REFLECTIONS OF SLASH-AND-BURN CULTIVATION CYCLES IN A VARVED SEDIMENT OF LAKE PITKÄLAMPI (NORTH KARELIA, FINLAND)

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ABSTRACT

Land-use history of a small village from North Karelia, Finland, was studied with pollen and charcoal analyses. The principal aim of the study was to identify and quantify slash-and-burn induced rotational cycles using detrended correspondence analysis (DCA) and rarefaction analysis. Rotational cycles were especially clear in the rye pollen abundances, but were also manifested in the DCA ordination on the pollen assemblage level. Changes in land-use practices were distinct in the pollen richness in species, which was estimated with rarefaction analysis.

Introduction

Slash-and-burn or swidden was a rotational cultivation method commonly practised in East Finland until as late as the early 20th century. Each slash-and-burn cultivation cycle began with the felling and burning of forest. After a few years of crop cultivation the lands were either used for hay-making and grazing or left fallow, which was succeeded by forest regeneration. Strong tilling of the soil was not practised (Heikinheimo 1915).

The present paper is a palaeoecological study of land-use history in Tohmajärvi commune, province of North Karelia. The main aim of this study was to identify vegetation successions induced by slash-and-burn cultivation cycles. Detrended correspondence analysis (DCA, Hill 1979) and rarefaction analysis (Simberloff 1979) were applied to the pollen data in order to extract and quantify the different forms of land-use and their manifestation in pollen analysis.

Material and methods

The study site and sample treatment

The study area, Tohmajärvi, was known as an important agricultural area in North Karelia already in the 17th century (Saarenseppä 1912) (fig 1). The bedrock of Karelidic schists accounts for relatively fertile soils of the study area. The study site, Lake Pitkälampi (62°15'N, 30°27'E) lies in the village of Saario, which is mentioned in historical records already in the 16th century (Könönen & Kirkinen 1969). Pitkälampi is 20 m deep, with a surface area of 0.3 km^2 and a drainage area of 8 km^2. The lake is surrounded by forests and fields; there are extensive bogs in the northern part of the catchment which have been extensively drained for forestry mainly during the last decades.

The lake sediment was sampled with a freezing corer (Huttunen & Meriläinen 1978) in 1989. In the laboratory the frozen cores were photographed and cut into 1 cm high subsamples. The laboratory procedures for pollen and sediment analyses follow Berglund & Ralska-Jasiewiczowa (1986). In charcoal analysis all the charcoal particles with a minimum cross-section of 5 μm were counted against 10 % Lycopodium spores counted in the pollen analysis. The annual laminae were counted from the frozen cores in a coldroom.

Statistical treatment of pollen data

Detrended correspondence analysis (DCA) (Hill 1979) is an indirect ordination method that summarizes directions of variation in a given data set and reveals relationships between ecological assemblages. DCA reduces the dimensionality of ecological data by positioning similar entities (here: stratigraphic samples and pollen species) close together along the orthogonal DCA-axes (Hill 1979). The DCA data set was composed of the relative quantities of terrestrial pollen and spores of *Huperzia selago*, *Isoëtes* sp., Polypodiaceae and *Pteridium aquilinum*.

