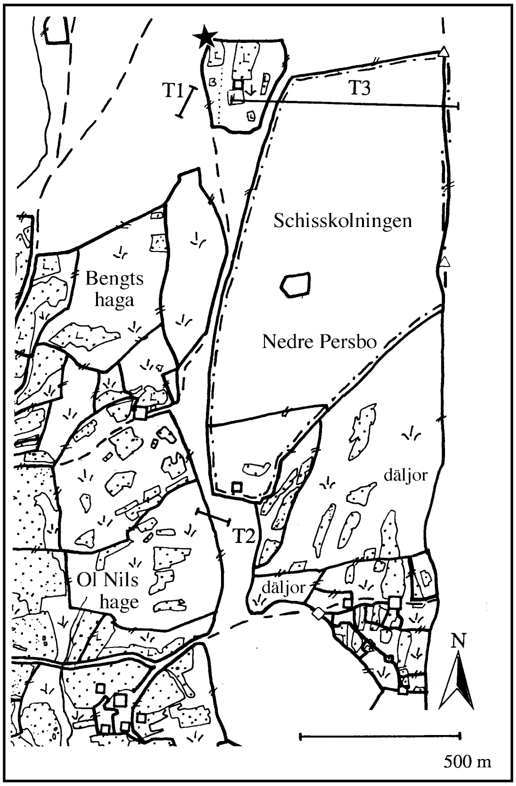


FIGURE 2. A copy of the Persbo map from privatisation of the in-fields in 1806 (Carlsson and Sandberg 1996). The western part was mainly fields (areas marked with dots) or meadows and pastures (⸜ı⸝) with scattered fields. The unmarked, elongated area in the middle of the map is the cattle path. It was used to take the cattle from the farms to the forest pastures north of the village. The sampling site of the peat profile (★) and the three transects (T1, T2, T3) are marked. The transect T2 runs across the cattle path, while the transect T3 passes Schisskolningen, which was part of the forest of the village Nedre Persbo.

of the most important methods for studying the vegetation history, including the land use history, of an area.[23] The method is based on the continuous accumulation of pollen in peat or mor humus[24] over hundreds of years and on the correspondence between the vegetation and the pollen assemblage at a given period of time. Changes in the vegetation, due to natural disturbances or human impact, are indicated by altered pollen assemblages. The size of the sampling site determines the land area represented in the pollen analysis.[25] The mire of Persbo, which is a moist depression of about 10 × 50 m surrounded by morainic ridges (Figure 3), receives a significant proportion of the pollen from the wind-pollinated tree species found within a few hundred metres of the mire.[26] Pollen from the ground vegetation, e.g. dwarf shrubs, herbs and grasses, is derived from an even smaller area due to it being shed close to ground level. Pollen analysis is here combined with the analysis of charcoal particles. The charcoal particles are regarded as indicating fires in the vicinity of the mire. Just as in the case of pollen analysis, the size of the sampling site determines the land area represented by the charcoal particle analysis.[27] Additionally, the size of the particles themselves also provides information about the source area; the larger the fragments, the closer to the site their area of origin.[28]

A peat profile 50 cm in depth was sampled from the mire in Persbo.[29] From the profile, 1-cm-thick samples were cut out and analysed for both pollen and

FIGURE 3. The mire where the peat profile was sampled in Persbo (Photo: Emanuelsson).

microscopic (50–500 μm) and macroscopic (>500 μm) charcoal particles. For the pollen analysis, microscope slides were prepared using standard methods, i.e. treatment with KOH and acetolysis, and mounting in safranine-stained glycerine.[30] The general keys of Beug, Moore and Webb and Moore *et al*. were used for the identification of the pollen types;[31] see Figure 4 for the Latin names of pollen taxa. The number of microscopic charcoal particles on the pollen slides was also registered. The percentage frequencies of each pollen type were calculated on the basis of the total terrestrial pollen sum including sedges, i.e. 500–700 pollen grains, for each sample, whereas the percentage of microscopic charcoal particles was calculated on the basis of the sum of terrestrial pollen plus the number of charcoal particles at each level. Pollen types which occur in low frequencies and are not relevant for the interpretation have been omitted from the diagram. The number of macroscopic charcoal particles was counted after treatment with diluted KOH and by using a stereo microscope with low magnification.[32] The age determination of the peat stratigraphy was made by ^{14}C-analysis of two bulk samples (Table I).

Table I. The ^{14}C-dates and calibrated ages from the peat sample from Persbo. The analyses were made by the Ångström Laboratory at Uppsala University. The calibrations were made with the programme Calib 4.2 (revised version of Calib 3.0; Stuiver and Reimer 1993). The age ranges obtained from intercepts are given.

Laboratory code	**Depth (cm)**	**^{14}C age B.P.**	**Calibrated A.D. age at 1σ**	**Calibrated A.D. age at 2σ**
Ua-13305	35–36	340±50	1475–1640	1442–1656
Ua-13306	39–40	610±55	1298–1405	1283–1428

The stratigraphical analyses provide the temporal variation of changes in vegetation and agrarian land use. In addition, the spatial variation was studied through pollen analysis of a series of soil samples taken along transects, following the strategy of Segerström.[33] Sample preparation and analysis were made using standard methods (see above), however including preparation with HF.[34] By means of this type of analysis, the spatial distribution of the most recent cereal cultivation in the surroundings of the Persbo mire can be detected; earlier occasions of cultivation are obliterated by the last one, due to the destruction of the older pollen by soil mixing, humus consuming fires and humus decomposition.

RESULT AND INTERPRETATION

The result of the analyses from the Persbo peat profile is presented in Figure 4. The local land use history, as interpreted from the pollen diagram, comprises four major phases (I-IV); phase II is further divided into four parts (IIa-IId). The chronology of the land use history is based on the two ^{14}C-dates (Table I). The beginning of phase III, at a depth of 22.5 cm, is approximated to about A.D. 1700 on the basis of the ^{14}C-dates and the estimated rate of peat accumulation.

