Abstract no. 54456

Anne Birgitte Nielsen
Department of Quaternary Geology
GEUS (Geological Survey of Denmark and Greenland)
Copenhagen, Denmark
E-mail: abn@geus.dk

Relationships between landcover and pollen assemblages from small Danish lakes around AD 1800

Anne Birgitte Nielsen

GEUS

POLLANDCAL network

AGRAR 2000

1. Introduction

A better understanding of the quantitative relationships between pollen assemblages from lakes and the composition and structure of the vegetation in the surrounding landscape will allow a more detailed interpretation of late Holocene pollen diagrams, and thus hopefully lead to a better understanding of the history of the cultural landscape.

The aim of this study, which is part of a Ph.D. project at the University of Copenhagen (Nielsen, 2003) was to improve the quantitative interpretation of fossil pollen diagrams from small lakes by estimating the size of the pollen source area and by testing the POLLSCAPE model, which can potentially be used for quantitative pollen-vegetation calibration.

2. The historical analogues approach

Many studies of pollen/vegetation relationships have used modern calibration data sets, but in Denmark extensive plantation, drainage, fertilisation and use of pesticides have greatly altered the vegetation during the last two centuries (Fig.1), so good analogues for older landscapes, as reflected in fossil pollen diagrams, are not available.

However, historical maps that show areas of different land cover such as arable fields, forest, meadow and heath are available from around A
As the AD 1800 l
was mor
ana

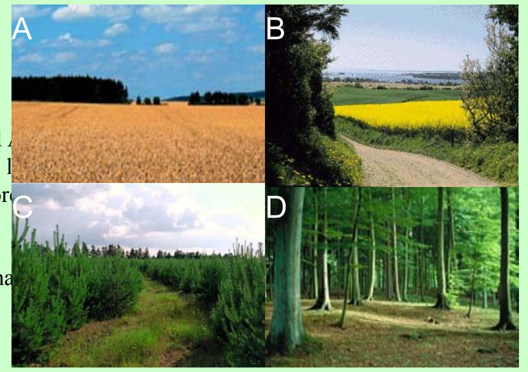

Figure 1. Danish landscapes today are very different from AD 1800 landscapes. A: Fields are drained, fertilised and treated with pesticides. B: New crops, such as Nape, have been introduced. C: Plantations of introduced conifers are common. D: Woodlands are managed as high forest, without grazing, usually monocultures.

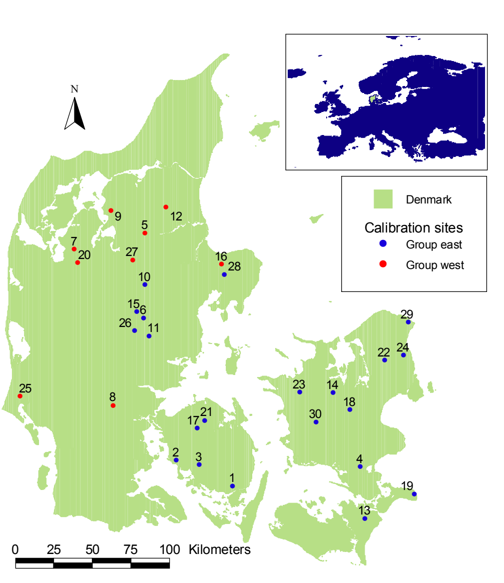

Figure 2. Map of Denmark showing the location of the calibration sites, divided into two groups by a TWINSPAN analysis.

3. Study design

From 30 small (3-30 ha) Danish lakes (Fig.2), sediment cores were collected and dated using ^{210}Pb, the AD 1800 level was estimated by extrapolation, and the pollen assemblage at this level counted.

Landcover on historical parish maps was digitised for a 2 km radius surrounding the lakes (Fig.3). The maps were georeferenced using a number of points which could be identified on modern maps, and neighbouring parishes were joined. The spatial accuracy of the maps compared to modern ones was good, as the mean error (RMSE) was ca. 20 m.