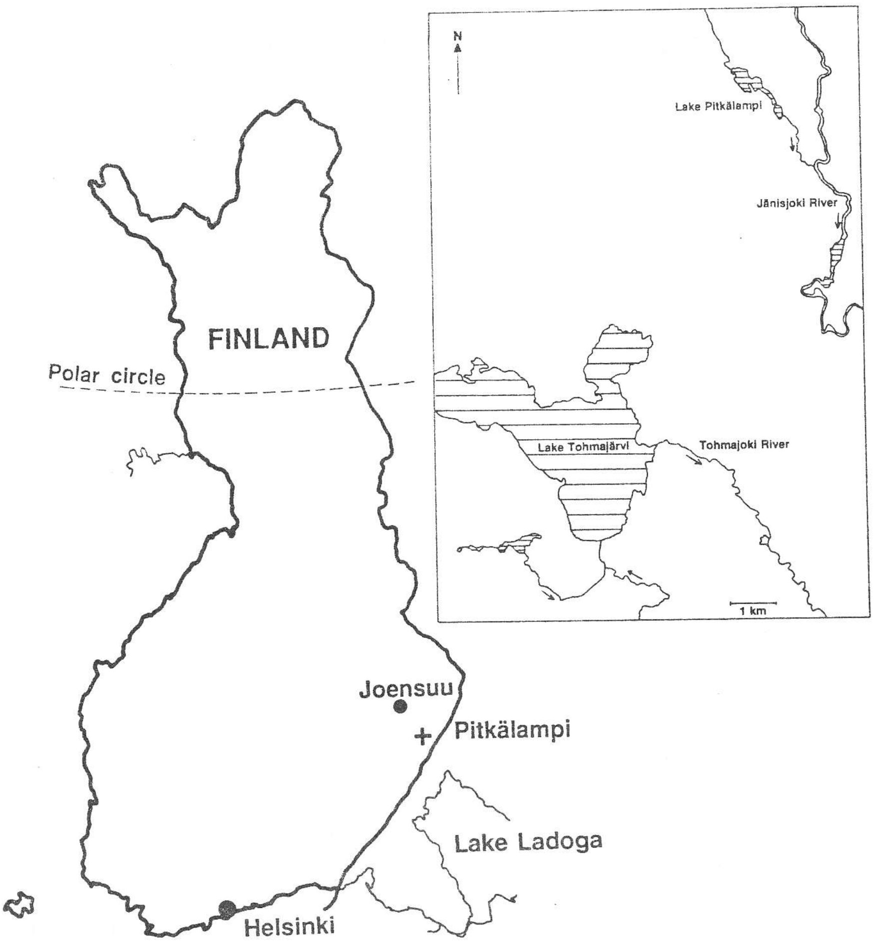

Fig 1. Location of Lake Pitkälampi in North Karelia (East Finland).

A standardized measure for pollen diversity (richness) was obtained by rarefaction analysis (Hurlbert 1971, Simberloff 1979). This method allows comparisons of species numbers when sample sizes are not equal. The rarefaction data set consisted of terrestrial spore and pollen taxa. The rarefaction estimates E(Sn) were calculated for every sample, for a constant sample count of 400 pollen grains. The analysis was performed with programs RARECEP and RAREPOLL by J.M. Line (see Birks et al. 1988).

Results

Sediment and pollen analyses

Varve countings dated the base (150 cm) of the sediment core to 1288 AD. Sedimentation rate has been high, exceeding 2.5 mm yr^{-1} throughout the core (fig 2).

The Cerealia-type pollen grains were found sporadically in the samples of 1288-1450 AD (150-124 cm) indicating short term and small scaled cultivation in the catchment area (fig 3). Rye pollen occurs continuously since 1450 AD, accompanied by a marked decrease of spruce (*Picea abies*) and increase of birch (*Betula* sp.), alder (*Alnus* sp.) and non-arboreal pollen abundances.

Since about the 1550's (100 cm) there is a distinct and regular fluctuating pattern in the rye pollen abundances reflecting the slash-and-burn cultivation cycles. The duration of the rye pollen cycles is ca. 30 years. Another indication of rotational burning are the peaks of charcoal particle influx (fig 2), which do not, however, appear perfectly synchronous with the rye pollen fluctuation. The pollen curves for alder, birch, sorrel (*Rumex* sp.) and wild grasses (Poaceae) also show fluctuations, but not as regular ones as the rye pollen curve. Additionally, during this period all the culture indicating pollen abundances increase gradually.

During the 19th century in East Finland the land-use practices changed drastically (Soininen 1974): slash-and-burn cultivation cycles shortened, while the areas of permanent fields on mineral soils, peat-land cultivation and pasture land increased markedly. These trends are reflected in the Pitkälampi pollen spectrum by e.g. a conspicuous increase of wild grass (Poaceae), rye and sorrel (*Rumex* sp.) pollen proportions. Introduction of the Scottish plough in the 1850's (Soininen 1974) resulted in heavy erosion of mineral soil rich in charcoal particles. A distinct increase of the *Sphagnum* spore abundances in the topmost samples indicates intensive peat-land drainage for forestry around the lake especially during the 1960's and 1970's.

Detrended correspondence analysis

The pollen samples ordinate stratigraphically into four groups, A-D (fig 4b): **Group D (1288-1450 AD)** is a well-defined group reflecting a stable forest vegetation with boreal forest and deciduous forest species. **Group C (1450-1600 AD)** samples are characterized by the deciduous forest species tree species; within this group the variation in sample ordination is mainly along the