Phase I: Closed forest before the initiation of agriculture

The boreal forest trees – alder, birch, pine and spruce – dominated the forest around the mire in Persbo, while species such as hazel and sallow occurred sparsely. The ground flora of herbs and grasses was scarce during this period. The presence of charcoal particles is probably due to natural wildfires but, according to the diagram, these fires did not alter the vegetation substantially. The high portion of fern spores, together with the actual pollen assemblage,

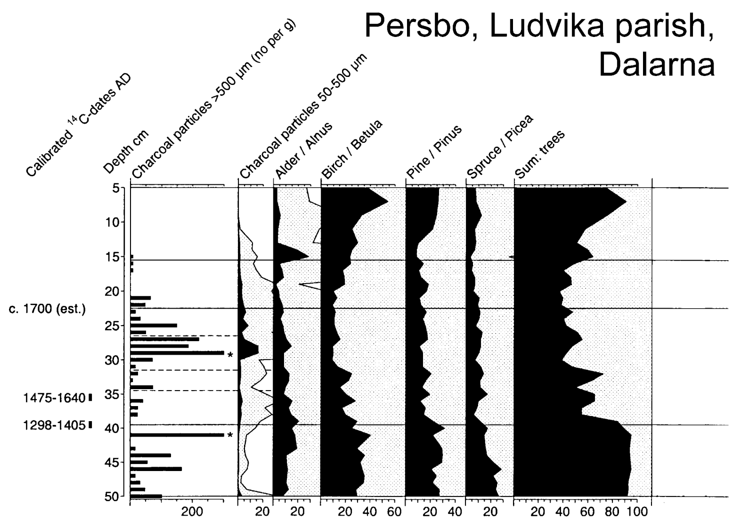
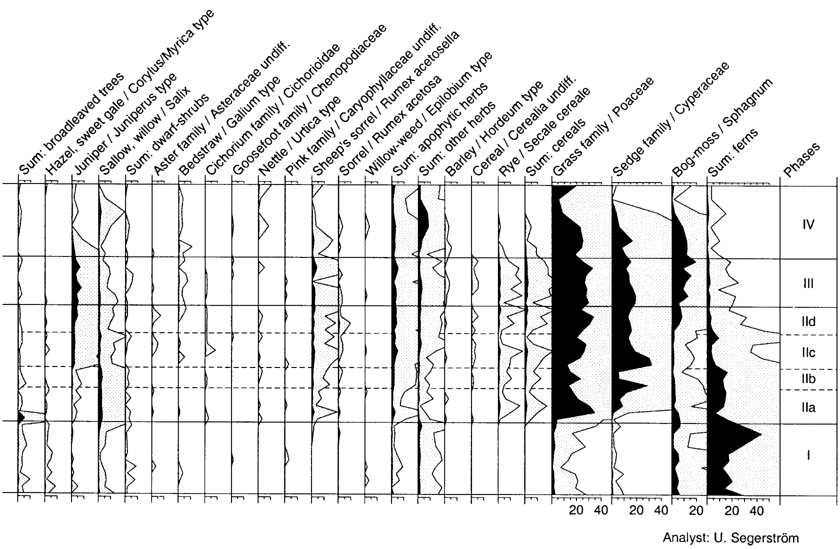


FIGURE 4. Percentage pollen diagram analysed from the peat profile from Persbo. From the left: calibrated ^{14}C-dates (1 σ); depth scale; charcoal particles >500 μm as the number of particles per gram peat (dry weight); charcoal particles 50–500 μm as percentage; individual pollen types and sum curves of the major pollen and spore groups; the major vegetation phases mentioned in the text. Black fields represent the percentage of each

indicates that the forest was closed and not subjected to human activities.[35] However, this pollen analysis which represents the local situation at Persbo cannot exclude that humans were present in the region.

Phase IIa: The establishment of agriculture in the fourteenth century

The closed forest gave way to a partly open, partly forested agrarian mosaic landscape. Cereals, mainly rye, appear in the pollen diagram at the same level as grasses and herbs associated with agriculture, i.e. apophytes, appear or increase distinctly. The forest was cut and burnt before the cultivation of rye for one or a few years in the clearings, as indicated by the decline in tree pollen and the presence of charcoal particles.[36] The absence of weeds growing on manured fields, e.g. species of the goosefoot family, supports the interpretation that slash-and-burn cultivation, rather than cultivation on permanent fields, was practised.[37] After rye cultivation, the clearings were probably used as meadows;[38] this is seen in the high proportion of grass pollen.[39] Hay-making was succeeded by grazing in the former cleared areas, which were becoming overgrown with



pollen type and grey fields the 10× exaggeration of the percentage values. Note the estimated date given for phase III. Also note that the numbers of charcoal particles >500 µm in fact exceed 500 per gram peat (dry weight) for the two highest values in the diagram (marked with asterisks).

shrubs, e.g. birch and willow. When rye cultivation and hay-making ceased in the close vicinity of the mire, which is implied by declining frequencies of rye and grass pollen, the forest recovered slightly. However, it was not only in the slashed-and-burnt area that hay-making and grazing were practiced. The damp part of the mire itself was most likely used for sedge hay production.[40] The sharp increase in sedge pollen suggests that the water flow has been manipulated, the bog-mosses have been removed and the cattle have been kept away from the mire, so as to maximise hay production.[41] The cattle were grazing in the forest where herbs and grasses grew beneath the semi-open tree canopy. Especially the spread of juniper and sheep's sorrel could have been favoured of grazing and trampling by the domestic animals,[42] since they reject such spiney and unpalatable plants.

Phases IIb – IId: The continuation of agriculture with repeated slash-and-burn cultivation

This similar set of changes in the pollen assemblages reoccurs three times: The forest was cut down, which is seen as a decrease in the tree pollen, and burnt; rye was cultivated in the clearing, seen as an increase in cereal pollen; the former cultivated area was used as meadows, seen as an increase in grass pollen, and as pastures; after which the forest returned (Figure 5). Using the estimates of the rate of peat accumulation, the duration of each sequence is approximately 80-100 years. This interpretation agrees with historical records of known slash-and-burn cycles.[43] The continual occurrence of rye pollen in the diagram suggests that slash-and-burn cultivation was practised at several places in the forest, while the slightly higher peaks in rye pollen represent the local land use within a few dozen metres.[44] For the period of time represented by land use phase II, the forest was increasingly reduced due to the land use activities in the area, and by phase IId, the portion of trees was noticeably low. The clear pattern of vegetation changes as seen in the land use phases IIa and IIb is somewhat distorted later on, especially in phase IId. This is most likely the result of two factors, which act in conjunction with each other. Firstly, the increased openness of the forest around the sampling mire allowed pollen from a larger area – and thereby more diverse vegetation – to be deposited in the peat.[45] Secondly, the land use may have become more varied with some other form of cultivation, e.g. on fields, in the area.