The land cover composition was calculated in 20 m wide concentric rings around each site, to a radius of 2 km (2.5 km for estimation of RSAP). From the land cover composition, the approximate plant species composition could be estimated, based on archival data on crop composition in the arable fields (Rømer, pers. comm.), and the dominant tree species in a number of woodlands (Fritzbøger, pers. comm.), along with vegetation analyses from modern analogues of historical land use in the neighbouring southern Sweden (Broström, 2002). Pollen types and corresponding plant species were grouped into eleven, ten and four groups (taxa), to make the conversion simpler.

The plant composition was distance weighted according to the Prentice/Sugita model of pollen dispersal and deposition (Prentice, 1985; Sugita, 1993). The distance weighting function for each pollen type depends on its fall speed, average wind speed, atmospheric conditions and basin size. The ten and eleven groups were defined so that the pollen types in each group had similar fall speed. The Extended R-value (ERV) model (Prentice and Parsons, 1983; Sugita, 1994) is used to analyse the relationship between pollen proportions and distance weighted plant abundance.

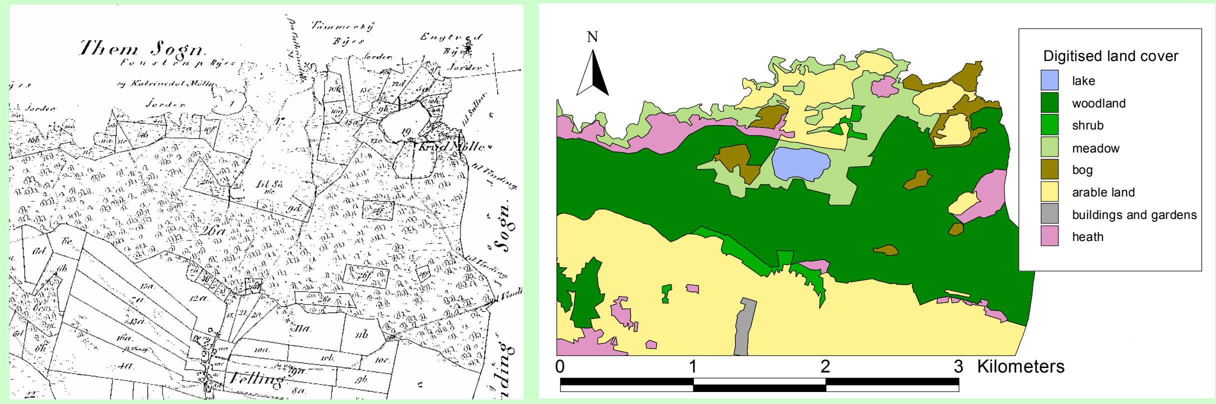

Figure 3. Left: The parish map of the area around Velling Igelsø, Central Jutland (site 26, Figure 2). Right: The digitised map of the area. The map shows different land cover signatures. Once the land cover has been digitised and georeferenced, the area of different land covers can be calculated and distance weighted using GIS.

4. Estimating the Relevant Source Area of Pollen (RSAP)

RSAP is defined by Sugita (1994) as the area beyond which the goodness-of-fit between pollen assemblages and distance weighted plant abundance does not improve. When using the ERV model, the likelihood function score decreases as goodness-of-fit improves, and the radius of RSAP is estimated as the distance where the likelihood function score reaches an asymptote.

The size of the Relevant Source Area of Pollen (RSAP) for the lakes is estimated by applying the ERV model to the AD 1800 pollen assemblages from the calibration sites and distance weighted plant abundance inferred from the historical maps, on a subset of 25 sites for which land cover data was available in a 2.5 km radius.

Empirical results:

Wind speed: Although this is one of the factors affecting pollen dispersal, changes in average wind speed within a realistic range has little or no effect on the size of the RSAP (Fig.4). From 0.8 to 10 m/s the RSAP radius was ca. 1700 m. Lower fall speed of pollen and unstable atmospheric conditions both have a similar effect on pollen dispersal as increased windspeed, and thus probably do not affect RSAP.

Difference between regions: The sites were divided into two groups, based on a numerical classification (TWINSPAN, Hill, 1979) of the landcover composition (Figs.2 and 5). One group consists of lakes on sandy soils in western Jutland, where Calluna dominated heathland was very common, whereas arable land was more dominant around the eastern group of sites. Both regions were dominated by open areas. There is a large difference in average patch size between the two regions. The analysis shows a difference between the RSAP for the two groups (Fig. 6). A series of simulations was designed to analyse the possible causes of this difference.