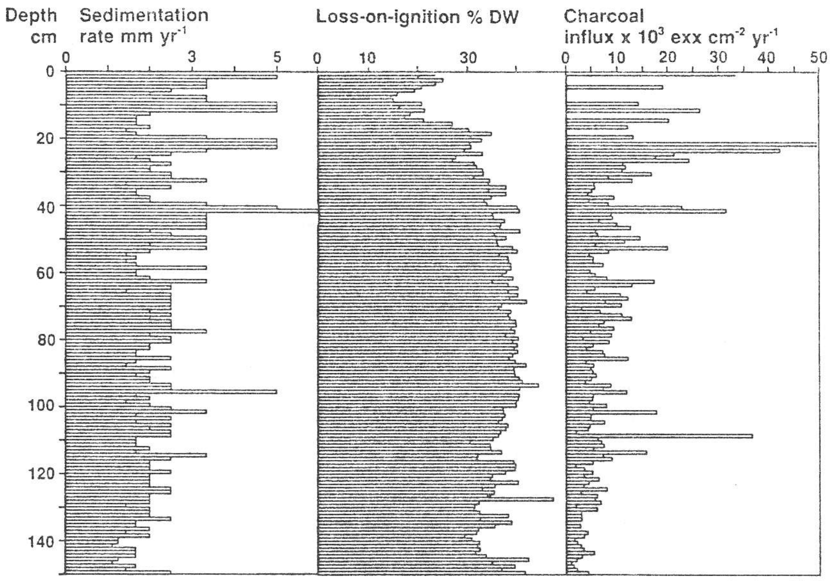

Fig 2. Sedimentation rate, ignition residue (= organic matter) and charcoal particle influx. Dating as in fig 3.

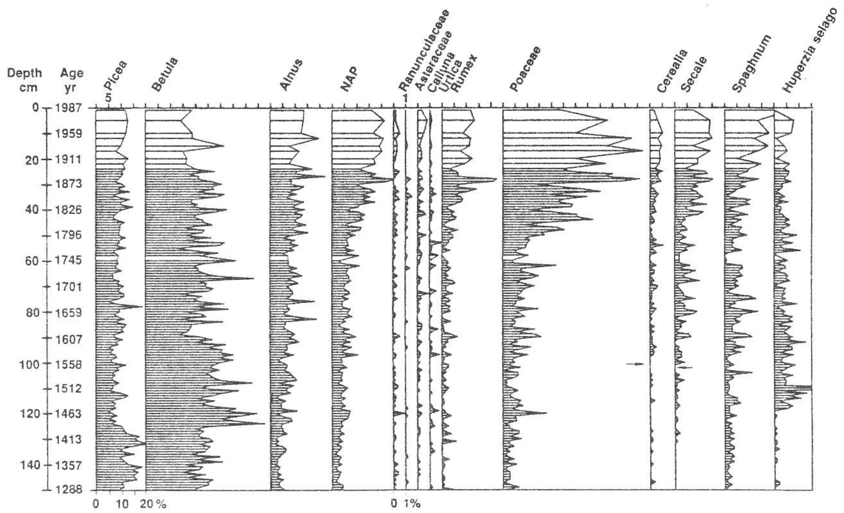

Fig 3. Relative pollen diagram of selected taxa. Percentage base is the sum of land pollen. NAP = non-arboreal pollen. The dating is based on varve counts.

second axis. **Group B (1600-1800 AD)** is more heterogeneous than the preceding groups with several aberrant samples. This "wandering" is interpreted as vegetation successions during slash-and-burn rotational cycles. One such cycle is drawn in detail in fig 4b. In comparison to the earlier groups, group B represents a more open vegetation reflecting human influence. The samples in **group A (1800-1988 AD)**, spread widely along the first axis and are associated with pollen species indicative of cultivation and pasture, e.g., cereals, sorrel and plantain (*Plantago major/media*) whilst the concomitant increase of quillwort spores (*Isoëtes* sp.) reflects a more minerogenic littoral sediment.

In the oldest groups D and C the sample points are ordinated mainly along the second axis and most of the variation results from variation in the tree taxa. In contrast, in the group A, the variation between samples is larger and the stratigraphically adjacent sample points show variation along the first axis apparently due to changes in the proportion and composition of the herb pollen component.

In the DCA analysis of the Lake Pitkälampi pollen data the first axis is interpreted as a gradient ranging from closed boreal forest (left-hand side of the DCA-plot in fig 4b) to open cultural landscape (right). The second axis appears to indicate the forest tree composition from mature conifer forests (bottom, fig 4a) to deciduous forests (top).

