# Adding a New Dimension to Pollenanalysis: Human Impact in Space and Time

Jutta Lechterbeck
Institut für Geologie der Universität zu Köln
Zülpicher Str. 49a, 50674 Köln, Germany
jutta.lechterbeck@uni-tuebingen.de

Abstract

The high resolution palynological record of the annually laminated sediments of Lake Steisslingen (SW-Germany) was subject to correspondence analysis (CA). The results of the CA showed that a single gradient dominated the pollen distribution. Further investigations allowed identifying this gradient as increasing human impact from the Neolithic to the Middle Age. The eigenvalues of each pollensample were plotted against time. The resulting curve proved to be a proxy for human impact. This proxy could be tested against the archaeological record of the region. A tool for presenting complex stratigraphical data in a single curve was thus found.
This tool was applied to two other pollen profiles of the region, which proved likewise to be dominated by human impact. The next step will be to display the data spatially for different time slices and thus show the differences in the intensity of human impact in a certain region at a given time. This project is planned as a contribution to LUCIFS.

## Introduction

Pollen analysis is a conventional and established method to reconstruct former vegetation. Pollen contain the male gametes, i.e. reproductive cells, of flowering plants. They are emitted in great numbers, transported and deposited in natural archives, such as lakes and mires. From those deposits they are recovered, determined and counted. The composition of the pollen assemblage is used for the reconstruction of the contemporary vegetation cover.

Naturally, the question after the pollen source area is one crucial to pollen analysis: How large is the area represented by a pollen assemblage?

The question was primarily addressed by determining how far pollen can be transported. It was generally agreed, that a given archive reflects the vegetation of the surrounding landscape depending on the openness of the area and the size of the archive (cf. Faegri and Iversen 1989).

More recent studies employing data recovered from pollen traps, however, showed that the role of long distance transport was generally overestimated (for example Damrath 1998).

If the modelling of vegetation of entire landscapes is concerned, the question "How far can pollen travel?" is not adequate. The appropriate question should be: "How large is the area which allows to reproduce the pollen record adequately?"

The same approach underlies simulation studies and much of the theoretical work already done by Odgaard and Rasmussen, who come to the conclusion that a diameter of 2 to 5 km accounts for over 90 % of variation in the pollen record (Odgaard and Rasmussen 2000). In this paper I will show how this radius can be confirmed with the help of archaeological and pollenanalytical data and correspondence analysis. With help of correspondence analysis a main dimension of explanation can be extracted from the pollen data and identified with a certain factor, for example human impact.