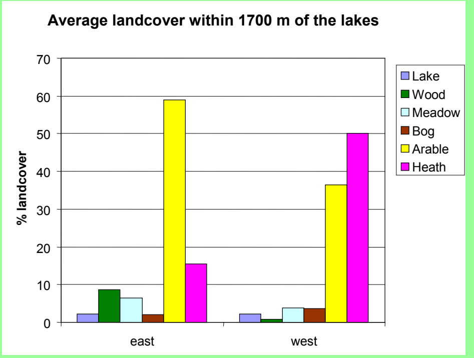

Figure 5. Average landcover composition around the sites in the two TWINSPAN groups. The eastern group is dominated by arable land, the western group by heathland. Woodland is relatively scarce in both regions. The average patch size of the vegetation is 79 ha in the western region and 33 ha in the east.

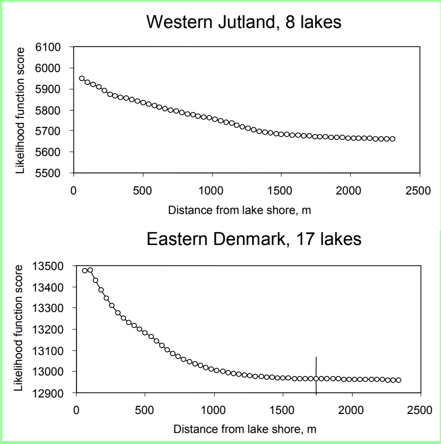

Figure 6. Likelihood function scores for the lakes in each of the two regions, estimated using ERV model 1, 4 taxa wind speed 2.75 m/s and the Sugita distance weighting function.

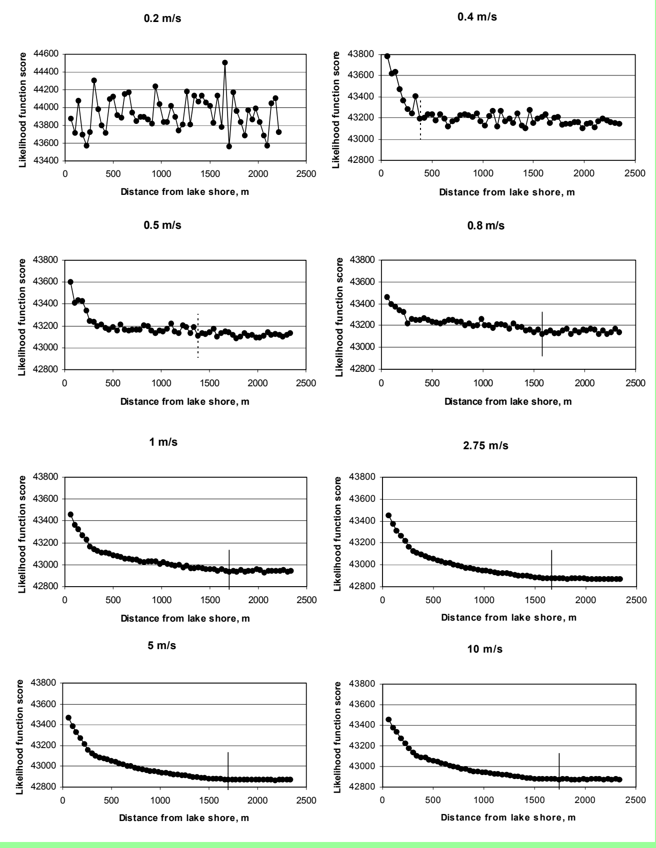

Figure 4. RSAP for 25 Danish lakes (3-30 ha), estimated at different wind speeds using ERV model 1, 11 taxa, the Sugita model of pollen dispersal, fall speed and pollen productivity estimates following Sugita et al, 1999 and Broström et al., 2002.

For wind speeds between 0.8 m/s and 10 m/s the RSAP remained practically constant, with a radius of ca. 1700 m from the lake shore. At very low wind speeds RSAP can not be estimated.

The average wind speed in Denmark today is 4.8 m/s for the months March to August, when most plants flower, measured at western stations(Cappelen and Jørgensen, 1999). The wind speeds at the lake surface are somewhat lower.

