the response of species to winter cold, growing season warmth and soil moisture. The climate database used to run STASH comprised paleotemperature anomalies reconstructed from Fennoscandian tree-rings (Briffa *et al.*, 1992) and paleoprecipitation anomalies obtained from the semi-quantitative historical reconstruction by Lamb (1967) covering the last 1000 years. The application of northern data to southern Scandinavia is supported by the observation that major northern temperature anomalies are duplicated in shorter datasets from further south (Kalela-Brundin, 1999).

The comparisons of observed and modelled range limits for *Picea* in southern Scandinavia strongly suggested that the species distribution has tracked climate change during the last 1000 years, with only a small lag owing to the limits imposed by seed dispersal (Woods and Davis, 1989)(Fig. 2). The rate of change of the European *Picea* distributional limits has been rather slow during the last 1000 years compared to earlier in the Holocene, when very rapid rates of population expansion were recorded (Huntley and Birks, 1983). During the last 1000 years, the modelled, climatically imposed, potential range limits have been relatively stable, with some oscillations back and forth during the MWA and LIA. The realised range limit of *Picea* has approached the potential range limit and overshot during the last few centuries as a result of planting and establishment during climatically favourable years. Future predictions suggest that the range will retreat northwards, and outlying populations will be out of equilibrium with climate and under threat.

We conclude that the shift from deciduous to coniferous forest that we observed in southern Scandinavia was driven by anthropogenic land-use changes acting in conjunction with climate-driven shifts in distributional limits of a forest dominant – *Picea abies*. The climatic component is largely concealed by the anthropogenic, which comprises changes in grazing management and agricultural practices. Future research carried out as part of HITE will investigate the reversibility of this change and its possible feeedbacks to the global climate system.

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Long Term Land-Cover Changes on Regional to Global Scales Inferred From Fossil Pollen – How to Meet the Challenges of Climate Research?

Two major foci of global-change research are climate modelling and the use of paleoclimate reconstructions to test model outputs. In this respect, the effects of climate change on land-cover and the feed-back effects of land-cover change on climate belong to the numerous processes that we need to understand more fully over short and long time-scales.

A wealth of pollen data is presently available at more or less high-resolution over short to long time-scales, which represent an enormous potential for reconstructions of past land-cover at different temporal and spatial scales. However, setting up the approach and establishing the tools for translating pollen data into quantitative land-cover units are not an easy task.

Earlier Attempts to Quantify Landscape Openness in Europe

Within the frame of the European Science Foundation "Climate and Man" programme (1985-1995, leader: B. Frenzel), a major focus was the assessment of land-cover changes in terms of deforestation/afforestation in Europe during the last 6000 calendar years and their possible role in climate change (e.g. albedo effects). Archeological and palynological data were brought together for a series of time windows in order to get an estimate of the extent of deforestation or afforestation (e.g. Frenzel, 1992), especially during the Roman Iron Age (c. AD 200) and the time of migrating German tribes (c. AD 600). In this reconstruction, maps of non-arboreal pollen (NAP) percentages for more than 200 selected sites were drawn for the two time slices. These maps were then interpreted assuming that changes in NAP percentages could be compared directly between sites and interpreted in terms of differences in landscape openness between sites and through time.

The results provided a clearer qualitative picture of the history of landscape openness in Europe. Periods of extensive deforestation are recorded in many areas already during the Bronze Age (from c. 3500–3000 calendar years), when the landscape may have been as open or even more open than today (e.g. in Britain, Ireland, Denmark and southern Sweden). However, the first period of major deforestation in Europe as a whole occurs during the Late Iron Age (from c. AD 500–0). In most areas, landscape openness increased further through the Middle Ages. Modern Times are characterised by contrasting developments in different parts of Europe. Some areas were simply abandoned, or the management changed from an agricultural to a sylvicultural one, both resulting in afforestation; in other areas deforestation continued.

Case Study in Southern Sweden

In southern Sweden, since 1989, a series of research projects have been devoted to the study of pollen/land-use relationships, with the purpose of improving pollen-analysis as a basis for reconstructing past cultural landscapes. A database of over 125 pollen assemblages (from moss polsters) and related vegetation and soil properties from non-fertilized hay meadows, pasturelands and cultivated fields, all managed in a traditional way, was used for qualitative and quantitative reconstruction of past land-use and soils (e.g. Gaillard *et al.*, 1992, 1994). Moreover, a first calibration of pollen data on landscape openness was attempted using pollen assemblages from lake surface sediments and vegetation mapping around 13 lakes in the same traditional cultural landscapes (Gaillard *et al.*, 1998). Predictive models were developed for a series of landscape units such as totally open land or dense forest, based on partial least squares (PLS) regression of the total modern pollen assemblages. PLS calibrations of these landscape units were then tested on a fossil data set. The results showed that the reconstructed percentage covers of total open-land were 10–20% higher than the NAP percentages, whereas the percentage covers of dense forest were 15–40% lower than the AP percentages. Comparison of the PLS reconstructions with historical maps demonstrated that the PLS reconstructions were reliable. This pilot study was performed in the southernmost province of Sweden, Scania.