Phase III: The stabilisation of agrarian activities around A.D. 1700 (estimated date)

The obvious successions of trees, rye and grasses ceased at the same time as the proportion of charcoal particles decreased, and that of cereals, such as barley, increased. Together, these indicate the end of the slash-and-burn practice in the forest of Persbo and the expansion of another form of land use. The fact that

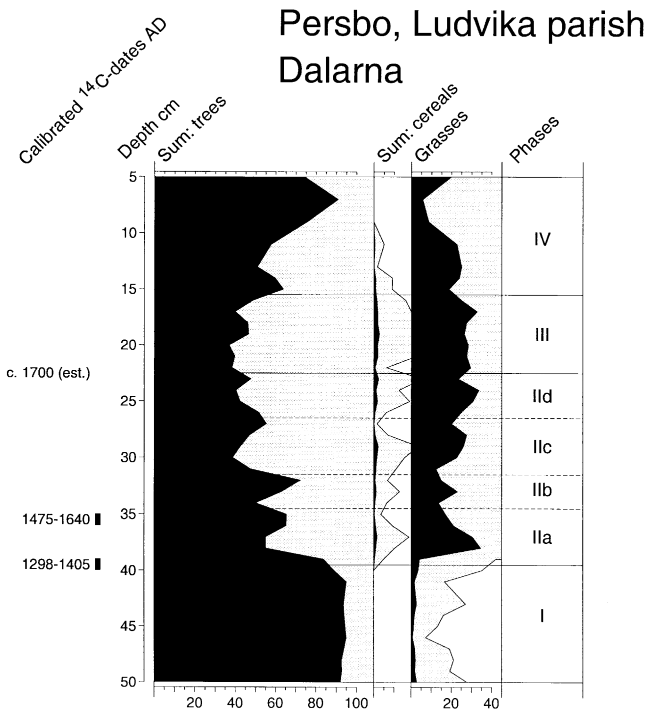


FIGURE 5. Simplified percentage pollen diagram from the peat profile from Persbo. Only the pollen curves for trees, cereals, and grasses are shown. For further information about the pollen diagram, see Figure 4.

barley and other cereals became more frequent, and that goosefoot species are present suggests that cultivation took place, at least partly, on manured, permanent fields.[46] However, it is also possible that cultivation of cereals occurred on scattered fields, of short duration, in the grass meadows. This type of short-term cultivation and long-term fallow, in Swedish called *lindbruk* or *koppelbruk* and henceforward called meadow-field-rotation, is known from historical records from Bergslagen.[47] Small plots in the meadow were dug up or ploughed, manured and sown with seeds for a few years before they turned into meadows again. This gave a harvest of cereals as well as improving grass production. The high frequency of grass pollen and the presence of weeds support this interpretation.[48] Forest grazing continued as before, although juniper benefited even more by the reduced use of fire when the practice of slash-and-burn ceased.

Phase IV: The reduction of agriculture and re-growth of the forest approximately in the nineteenth and twentieth centuries

The pollen frequencies of species such as juniper, sorrels, cereals, grasses and sedges decline and, at the same time, the proportion of tree pollen increases. This is interpreted as the end of the agricultural use of the forest and the mire. The coniferous forest returned on the drier ridges, while the mire was overgrown with e.g. alder, birch and willow. The little remaining pollen of apophytic herbs and grasses most plausibly originates from relict plants in the forest or from the in-fields of the village that are still in use for agriculture at end of the twentieth century.

The spatial distribution of cereal cultivation

The soil pollen analysis of three transects shows the spatial variation of land use in Persbo. How widespread were the types of land use, e.g. slash-and-burn

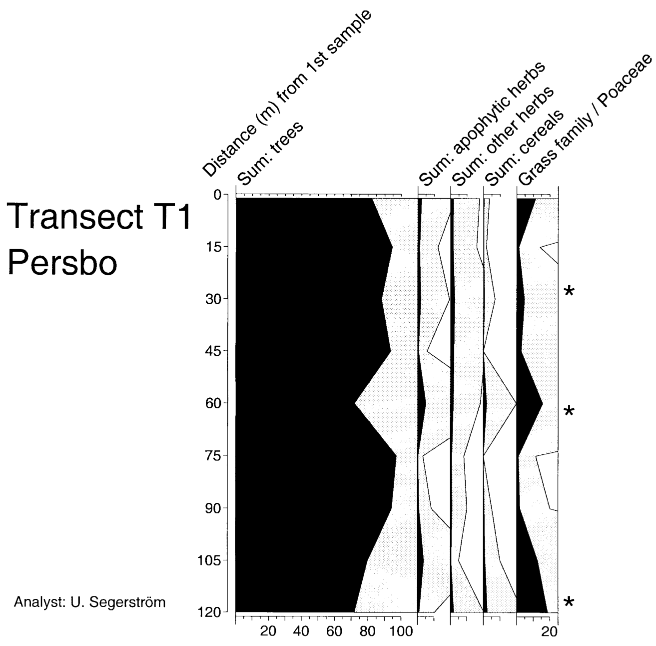


FIGURE 6. Percentage pollen diagram along transect T1 at Persbo. The scale on the left-hand side shows the horizontal distribution of the samples, beginning in the northern part of the transect. Only the sum curves of the major pollen groups and the curve for grasses are shown. Possible areas of cereal cultivation are marked with asterisks. For further information about the pollen diagram, see Figure 4. Note that there are no temporal records of vegetation in this diagram.

cultivation and meadow-field-rotation, recognised in the peat stratigraphy? The result from transect T1 in the north of the village very close to the mire (Figure 2) illustrates a landscape with cultivated land and open forest (Figure 6). Throughout the transect trees were common together with herbs and grasses. On the basis of these pollen samples, there are three possible areas along the transect where cereals have been cultivated. The presence of pollen of barley, weeds and grasses suggest that the cultivation was on either manured, permanent fields or scattered fields in the grass meadows.[49] Transect T2 is situated partly in the in-fields and partly on the cattle path, marked on the map from 1806 (Figure 2). The pollen analysis results suggest an open landscape influenced by cultivation and grazing (Figure 7). There are two potential areas where cereals may have been cultivated, one of which has also been excavated archaeologically.[50] Both the analysis and the excavation suggest that the areas were manured fields, either permanent or part of the meadow-field-rotation system. Transect T3, which is the longest and runs west-east in the northern part of the village (Figure 2), passes

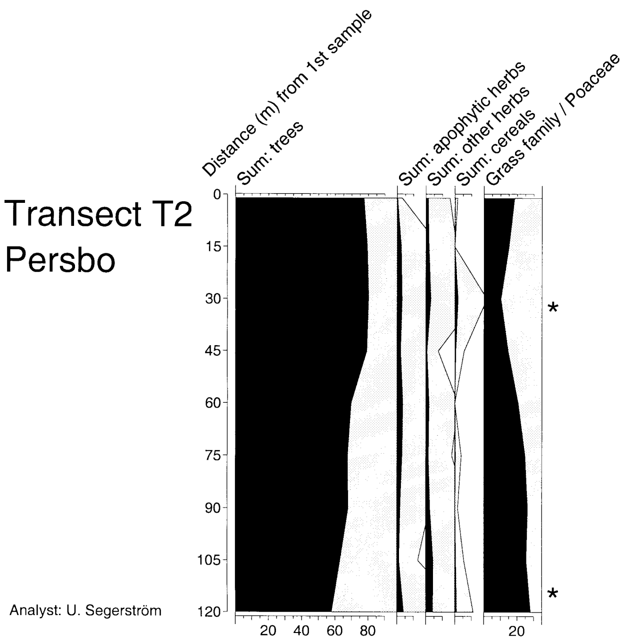


FIGURE 7. Percentage pollen diagram along transect T2 at Persbo. The scale on the left-hand side shows the horizontal distribution of the samples, beginning in the eastern part of the transect. Possible areas of cereal cultivation are marked with asterisks. For further information about the pollen diagram, see Figures 4 and 6.