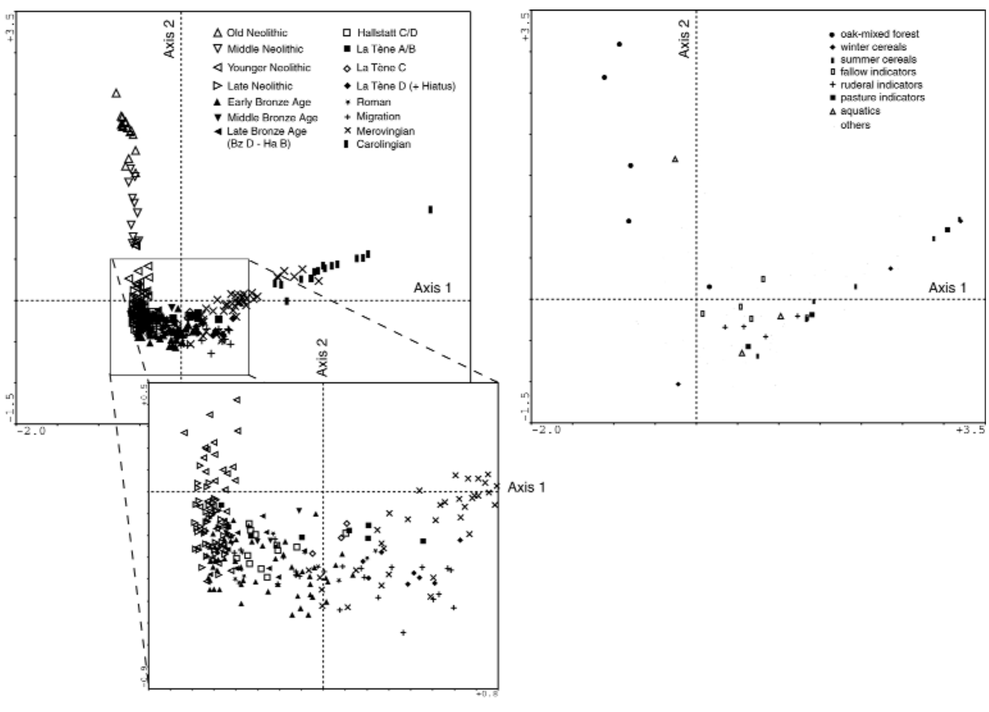
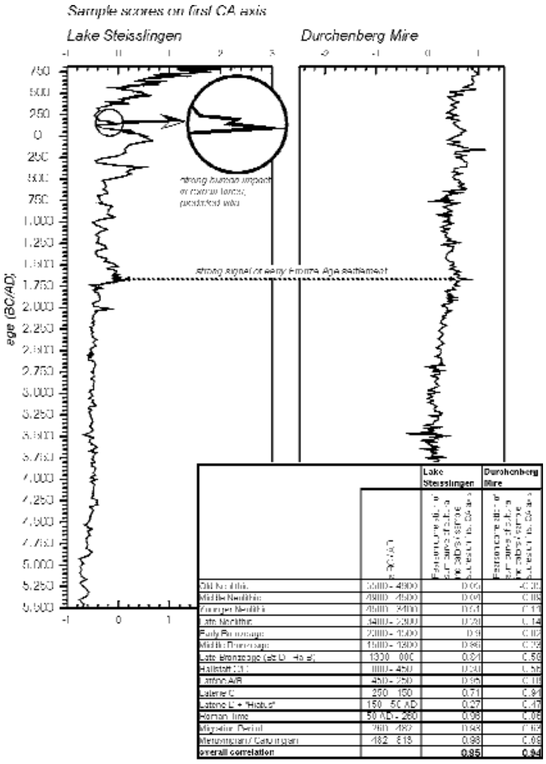



Figure 1 Lake Steisslingen. Correspondence analysis. Plot of sample and species scores in the plane of the first two eigenvectors

### Basics of Pollen Analysis

The structure of pollen data is that of a contingency table, where the rows are the samples and the columns contain the taxa; the cells contain counts.

Usually pollen data are displayed as a pollen diagram: The percentage values of every taxon in every sample are calculated and represented in stratigraphic order. The resulting curves reflect the changes in the pollen composition through time. Actually, the pollen profile shows changes in the fossil record which are induced by several factors. The most important factor is vegetational changes but others like transportation or selective destruction of pollen grains have to be considered likewise.




| | | Lake Steisslingen | Durchenberg Mire |
|---|---|---|---|
| | BC/AD | | |
| Old Neolithic | 5500 - 4900 | 0.05 | -0.35 |
| Middle Neolithic | 4900 - 4500 | 0.09 | 0.08 |
| Younger Neolithic | 4500 - 3400 | 0.61 | 0.11 |
| Late Neolithic | 3400 - 2200 | 0.28 | 0.14 |
| Early Bronze age | 2200 - 1500 | 0.9 | 0.02 |
| Middle Bronze age | 1500 - 1300 | 0.86 | 0.22 |
| Late Bronze age | 1300 - 800 | 0.84 | 0.50 |
| Hallstatt C/D | 800 - 450 | 0.30 | 0.56 |
| Latène A/B | 450 - 250 | 0.95 | 0.19 |
| Latène C | 250 - 150 | 0.71 | 0.94 |
| Latène D + "Hiatus" | 150 - 50 AD | 0.27 | 0.47 |
| Roman time | 50 AD - 260 | 0.98 | 0.06 |
| Migration Period | 260 - 482 | 0.98 | 0.62 |
| Merovingian / Carolingian | 482 - 813 | 0.98 | 0.09 |
| **overall correlation** | | **0.85** | **0.94** |