Simulations using POLLSCAPE

The POLLSCAPE model simulates the pollen deposition in a given basin from the spatial distribution of plants around the site by applying the Prentice/Sugita model of pollen dispersal and estimates of pollen productivity for the plants involved. The plant distribution can come from a digital map of a real landscape, or from a hypothetical landscape.

In this case, five landscapes characterised by different land cover compositions and patch sizes were designed, using the program MOSAIC (Middleton and Bunting, in prep.), which randomly places patches of a specified area, until the specified land cover composition is achieved. 25 lakes were placed in each 50 by 50 km landscape. As the number of pollen and plant taxa included in the analysis influenced the estimate of RSAP, the simulations were run with both 4 and 11 taxa. Pollen productivity estimates from modern analogue studies in neighbouring South Sweden were used (Sugita et al., 1999; Broström et al., 2002), and wind speed was assumed to be 2.75 m/s.

The design of the simulations, and the results are shown in Table 1.

The sizes of RSAP estimated by simulations A, B and D fit quite well with the empirical results (Figs. 5 and 6), indicating that the POLLSCAPE model provides realistic RSAP estimates.

The simulation results suggest, that patch size is the main factor determining the difference in RSAP between eastern and western Denmark.

This has implications for the interpretation of fossil pollen diagrams.
If vegetation patch size has changed through time, so has RSAP.
Simulations can be used to estimate the probable range of past RSAP.

			Estimated RSAP radius (meter)	
Empirical results	Average patch size		11 pollen taxa	4 pollen taxa
All sites	43 ha		1700	> 2300
Western sites	79 ha		-	> 2300
Eastern sites	33 ha		-	1800
Simulations (in order of increasing patch size)	Patch size equals	Land cover and species composition equals		
A	Eastern sites	Eastern sites	1500	2000
B	All sites	All sites	1800	3100
C	Eastern sites x 2	Eastern sites	1900	2600
D	Western sites	Western sites	2200	3200
E	Western sites x 4	Western sites	2500	5700

Table 1. Empirical and simulation estimates of the radius of RSAP (all estimates are +/- ca 100 m).

5: Modelling pollen sedimentation using POLLSCAPE

As an attempt to validate the POLLSCAPE model empirically, the plant distribution around the calibration sites calculated from the historical maps was used as input to the model. Pollen productivity estimates South Sweden were used (Sugita et al., 1999; Broström et al., in press), and the model predicted pollen proportions could be compared to the values observed in the AD 1800 lake sediments. The pollen types were split into four and ten groups, and vegetation beyond the relevant source area of pollen was assumed to be homogenous for all sites.

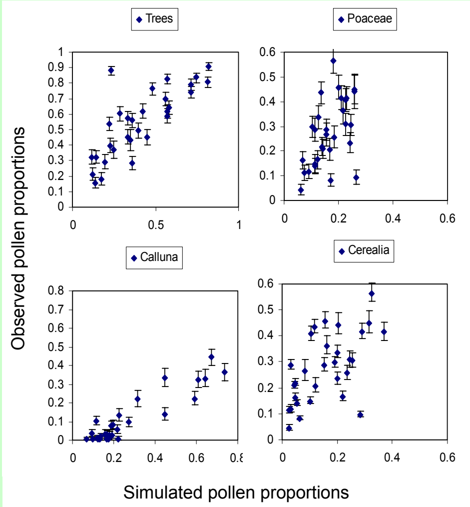

Figure 7. Comparison of model predicted and observed AD 1800 pollen proportions of four groups: Trees, Poaceae (grasses), Calluna (heather) and Cerealia (cereal crops) in the calibration lakes. 95% confidence intervals are shown for observed values. In the simulations wind speed was set at 2.75 m/s. For all four groups there is a significant correlation between observed and simulated values (p<0.01).