mainly through the forest, but still demonstrates a highly cultivated landscape (Figure 8). Pollen from cereals are present in every sample. However, there are some indications, such as differences in the herb species, that the western section of the transect represents slash-and-burn-cultivation while the cultivation in the eastern part took place on permanent fields.[51] It should be noted that the soil pollen analysis of the three transects represents the most recent occasion of cultivation,[52] i.e. the period of field cultivation and meadow-field-rotation in phase III in the pollen diagram from the mire (Figure 4), rather than the period of intensive slash-and-burn cultivation in phase II. However, no field cultivation has taken place after the last episode of slash-and-burn cultivation in the western part of transect T3. Taken together, the soil pollen analysis of the three transects gives the impression that the influence of human activities was highly extensive in Persbo.

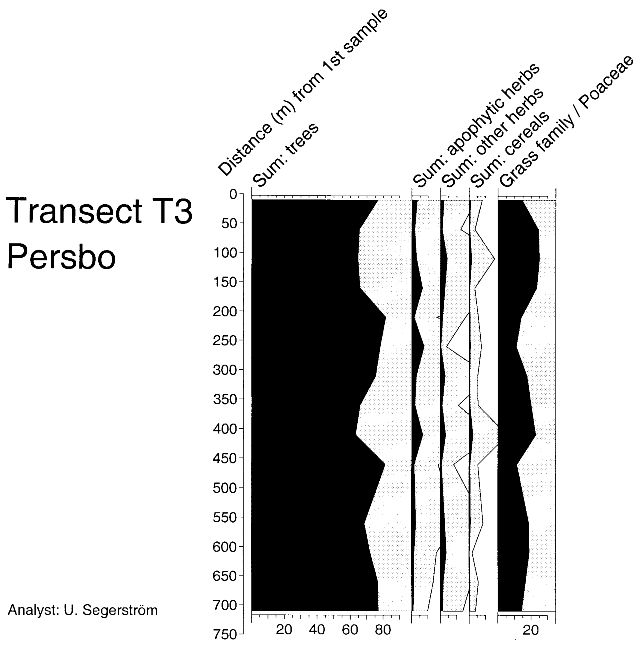


FIGURE 8. Percentage pollen diagram along transect T3 at Persbo. The scale on the left-hand side shows the horizontal distribution of the samples, beginning in the western part of the transect. For further information about the pollen diagram, see Figures 4 and 6.

DISCUSSION

The choice of slash-and-burn cultivation A.D. *1300*

The overall aim of this article is to examine the connection between the local agrarian land use and iron-making, with special emphasis on the production of charcoal. The result from the case study of Persbo in the Swedish mining district suggests an initial 400-year-period of slash-and-burn cultivation. On the basis of this result, we challenge the general view of an in-built conflict between iron-making and slash-and-burn cultivation by presenting an alternative perspective – the mutual relationship between these two. The benefits of the relationship are illuminated by the following course of practices: A forest area was cleared of trees, which, having been felled, were left on the ground to dry for a year or two. The slash, tree trunks and the ground were burnt early in the summer. After the removal of the charred tree trunks and branches, cereals, preferably rye, were sown in the ashes. The slash-and-burn cultivation did not suffer from the removal of the wood, since the main source of nutrients were the ashes from the burnt mor humus;[53] instead the cultivation and harvest, as well as the hay-making which followed were made easier.[54] The trunks, which had been superficially charred but not completely destroyed by the fire, were used for charcoal production in kilns. Supposedly, this charcoal, produced from pre-charred wood, was important for the production of high quality forgeable iron, as it was low in phosphor, because of the previous destruction of the highly phosphorous twigs and bark.[55] Given that slash-and-burn cultivation was practised for a few hundred years simultaneously with the production of iron, it seems plausible that slash-and-burn practice and iron-making acted in symbiosis rather than as competitors. Additionally, the slash-and-burn area, which was used consecutively as meadow and pasture, contributed with fodder for animal husbandry.[56] Thus, slash-and-burning appeared to be a method by which, without any extra effort, the forest could be turned into cereals, animal fodder and charcoal for iron-making.

We consider this system of land use practices as a deliberate choice by the people who settled in Persbo in the fourteenth century. The system was clever and elegant in terms of the effort involved and the outcome in terms of various utilities, i.e. the mining peasants could greatly decrease their overall work effort and still get double results by cutting down only one lot of trees for both iron-making and slash-and-burn cultivation. Which was the main motivation behind this system – cereal production, charcoal or maybe animal fodder – is difficult to assess, but it is likely to have varied in time and space. Although we consider charcoal for iron-making as being the main purpose in this case, the additional cereal production was of significant importance because of the generally poor conditions for cereal cultivation in the region.[57]

Of course, it is not sensible to generalise on the basis of a single palaeoecological case study. However, similar rotational practices combining charcoal production with agrarian land use are known from Finland, France and Germany.[58] Charcoal production after slash-and-burn cultivation, or vice versa, is also mentioned in some Swedish studies,[59] but not discussed in terms of a combination of different land uses. We suggest that the advantages for both agriculture and iron-making are evident enough to have made this kind of systematic symbiosis more widespread than just being a local coincidence.

The change to field cultivation and meadow-field-rotation A.D. 1700

The initial practice of slash-and-burn ceased after c. 400 years. Why, if it was such a clever land use system? The pollen analysis suggests that the forest at Persbo had become heavily exploited by the seventeenth and eighteenth centuries after four repetitions of local slash-and-burn episodes. The repeated slashing and burning must have diminished the number, as well as the size, of the trees in the forest. The falling size of the trees is observed in the charcoal, for example at an investigation of a medieval blast furnace in the eastern part of the Swedish mining district,[60] thus demonstrating that the forest was not allowed to grow old.[61] While the 400-year-period of slash-and-burn practice in Persbo confirms that there was no in-built conflict between iron-making and slash-and-burn cultivation, the practice led, in the long-term, to local forest scarcity and most certainly to depletion of the humus layer. This new situation seems to have brought about the change in land use from slash-and-burn cultivation to field cultivation and the meadow-field-rotation system. In so doing, the production of cereals and fodder in the in-fields was ensured while the forest was set aside for charcoal-making and grazing.