Figure 2 Lake Steisslingen and Durchenberg Mire. Sample scores plotted against time. Table of Pearson correlations between sample scores and sum of cultural indicators

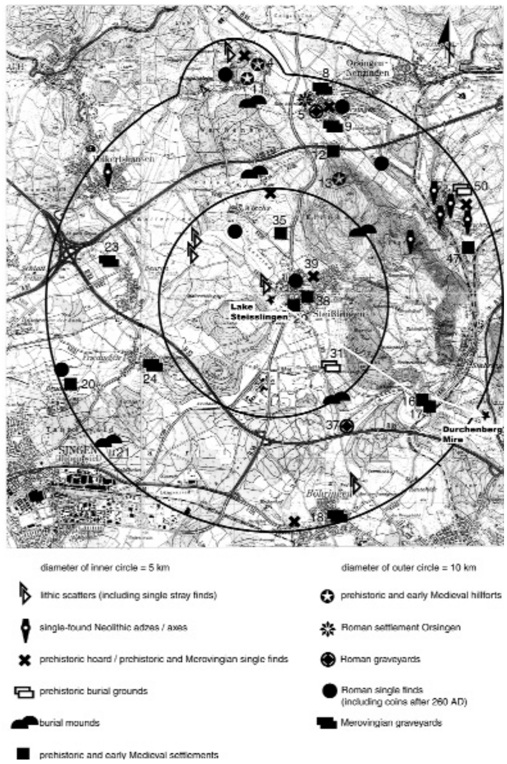



Figure 3 Archaeological map and location of Lake Steisslingen and Durchenberg Mire

Human impact in the pollen diagram can be determined in two ways: Positively by so called cultural indicators, which are pollen of cultivated plants, - such as cereals - , and of plants which are tolerant to human impact. And negatively by the disappearance of pollen from plants which do not tolerate human impact. The counts of cultural indicator pollen can be summarized in a single percentage curve. This curve already gives a kind of measure for the intensity of human impact through time.

### Case Study: Lake Steisslingen

Lake Steisslingen is a little hardwater lake in south western Germany near Lake Constance. It contains sediments from 16,000 years ago until today, most of them annually layered. This annual lamination allows the establishment of a very detailed chronology by counting the single layers, analogue to tree rings.

Lake Steisslingen was subject to an interdisciplinary project and one part of it was a high resolution pollen analysis. The Lake Steisslingen pollen profile consists of more than 600 samples. In each at least 500 pollen grains were counted. The data matrix and the resulting pollen diagram are quite large, so it was obvious to apply dimension reducing multivariate statistical methods. Based on the works of (Birks et al. 1988) and (Kalis and Zimmermann 1997) correspondence analysis was chosen.

Here, the results of a reduced dataset are presented covering the time span between probable first human impact in the Neolithic and the early medieval. The data matrix contains all samples and all taxa except single finds.

The plot of sample scores (Fig.1) in the plane of the first two eigenvectors forms a parabola, the higher axes show likewise a polynomial relationship. This means that a single natural gradient accounts for the pollendistribution. The parabola is ecologically meaningful evidence, proving a mathematical continuity of a clearly prevailing dimension (Wartenberg et al. 1987). In archaeological seriation, this dimension is usually equalled with time. In Steisslingen this is not the case: On first sight one could assume that the samples are roughly ordered according to their age. But a closer look reveals that they follow another gradient: one arm of the parabola is built of the relatively undisturbed forest plant communities of the Neolithic and the other arm is formed by the open landscape as seen in medieval times. The parabola represents an ecological continuum. The underlying natural gradient -the main dimension of explanation- is an ecological one.