Rarefaction analysis

The beginning of continuous cultivation in the 1450's is reflected as an increase in richness in species (fig 5), which lasts about 100 years. The increase is due both

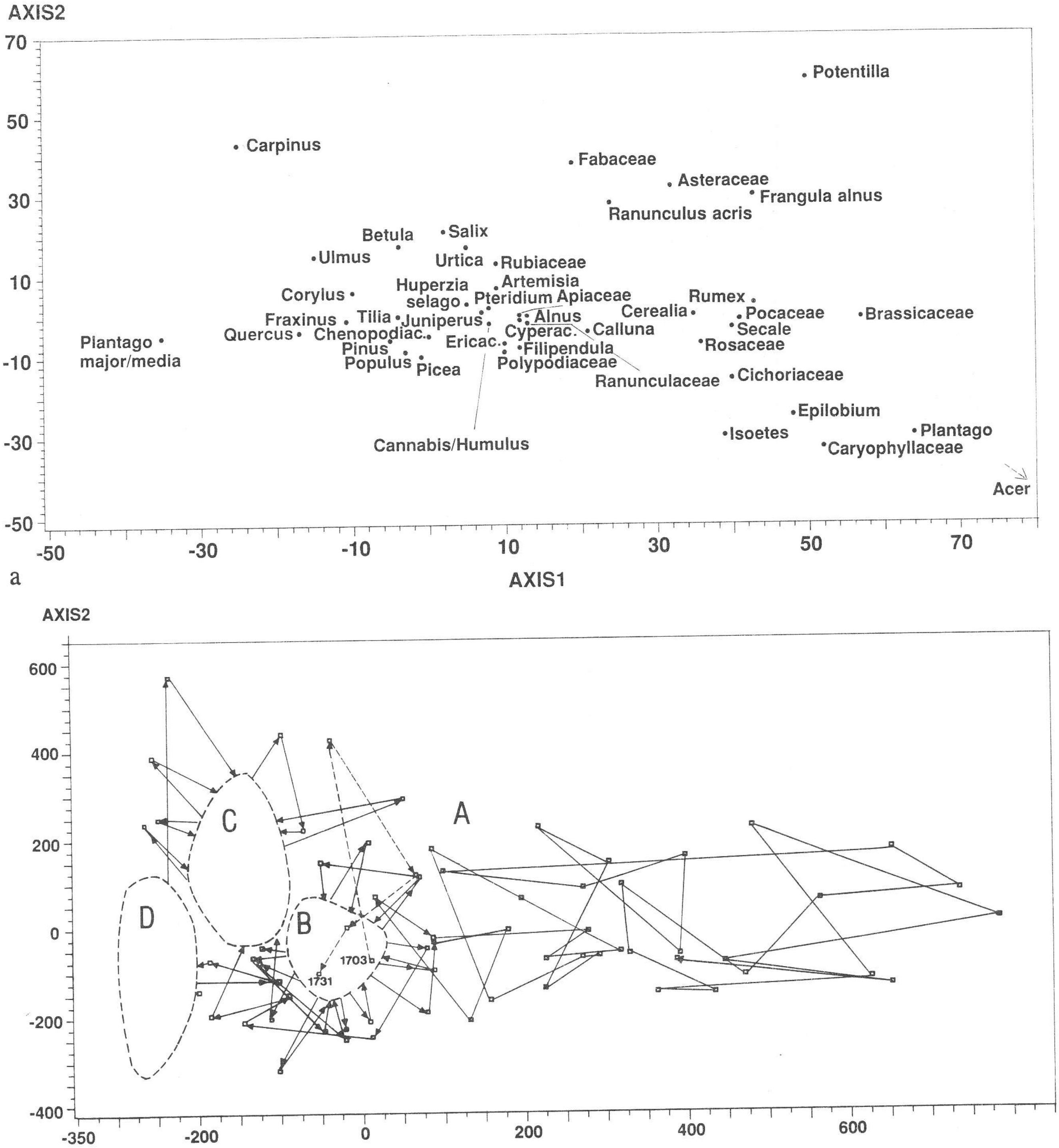

Fig 4. a) DCA ordination of pollen species, axes 1 and 2. Species scores are multiplied by 10. Eigenvalues: axis 1 = 0.067 and axis 2 = 0.025. b) DCA plot of stratigraphic samples axes 1 and 2. In group B one slash-and-burn cultivation cycle dated to 1703-1713 is shown with a dashed line. Sample score multiplier 100.

to an absolute increase in the number of species growing in the area and to the opening of the landscape, which permits the pollen grains to spread to a wider area. A clear decline in the number of species in the early 16th century reflects a regression phase in land-use lasting about 70 years, which is also apparent in the rye and cereal pollen diagrams (arrows in fig 3). The richness in species rises slightly at the beginning of slash-and-burn cultivation and returns to a lower level as the cycles shorten.