We consider the increasing exploitation and following scarcity of the forest resources to be caused largely by the rapid expansion of iron-making in the seventeenth century,[62] which required intensified extraction of trees for wood and charcoal. The use of the forests was moreover accelerated by an increasing population, and thus the need of more agricultural land for cultivation and animal husbandry.[63] The change of land use to field cultivation and meadow-field-rotation around 1700 may consequently be regarded as intrinsic, resulting from the internal dynamics of local conditions. However, several external factors may have had a crucial effect on this transformation. Firstly, the regulation of slash-and-burn cultivation in the mining district may have stimulated the abandonment of the practice.[64] But this explanation should not be overemphasised, knowing that the Crown prohibited slash-and-burn as early as the 1570s[65] and that slash-and-burn cultivation was practised – and continued to be important for at least another century – in Persbo. Secondly, the institutionalisation of iron-making, e.g. the formation of the Board of Mines (in Swedish *Bergskollegium*)[66] and the gradual professionalisation of the mining peasants and the iron workers may have practically and mentally cut off the linkage between agriculture and iron-making. This is assumed to be seen most clearly as land use changes in the forests, where the two economies confronted each other. In addition, the inability for the mining district to be self-sufficient in terms of agricultural products [67] may have enforced the separation. Thirdly, innovations in agrarian technology and farming were introduced to the mining district and the adjacent regions at an early stage.[68] The suggested meadow-field rotation in Persbo is an example of such a new cultivation system, which made it possible to produce large quantities of fodder for the animals needed in the iron industry.[69] Taken together, these internal and external factors may possibly explain the major change in land use in the mining district around A.D. 1700.

CONCLUSION

This article focuses on the local agrarian land use in the context of large-scale iron-making. The palaeoecological case study shows that slash-and-burn cultivation was established during the medieval period as an integrated part of the land use system. On the strength of this result and contrary to the general view of a conflict between iron-making and the practice of slash-and-burn cultivation, we propose a beneficial relationship between these two. However, new generalisations should be avoided; instead this study implies that local land use histories might differ from each other. Still, this study also shows that the practice of slash-and-burn as one aspect of the use of forest resources may be crucial to understanding the relationship between iron production and agriculture in the Swedish mining district. Initially it contributed cereals, meadows and pastures as well as charcoal for iron production, thus acting as a strategic linkage between the main economies. Later on, its effects on the forest were most likely an important reason behind the transformation of land use practices. To fully comprehend the function, structure and extent of the agro-industrial relationship in the Swedish mining district, however, further studies are needed. We want to point out that palaeoecological methods, e.g. pollen analysis, should be taken into account in these studies, not only as a complement to archaeological or historical investigations, but as investigations in their own right. If the practice of slash-and-burn is demonstrated as being a fundamental element in the livelihood of the mining peasants, parts of the history of the Swedish mining district would have to be rewritten.

NOTES

Thanks are due to Fredrik Sandberg, The Museum of Dalarna, for introducing Persbo to us and for assistance during field-work, to Ann-Britt Lindström for preparing the pollen samples and performing the macroscopic charcoal analysis, and to Rikard Andersson for helping with the map. We want to thank Anna Eriksson-Trenter, Greger Hörnberg, Maths Isacson, Gert Magnusson, Eva Svensson and Henrik von Stedingk for valuable comments on earlier versions of the manuscript. Sincere thanks are also due to Sheila Hicks for commenting on the manuscript as well as correcting the English. This study was funded by The Bank of Sweden Tercentenary Foundation, The Swedish Council for Forestry and Agricultural Research and Dalarna County Administration.

[1] Corresponding author.
[2] The historical use of the term slash-and-burn, in Swedish *svedjebruk*, is neither clear and unambiguous, nor historically static (Myrdal and Söderberg 1991; Myrdal 1995). However, in this article it is used to describe the following procedure: The forest is cut down and the wood is burnt, usually after having been left for one year to dry. After burning, the ground is cleared of the remaining wood and rye is sown for only one or two years. After harvesting, the slash-and-burn cultivation area is either used for hay-making and grazing before abandonment or abandoned directly to become overgrown with forest. Expressions such as swidden cultivation and burn-beating are used to describe the same or a similar practice. Other agrarian practices which involve the burning of forest land are clearance for permanent fields and improvement of pastures.
[3] Skogsstyrelsen 1879; Nellbeck 1953; Eliasson and Hamilton 1999.
[4] Faggot 1750; Heikinheimo 1987.
[5] Arpi 1951; Isacson 1992; Isacson and Poberezhnikov 1998.
[6] Bergslagen consists of parts of the provinces of Dalarna, Gästrikland, Närke, Värmland and Västmanland. In this article, only the production of iron is mentioned, although other metals, e.g. copper and silver, have been produced in Bergslagen. Regardless of the metal, production required wood and charcoal, and therefore the following text about forest resource is relevant to the production of a range of metals.
[7] Heckscher 1936; Hildebrand 1992; Magnusson 1997.
[8] Hildebrand 1992; Bladh 1997; Isacson 1997.
[9] Boëthius 1951; Sjöberg 1993; Magnusson 1997.
[10] Eliasson and Hamilton 1999.
[11] Brummer 1787; Nellbeck 1953; Eliasson and Hamilton 1999.
[12] Påhlsson 1988; Påhlsson unpub.; Segerström 1997; Eriksson 1998.
[13] Magnusson 1996; Meurman 2000; Brännvall et al. 2001; Ek and Renberg 2001.
[14] Carlsson and Sandberg 1998; Grälls and Ramström 1998; Sandberg et al. 2000.
[15] Granlund 1992; Sjöberg 1993; Magnusson 1997.
[16] Järta 1823; cf. Ågren 1992.
[17] Isacson 1992.
[18] Nellbeck 1953; Montelius 1962.
[19] Påhlsson 1988; Påhlsson unpub.; Almquist-Jacobson 1994; Segerström 1997; Eriksson 1998.
[20] Carlsson and Sandberg 1996.
[21] Ibid.