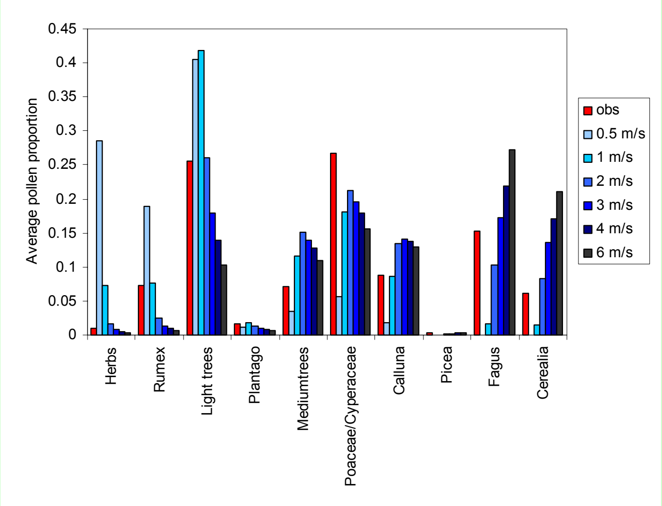

Figure 8. Average pollen proportion observed in AD 1800 sediment samples from 30 lakes, and average pollen proportions simulated at different windspeeds. The taxa are ordered after increasing fall speed, so that the heaviest pollen types are to the right.

The pollen types in each of the 10 groups (Fig.8) have similar fall speeds, which determine the shape of their pollen dispersal functions. The model predicts, that as wind speed increases, the proportions of heavy pollen types (high fall speed) increase, and light pollen types (low fall speed) decrease (Fig.8).

The fit between observed and simulated pollen proportions (measured using RMSE) has an optimum at 2.75 m/s. There are no instrumental data on average windspeed from AD 1800. This value is lower than modern measurements at meteorological stations (Cappelen and Jørgensen, 1999), but probably realistic for average wind speeds at lake surfaces.

6. Conclusions

The historical analogues approach has provided useful insights to the relationships between vegetation and pollen sedimentation:

- Validations of the POLLSCAPE model:
  - Estimates of RSAP from simulations are similar to empirical results using the same patch size and species composition (Table 1)
  - Simulated pollen proportions based on the historical vegetation data are correlated with observed values, and of similar magnitude (Figs. 7 and 8)
- The Relevant Source Area of Pollen:
  - RSAP for the Danish lakes has a radius of ca. 1700 m, plus or minus a few hundred meters, depending on the region (Figs. 4 and 5)
  - The difference in RSAP between western and eastern Denmark is probably determined by a difference in patch size (Table 1)
  - RSAP does not depend on windspeed (Fig. 4)
- Wind speed affects the composition of the pollen assemblages, even though it does not affect RSAP (Fig. 8)

References:

Broström, A. (2002). Estimating source area of pollen and pollen productivity in the cultural landscapes of southern Sweden -developing a palynological tool for quantifying past plant cover. Lundqua Thesis 46, Lund University, Lund

Broström, A., Sugita, S., Gaillard, M.-J. (in press). Pollen productivity estimates for the reconstruction of past vegetation cover in the cultural landscape of southern Sweden. The Holocene.

Cappelen, J., Jørgensen, B. (1999). Observed Wind Speed and Direction in Denmark -with Climatological Standard Normals, 1961-90. Report 99-13, Danish Meteorological Institute, Copenhagen.

Hill, M.O. (1979). TWINSPAN -a FORTRAN program for arranging data in an ordered two-way table by classification of the individuals and attributes. Cornell University, Ithaca, New York, USA.

Nielsen, A.B. (2003). Pollen based quantitative estimation of land cover -Relationships between pollen sedimentation in lakes and land cover as seen on historical maps in Denmark AD 1800. Ph.D. thesis. GEUS Rapport 2003/57. Geological Survey of Denmark and Greenland, Copenhagen, Denmark.

Prentice, I.C., Parsons, R.W. (1983). Maximum Likelihood Linear Calibration of Pollen Spectra in Terms of Forest Composition. Biometrics, 39, 1051-1057

Prentice, I.C. (1985). Pollen Representation, Source Area, and Basin Size: Toward a Unified Theory of Pollen Analysis. Quaternary Research, 23, 76-86

Sugita, S. (1993). A Model of Pollen Source Area for an Entire Lake Surface. Quaternary Research, 39, 239-244

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., Broström, A. (1999). Landscape openness and pollen records: A simulation approach. The Holocene, 9, 409-421