The richness in species shows an increasing trend from the bottom to the top of the analyzed sequence, as the human influence becomes stronger. Also, during a

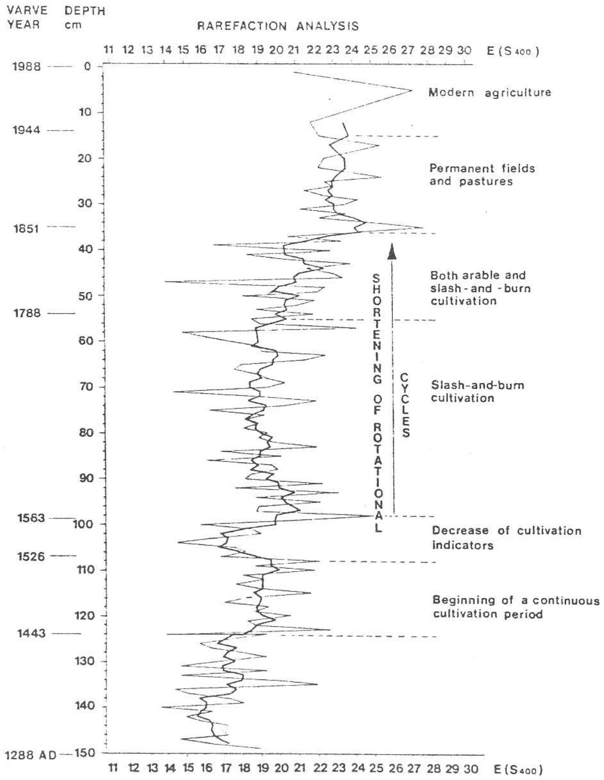

Fig 5. Stratigraphic plot of rarefaction estimates $E(S_{400})$ of species richness. Thin line = number of pollen species; thick line = floating mean of the rarefaction estimate.

phase of land-use change the richness in species increases abruptly and stabilizes to a new, higher level than previously. The variation of richness in species declines in the uppermost samples indicating a decrease in biotope diversity since the end of slash-and-burning (turn of the century) and forest pasturing; the lands have either reforested or been kept as arable fields, with little semicultural biotopes.

Discussion

Frequency of fires in relation to slash-and-burn cultivation has been studied with charcoal and pollen analyses from annually varved sediments in East Finland so far, e.g., by Vuorinen (1978), K. Tolonen (1983), Grönlund (1986, 1991), Simola et al. (1985, 1988) and in South Finland by M. Tolonen (1978) and Huttunen (1980). The annually laminated sediment of Lake Pitkälampi was well suited for this purpose, with its exceptionally high sedimentation rate providing a good time resolution and a reliable chronology. (see e.g. Berglund 1985).

In the catchment of Lake Pitkälampi slash-and-burn cultivation starts in the 1450's. The rotational pattern is clear in both pollen and charcoal analyses from 1600 AD onwards up to the 1800's when the rotation cycles became very short, which, together with grass mowing of the slash-and-burn fields, efficiently prevented forest regeneration (Heikinheimo 1915). Although the cultivation cycles are apparent in the rye, sorrel and wild grass pollen abundances, they do not represent one individual cultivation cycle in one single field, but are considered as an expression of slash-and-burning intensity. Simultaneously, in the 1800's, the areas of permanent fields increased (Heikinheimo 1915, Soininen 1974).

The slash-and-burn cycles are also distinctive in DCA and rarefaction analysis. These analyses reduced the multi-dimensionality of pollen data and provided graphical summaries being thus effective tools for palaeoecologists. A noteworthy result of the DCA ordination is that the slash-and-burn induced cyclic variation of vegetation (in group B) is established on the pollen assemblage level, not on indicator species level only. In the ordination the stratigraphic samples representing the same phase of slash-and-burn cycles are located close to each other and, also, different phases of one cycle ordinate farther apart.

Rarefaction analysis standardizes pollen counts, which otherwise are not usually equal between samples, enabling the estimation of richness in species. In Lake Pitkälampi the qualitative and quantitative changes of human impact are clearly seen as changes in the pollen diversity in spite of the fact that pollen identification to species level is seldom possible. The distinct rise in the number of pollen species is the result of a parallel practising of many land-use forms from the 1800's onwards, which 1) created new ecological niches 2) increased the area of ecotones 3) made the landscape open so that the pollen rain is more regional than local.

Although small permanent arable fields are known to have existed in Tohmajärvi already 1689 (Saarenseppä 1912), slash-and-burn cultivation remained the most important cultivation method in the surroundings of Lake Pitkälampi until early 19th century when the area of permanent fields along with meadows and pastures began to increase rapidly. Transition to permanent field cultivation was completed in early 20th century. According to Heikinheimo (1915) the total area of slash-and-burn cultivations in Tohmajärvi was only 19.3 hectares in 1910 compared to 50% of total crop yield obtained from slash-and-burn fields still in 1851.

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