[22] Sandberg et al. 2000.
[23] Moore et al. 1991; Ritchie 1995.
[24] Mor is a common type of surface organic matter which develops beneath a heathland or coniferous forest plant community. As the litter from dwarf-shrubs and conifers is acid, the activity of the soil fauna is inhibited. The retarded breakdown of the litter results in accumulation of an organic horizon, i.e. the mor humus (Bridges 1978). The preserved organic matter of the mor forms an archive that is well suited for palaeoecological studies.
[25] Jacobson and Bradshaw 1981; Prentice 1988.
[26] Bradshaw 1988; Sugita 1994; Calcote 1995; Hicks 1998.
[27] Patterson et al. 1987.
[28] Patterson et al. 1987; Clark and Royall 1995; Tinner et al. 1998.
[29] Full information about the methods is given in Sandberg et al. 2000.
[30] Moore et al. 1991.
[31] Beug 1961; Moore and Webb 1978; Moore et al. 1991.
[32] Segerström et al. 1996.
[33] Segerström 1991; see also Figure 2.
[34] Moore et al. 1991; Segerström 1991.
[35] Hicks 1988; Segerström et al. 1994.
[36] Hicks 1985; Segerström et al. 1994; Wallin and Segerström 1994.
[37] Viklund 1998.
[38] Levander 1943.
[39] Segerström et al. 1994.
[40] Segerström et al. 1996; Emanuelsson and Segerström 1998.
[41] Levander 1943; Frödin 1952.
[42] Behre 1981; Vorren 1986.
[43] Heikinheimo 1915; Soininen 1974.
[44] Cf. Grönlund and Asikainen 1992.
[45] Prentice 1988; Sugita 1994; Calcote 1995; Hicks 1998; Sugita et al. 1999.
[46] Engelmark 1995; Viklund 1998.
[47] Schultze 1747; Myrdal and Söderberg 1991; Carlsson 1996; Gadd 2000; Figure 2.
[48] Behre 1981; Hicks 1985; Vorren 1986.
[49] Behre 1981; Hicks 1985; Vorren 1986; Engelmark 1995.
[50] Sandberg et al. 2000.
[51] Hicks 1985; Engelmark 1995.
[52] Cf. Segerström 1991.
[53] Viro 1974; Prescott et al. 2000.
[54] Levander 1943.
[55] Arpi 1951; Björkenstam 1990.
[56] Levander 1943; Montelius 1953; Myrdal and Söderberg 1991.
[57] Gadd 2000.
[58] Heikinheimo 1915; Métailié et al. 1988; Pott 1993.
[59] Levander 1943; Nordström 1952; Nellbeck 1953; Montelius 1962.
[60] Gert Magnusson, personal communication.
[61] Cf. Axelsson 2001.
[62] Heckscher 1936; Hildebrand 1992; Magnusson 1997.
[63] Heckscher 1936; Myrdal 1999.
[64] Cf. Bladh 1995.
[65] Eliasson and Hamilton 1999.
[66] Karlsson 1990; Isacson 1997.
[67] Myrdal and Söderberg 1991; Jansson 1998; Myrdal 1999.
[68] Gadd 1998.
[69] Gadd 1998; Gadd 2000.

REFERENCES

Ågren, M. 1992. *Jord och gäld. Social skiktning och rättslig konflikt i södra Dalarna ca 1650–1850*. Studia Historica Upsaliensia 166. Uppsala: Uppsala universitet.

Almquist-Jacobson, H. 1994. *Interaction of the Holocene climate, water balance, vegetation, fire, and the cultural land-use in Swedish Borderland*. LUNDQUA Thesis 30. Lund: Lund University.

Arpi, G. 1951. *Den svenska järnhanteringens träkolsförsörjning 1830–1950*. Jernkontorets Bergshistoriska skriftserie nr 14. Stockholm: Jernkontoret.

Axelsson, A.-L. 2001. 'Old trees in Northern Sweden – a historical analysis'. In *Forest Landscape Change in Boreal Sweden 1850–2000 – a multi-scale approach*, A.-L. Axelsson. Silverstria 183. Umeå: Swedish University of Agricultural Sciences.

Behre, K.-E. 1981. 'The interpretation of anthropogenic indicators in pollen diagrams'. *Pollen et Spores* 23: 225–245.

Beug, H.J. 1961. *Leitfaden der Pollenbestimmung. Lieferung* 1. Stuttgart: Gustav Fischer Verlag.

Björkenstam, N. 1990. *Västeuropeisk järnframställning under medeltiden*. Jernkontorets Berghistoriska skriftserie nr 26. Stockholm: Jernkontoret.

Bladh, G. 1995. *Finnskogens landskap och människor under fyra sekler*. Forskningsrapport 1995:11. Karlstad: Högskolan i Karlstad.

Bladh, G. 1997. 'Gruvved och kolskog. Skogens utnyttjande i Bergslagen perioden 1500–1900'. In *Människan och skogen – från naturskog till kulturskog?*, ed. L. Östlund, 85–103. Stockholm: Nordiska museet.

Boëthius, B. 1951. *Gruvornas, hyttornas och hamrarnas folk. Bergshanteringens arbetare från medeltiden till gustavianska tiden*. Stockholm: Tidens förlag.

Bradshaw, R.H.W. 1988. 'Spatially-precise studies of forest dynamics'. In *Vegetation history*, eds B. Huntley and T. Webb III, 725–751. Dordrecht: Kluwer Academic Publishers.

Brännvall, M.-L., Bindler, R., Emteryd, O. and Renberg, I. 2001. 'Four thousand years of atmospheric lead pollution in northern Europe: a summary from Swedish lake sediments'. *Journal of Paleolimnology* 25: 421–435.

Bridges, E.M. 1978. *World Soils*, 2nd edn. Cambridge: Cambridge University Press.

Brummer, M.H. 1787. *Kort Utdrag Af alla Kongl. Förordningar, Resolutioner och Bref, Rörande Skogarnas wård och nyttjande i Riket, Samt Jagt och Diurfång*. Stockholm.

Calcote, R. 1995. 'Pollen source area and pollen productivity: evidence from forest hollows'. *Journal of Ecology* 83: 591–602.

Carlsson, E. 1996. 'Lindbruk – en bergslagsmetod?'. *Dalarna* 1996, 66: 73–84.

Carlsson, E. and Sandberg, F. 1996. *Arkeologisk utredning Riksväg 60, Ludvika. Ludvika socken och kommun, Dalarna*. Arkeologisk rapport 1996:10. Falun: Dalarnas museum.

Carlsson, E. and Sandberg, F. 1998. *Arkeologisk utredning Västra Korsgården, Korsarvet, St Kopparbergs socken, Falu kommun, Dalarna*. Arkeologisk rapport 1998:7. Falun: Dalarnas museum.

Clark, J.S. and Royall, P.D. 1995. 'Particle-Size Evidence of Source Areas of Charcoal Accumulation in Late Holocene Sediments of Eastern North American Lakes'. *Quaternary Research* 43: 80–89.

Ek, A.S. and Renberg, I. 2001. ‘Heavy metal pollution and lake acidity changes caused by one thousand years of copper mining in Falun, central Sweden’. *Journal of Paleolimnology* 26: 89–107.

Eliasson, P. and Hamilton, G. 1999. ‘ “Blifver ondt att förena sigh” – några linjer i den svenska skogslagstiftningen om utmark och skog’. In *Skogshistorisk forskning i Europa och Nordamerika,* ed. R. Pettersson, 47–106. Stockholm: Kungl. Skogs- och lantbruksakademien.