The data set was extended to include sites north of Scania, up to the area of the large lakes Vänern and Vättern (Broström *et al.*, 1998). This study demonstrated that the relationship between landscape openness and NAP percentages from lake surface sediments is not straightforward. It was hypothesized that the complex relationship between landscape openness and NAP percentages could be explained by differences in regional vegetation composition and specific spatial patterns of vegetation patchiness between areas, resulting in different regional pollen productions and source areas of pollen. This assumption was further tested with a simulation model of pollen dispersal and deposition (e.g. Sugita, 1994) using landscapes simplified from the modern open agricultural and semi-open forested regions in southern Sweden (Sugita *et al.*, 1999). The simulated relationships between NAP percentages and percentage cover of open land within 1000 m around the lakes agreed with the empirical relationships (see figure). These simulations demonstrated that simple NAP percentages are insufficient to quantify the percentage cover of open land in open to semi-open landscapes such as those characteristic of South Sweden.

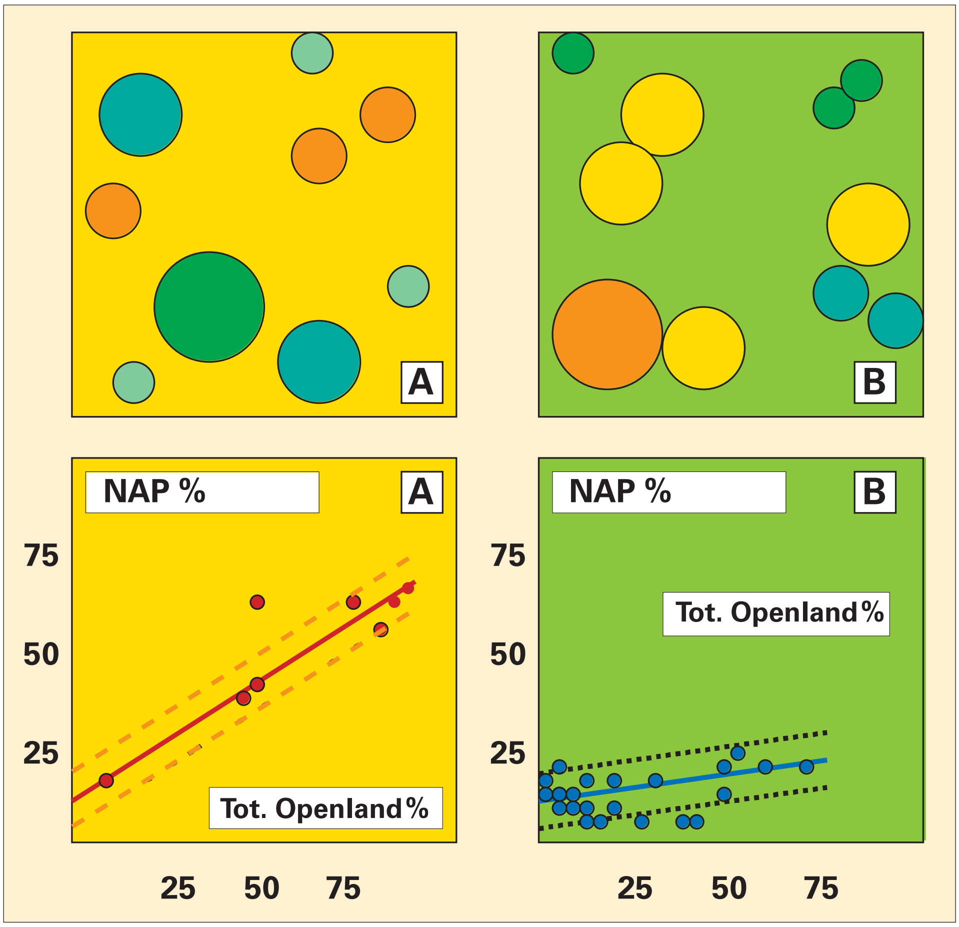

Figure 1: Hypothetical landscapes mimicking (A) the open, agricultural landscape in southern Skåne (southern Sweden), with a matrix of open land (yellow) and scattered patches of different woodland types (green and orange), and (B) the semi-open, forested landscape in northern Skåne and Småland with a matrix of spruce (green) and scattered patches of open land (yellow) and different woodland types (green and orange). The hypothetical landscapes are simplified from real landscapes, and species composition in each patch is simplified from existing vegetation inventories. In the scatter plots, the points and the plain lines represent the empirical relationships between NAP percentage versus percentage cover of open land within 1000 m of the lakes in southern Skåne (A, red) (Gaillard et al. 1998) and in northern Skåne and Småland (B, blue) (Gaillard et al. 1998, Broström et al. 1998). The dashed lines represent the area including the simulated relationships between NAP percentage versus percentage cover of open land within 1000 m of 3.14-ha lakes for landscape designs with 90 % openness (red, A) and 30% openness (blue, B) (the individual simulated values are not shown). Modified and simplified from Sugita et al. (1999).

Work in Progress

We are presently following a new research strategy to develop a more robust calibration tool than the ones attempted earlier for quantitative reconstruction of past land cover. We are using a two step procedure, i.e. the "Landscape Reconstruction Algorithm LAR" of Sugita (in press): (1) estimating the changes in background pollen through time and (2) reconstructing vegetation composition and landscape patterns using the background estimates. This strategy also implies that reliable estimates of pollen productivity for key taxa (trees, shrubs and herbs) are available. Such estimates have been published for all North-European tree species by Andersen (1970). These were, however, based on data collected in forest vegetation. Our approach requires pollen productivity estimates of trees growing in open to semi-open landscapes. Moreover, pollen productivity estimates are needed for herbs. This work is in progress and should result in quantitative reconstructions of past land-cover units such as various types of forests and open lands in southern Sweden for the past c. 2000–3000 years, i.e. the time for which the modern analogues used in our studies may be valid.