The scores on the first CA-axis for the samples can be plotted against time, the resulting curve (Fig.2) shows the behaviour of the main dimension of explanation through time. In the case of Lake Steisslingen the curve of the eigenvaluesolution ("eigenvaluecurve") correlates from the early bronze age on strongly with the curve of the cultural indicators. The two exceptions are correlated with sedimentological events.

From the strong correlation of the eigenvaluecurve with the cultural indicators it is concluded that the main dimension of explanation in this dataset is in fact increasing human impact from the Neolithic to the middle ages. The eigenvaluecurve is a kind of proxy for human impact and it has the advantage that it contains more information than the sum curve of the cultural indicators.

To compare this curve with the actual archaeological situation, a map and an inventory of the archaeological finds in the surrounding of the lake (Kerig and Lechterbeck 2000) was made. The area chosen for the mapping was an arbitrary 5 km radius around the lake (Fig.3). According to historic and ethnographic parallels, such a distance of one hour's walk is thought to be the range of the frequently used landscape around a settlement (Higgs and Vita-Finzi 1972, Higgs 1975). The pollenprofile as well as the eigenvaluecurve were compared with the archaeological map, but as these results are already published or under publication (Kerig and Lechterbeck 2000, 2003), only one striking example should be given: A little peak in the roman times (Fig.2) indicates roman impact in strength not visible in the pollen diagram. Before mapping a roman villa was predicted on the basis of the eigenvaluecurve, but could at first not be found in the course of the mapping. After mapping a post-it-note was found with a hint that the documentation of roman finds from Steisslingen was filed by accident under another parish name. It turned out to be a little cemetery of the kind regularly situated in the vicinity of roman villae. One terra sigillata sherd could be dated to exactly the period the peak of the eigenvaluecurve covers. This filing accident serves as an experiment: The hypothesis "roman villa" stated by the evidence of the curve could be tested against the actual archaeological situation. Thus the curve can serve for predicting unknown archaeological evidence.

With the eigenvaluecurve a tool to characterise the main dimension of explanation of pollen diagrams is found. In Lake Steisslingen this is human impact. The idea, that this is the case in all long settled landscapes was tempting.

## Durchenbergried

The western Lake Constance region is such a long settled landscape and has furthermore several well-dated, high resolution pollen profiles. The next such profile comes from the Durchenberg Mire (Rösch 1990), about 5 km away from Lake Steisslingen, just outside the 5 km radius of the archaeological map (Fig.3). The Durchenberg Mire contains sediments from the Late Glacial until today. The Holocene deposits consist mainly of peats. The stratigraphy is dated by a series of radiocarbon dates. Analogue to Lake Steisslingen, a CA with the pollen data was carried out (Fig.2). Here, the eigenvaluecurve and the cultural indicators do not correlate much. Obviously, in the Durchenberg Mire human impact is not the main dimension of explanation or at least not in the same way, cultural indicators are. In both profiles however, the early bronze age settlement which lies in between the two localities is reflected clearly.

## Conclusions

The established and conventional idea, that pollenprofiles are representative for large areas can be rejected by the combination of applying the established and conventional methods of pollen analysis and archaeological mapping. Furthermore, multivariate methods could show that the main dimension of explanation changes already at short distances. This result is in agreement with the simulation studies of Odgaard and Rasmussen.

Pollen analysis is thus a more sensitive method than hitherto thought. More and more detailed information can be gained from pollenprofiles. They deliver reliable data for the reconstruction of landscapes, but this demands a dense network of pollenprofiles.

The eigenvaluecurve is a tool to present complex pollen data in a single curve. The next step is to display the data spatially for different time slices and map the differences in the main dimension of explanation in a certain region at a given time. This is planned as a contribution to the LUCIFS project (Land Use and Climate Interactions in Fluvial Systems).

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