Emanuelsson, M. and Segerström, U. 1998. ‘Forest grazing and outland exploitation during the Middle Ages in Dalarna, central Sweden: a study based on pollen analysis’. In *Outland use in Preindustrial Europe*, eds H. Andersson, L. Ersgård and E. Svensson, 80–94. Lund: Lund University.

Engelmark, R. 1995. ‘Experiment kring förhistoriskt svedjebruk’. In *Svedjebruk och röjningsbränning i Norden – terminologi, datering, metoder,* ed. B. Larsson, 28–36. Stockholm: Nordiska museet.

Eriksson, J.A. 1998. ‘Pollenanalys’. In *Arkeologisk undersökning Nedre Gruvriset, Dalarna, Stora Kopparbergs socken. Nedre Gruvriset 33:1, RAÄ 224E,* eds A. Gräls and A. Ramström. Rapport 1998: 11, 36–55. Stockholm: Riksantikvarieämbetet/UV Mitt.

Faggot, J. 1750. ‘Afhandling om Svedjande, samt utväg til Hushållning med skogar’. *Kongl. Svenska Vetenskaps Academiens Handlingar* Vol: XI: 138–148. Stockholm.

Frödin, J. 1952. *Skogar och myrar i norra Sverige i deras funktioner som betemark och slåtter*. Instituttet for sammenlignende kulturforskning Ser. B, skrift XLVI. Oslo: Aschehoug.

Gadd, C.-J. 1998. ‘Jordbruksteknisk förändring i Sverige under 1700- och 1800-talen – regionala aspekter’. In *Ett föränderligt agrarsamhälle. Västsverige i jämförande belysning*, eds L. Andersson Palm, C.-J. Gadd and L. Nyström, 83–228. Göteborg: Göteborgs universitet.

Gadd, C.-J. 2000. *Den agrara revolutionen 1700–1870*. Det svenska jordbrukets historia, band 3. Stockholm: Natur och Kultur/LTs förlag.

Grälls, A. and Ramström, A. 1998. *Arkeologisk undersökning Nedre Gruvriset, Dalarna, Stora Kopparbergs socken. Nedre Gruvriset 33:1, RAÄ 224E*. Rapport 1998:11. Stockholm: Riksantikvarieämbetet/UV Mitt.

Granlund, J. 1992. ‘Greksåsars bergsmän i hyttlag och gruvlag’. *Med hammare och fackla* 32: 53–109.

Grönlund, E. and Asikainen, E. 1992. ‘Reflections of slash-and-burn cultivation cycles in a varved sediment of Lake Pitkälampi (North Karelia, Finland)’. *Laborativ Arkeologi* 6: 43–48.

Heckscher, E.F. 1936. *Sveriges ekonomiska historia från Gustav Vasa. Del 1: Före frihetstiden*. Bok 2: Hushållningen under internationell påverkan 1600–1720. Stockholm: Albert Bonniers förlag.

Heikinheimo, O. 1915. *Kaskiviljelyksen vaikutus Suomen metsiin*. Acta Forestalia Fennica 4. Helsinki: Suomen Metsätieteellinen Seura.

Heikinheimo, O. 1987. ‘The Impact of Swidden Cultivation on Forests in Finland. – Extracts’. *Suomen Antropologi* 4: 199–206.

Hicks, S. 1985. ‘Problems and possibilities in correlating historical/archaeological and pollen-analytical evidence in a northern boreal environment: an example from Kuusamo, Finland’. *Fennoscandia Archaeologica* II: 51–84.

Hicks, S. 1988. 'The representation of different farming practices in pollen diagrams from Northern Finland'. In *The Cultural Landscape – Past, Present and Future*, eds H.H. Birks, H.J.B. Birks, P.E. Kaland and D. Moe, 189–207. Cambridge: Cambridge University Press.

Hicks, S. 1998. 'Fields, boreal forests and forest clearings as recorded by modern pollen deposition'. In *Quantification of Land Surfaces Cleared of Forests during the Holocene – Modern pollen/vegetation/landscape relationships as an aid to the interpretation of fossil pollen data*, ed. B. Frenzel, 53–66. Stuttgart: Gustav Fischer Verlag.

Hildebrand, K.-G. 1992. *Swedish Iron in the Seventeenth and Eighteenth Centuries Export Industry before the Industrialization*. Jernkontorets Bergshistoriska skriftserie nr 29. Stockholm: Jernkontoret.

Isacson, M. 1992. 'Bruk, träkol och bönder'. *Bergslagsarkiv* 4: 3–14.

Isacson, M. 1997. 'Bergskollegium och den tidigindustriella järnhanteringen'. *Dædalus* 1998, 66: 43–58.

Isacson, M. and Poberezhnikov, I. 1998. 'Charcoal: Production and Transport'. In *Iron-Making Societies. Early Industrial Development in Sweden and Russia, 1600–1900*, ed. M. Ågren, 179–217. Providence: Berghahn Books.

Jacobson, G.L.Jr. and Bradshaw, R.H.W. 1981. 'The Selection of Sites for Paleovegetational Studies'. *Quaternary Research* 16: 80–96.

Jansson, U. 1998. *Odlingssystem i Vänerområdet. En studie av tidigmodernt jordbruk i Västsverige*. Stockholm: Stockholms universitet.

Järta, H. 1823. *Underdånig Berättelse om Stora Kopparbergs län*. Fahlun.

Karlsson, P.–-A. 1990. *Järnbruken och ståndssamhället. Institutionell och attitydmässig konflikt under Sveriges tidiga industrialisering 1700–1770*. Jernkontorets Bergshistoriska skriftserie nr 25. Stockholm: Jernkontoret.

Levander, L. 1943. *Övre Dalarnes bondekultur under 1800-talets förra hälft. 1 Självhushåll*. Stockholm: Jonsson & Winter Förlags A.B.

Magnusson, G. 1996. 'Bergsmän, arbetare, bönder, gruvor, hyttor och oxar. Kring den äldsta industrialiseringen i Sverige'. *Dædalus* 1997, 65: 31–50.

Magnusson, L. 1997. *Sveriges ekonomiska historia*. 2nd edn. Stockholm: Prisma.

Métailié, J.P., Bonhote, J. and Fruhauf, C. 1988. 'A thousand years of forest history in the French Pyrenees mountains: the Ariege example'. In *Human Influence on Forest Ecosystems Development in Europe*, ed. F. Salbitano, 159–167. Bologna: Pitagora Editrice.

Meurman, R. 2000. *Silverberg i Järnbärarland. Bergshanteringens begynnelse i ljuset av Schmidt Testhammardateringar*. Occasional Papers in Archaeology 21. Uppsala: Uppsala Universitet.

Montelius, S. 1953. *The burning of forest land for the cultivation of crops. "Svedjebruk" in central Sweden*. Meddelanden från Uppsala universitets geografiska institution Ser. A. 87: 41–54.

Montelius, S. 1962. *Säfsnäsbrukens arbetskraft och försörjning 1600–1865*. Geographica nr 37. Falun: Uppsala universitet.

Moore, P.D. and Webb, J.A. 1978. *An Illustrated Guide to Pollen Analysis*. London: Hodder and Stoughton.

Moore, P.D., Webb, J.A. and Collinson, M.E. 1991. *Pollen analysis*. 2nd edn. Oxford: Blackwell Scientific Publications.

Myrdal, J. 1995. 'Inledning'. In *Svedjebruk och röjningsbränning i Norden – terminologi, datering, metoder*, ed. B. Larsson, 5–13. Stockholm: Nordiska museet.

Myrdal, J. 1999. *Jordbruket under feodalismen 1000–1700*. Det svenska jordbrukets historia, band 2. Stockholm: Natur och Kultur/LTs förlag.

Myrdal, J. and Söderberg, J. 1991. *Kontinuitetens dynamik. Agrar ekonomi i 1500-talets Sverige*. Stockholm Studies in Economic History 15. Stockholm: Almqvist & Wiksell International.

Nellbeck, R. 1953. *Några drag ur svensk skogsvårdshistoria. En historisk exposé med särskild hänsyn tagen till utvecklingen i sydligaste Sverige och Bergslagen under 1700-talet och tidigt 1800-tal*. Sveg.

Nordström, O. 1952. *Relationer mellan bruk och omland i östra Småland 1750–1900*. Lund: Gleerupska universitetsbokhandeln.

Påhlsson, I. 1988. 'Kulturlandskapet'. In *Bondeplågarens borg: Om och kring undersökningen av fogdefästet Borganäs i Dalarna*, eds M. Mogren and K. Svensson, 27–29. Stockholm: Riksantikvarieämbetet/UV.

Påhlsson, I. Pollenanalyser vid Lapphyttan. Unpublished report to Gert Magnusson, The Swedish Central Board of National Antiquities, Stockholm.

Patterson, W.A.III, Edwards, K.J. and Maguire, D.J. 1987. 'Microscopic charcoal as a fossil indicator of fire'. *Quaternary Science Reviews* 6: 3–23.

Pott, R. 1993. 'Landnutzungsformen des südwestfälischen Berglandes in prähistorischer und historischer Zeit'. *Naturwissenschaften* 80: 99–107.

Prentice. I.C. 1988. 'Records of vegetation in time and space: the principles of pollen analysis'. In *Vegetation History*, eds B. Huntley and T. Webb III, 17–42. Dordrecht: Kluwer Academic Publishers.

Prescott, C.E., Maynard, D.G. and Laiho, R. 2000. 'Humus in northern forests: friend or foe?'. *Forest Ecology and Management* 133: 23–36.

Ritchie, J.C. 1995. 'Tansley Review No. 83. Current trends in studies of long-term plant community dynamics'. *New Phytologist* 130: 469–494.

Sandberg, F., Segerström, U. and Emanuelsson, M. 2000. *Arkeologisk förundersökning Riksväg 60, Ludvika. Ludvika socken och kommun, Dalarna*. Arkeologisk rapport 2000:8. Falun: Dalarnas museum.

Schultze, S. 1747. *Tägtejords Skötsel, Eller om Sättet at Bruka Åker och Äng Wid Stora Kopparberget och omkring Fahlu Stad Som med lika nytta å andra orter är försökt och framgifwen af S. S.* 2nd edn. Stockholm.

Segerström, U. 1991. 'Soil Pollen Analysis – An Application for Tracing Ancient Arable Patches'. *Journal of Archaeological Science* 18: 165–175.

Segerström, U. 1997. 'Long-term dynamics of vegetation and disturbance of a southern boreal spruce swamp forest'. *Journal of Vegetation Science* 8: 295–306.

Segerström, U., Bradshaw, R., Hörnberg, G. and Bohlin, E. 1994. 'Disturbance history of a swamp forest refuge in northern Sweden'. *Biological Conservation* 68: 189–196.

Segerström, U., Hörnberg, G. and Bradshaw, R. 1996. 'The 9000-year history of vegetation development and disturbance patterns of a swamp-forest in Dalarna, northern Sweden'. *The Holocene* 6: 37–48.

Sjöberg, M. 1993. *Järn och jord. Bergsmän på 1700-talet*. Studier i stads- och kommunshistoria 9. Stockholm: Stads- och kommunhistoriska institutet.

Skogsstyrelsen 1879. *Skogs-styrelsens underdåniga berättelse angående skogs- och jagtväsendet i Sverige intill år 1870*. Bidrag till Sveriges officiela statistik. Q. Skogsväsendet. I. Stockholm: P.A. Norstedt & Söner.

Soininen, A.M. 1974. *Vanha maataloutemme. Maatalous ja maatalousväestö Suomessa perinnäisen maatalouden loppukaudella 1720-luvulta 1870-luvulle*. Journal of the Scientific Agricultural Society of Finland 46, Supplement. Helsinki: Suomen Maataloustieteellinen Seura.

Stuiver, M. and Reimer, P.J. 1993. 'Extended ^{14}C Data-Base and Revised CALIB 3.0 ^{14}C Age Calibration Program'. *Radioncarbon* 35: 215–230.

Sugita, S. 1994. 'Pollen representation of vegetation in Quaternary sediments: theory and method in patchy vegetation'. *Journal of Ecology* 82: 881–897.

Sugita, S., Gaillard, M.-J. and Broström, A. 1999. 'Landscape openness and pollen records: a simulation approach'. *The Holocene* 9: 409–421.

Tinner, W., Conedera, M., Ammann, B., Gäggeler, H.W., Gedye, S., Jones, R. and Sägesser, B. 1998. 'Pollen and charcoal in lake sediments compared with historically documented forest fires in southern Switzerland since AD 1920'. *The Holocene* 8: 31–42.

Viklund, K. 1998. *Cereals, Weeds and Crop Processing in Iron Age Sweden*. Archaeology and Environment 14. Umeå: University of Umeå.

Viro, P.J. 1974. 'Effects of Forest Fire on Soil'. In *Fire and Ecosystems*, eds T.T. Kozlowski and C.E. Ahlgren, 7–45. New York: Academic Press.

Vorren, K.-D. 1986. 'The impact of early agriculture on the vegetation of Northern Norway. A discussion of anthropogenic indicators in biostratigraphical data'. In *Anthropogenic Indicators in Pollen Diagrams,* ed. K.-E. Behre, 1-18. Rotterdam: A.A. Balkema.

Wallin, J.-E. and Segerström, U. 1994. 'Natural resources and agriculture during the Iron Age in Ostrobothnia, western Finland, investigated by pollen analysis'. *Vegetation History and Archaeobotany* 3: 89–105.