In parallel to these studies, the simulation program of Sugita (Sugita, 1994; Sugita *et al.*, 1999) is being modified in order to be used in a GIS environment (Eklöf *et al.* in progress). Thanks to this technical improvement, it will be possible to simulate pollen assemblages in real modern landscapes, and therefore to test and improve the simulation approach. Moreover, it will open invaluable possibilities of comparing simulated pollen assemblages from past landscape scenarios against empirical pollen data, which should be the most effective tool for landscape reconstructions from fossil pollen data to date.

Prospects

The research strategy described above has as its ultimate goal, estimation of past openness at the global scale, which is a necessity if the effect of past vegetation changes on climate is to be modelled and understood. There are today several ongoing international research programmes tackling these questions. BIOME 300 was initiated this year by PAGES/LUCC/GAIM in order to generate global land-cover maps for a large number of time windows covering the past 300 years with the spatial resolution relevant to the needs of climate models. One of BIOME 300's priorities is to improve the accuracy of the maps with the help of all possible expertise within land-cover research, e.g. geographers, historians and paleoecologists (mainly palynologists). In order to achieve this enormous and challenging task, we believe that there are two possible complementary approaches if pollen data are to be used: (1) extrapolation of reconstructions from local to regional scale (areas of one to 500 kilometers diameter) using a robust calibration of pollen assemblages against landscape units, model simulations of past landscape scenarios, and model-data intercomparison ; (2) "biomization" based on the approach used in the reconstruction of past natural vegetation for the purpose of climate modelling (i.e. Prentice *et al.*1996), but introducing new "human-induced" biomes. We plan to test and combine both approaches. The former is currently tested in southern Sweden, and the latter approach is still in its very initial phase and proceeds independantly (Sugita *et al.* in progress).

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WORKSHOP REPORTS

BIOME 300 – A Joint Initiative of LUCC and PAGES

An organizational workshop for BIOME 300 was held in Bern, Switzerland from the 5th through the 7th of March, 2000, under the auspices of PAGES, LUCC, and the Bern Geobotanical Institute, and funded largely by the Netherlands NWO. This meeting brought together over 40 researchers from nearly 20 countries in Europe, Asia, and the Americas to discuss which methods and data are most appropriate to the detailed reconstruction of past land-cover changes. More extended accounts of the meeting and subsequent progress may be found in current LUCC, IHDP and IGBP Newsletters.

Under the leadership of Frank Oldfield (PAGES), Emilio Moran (LUCC Focus Group 1), Rik Leemans (GAIM/LUCC), Andre Lotter (Switzerland), and Marie-Jose Gaillard (Sweden), this group had two primary objectives. The first is to devise a plan for the production of coordinated databases and revised land cover maps at 50 year intervals since AD 1700. The planned development path for this Fast Track BIOME 300 product will be approximately one year. Klein Goldewijk (Netherlands) and Navin Ramankutty (USA) will harmonize the results of their ongoing efforts to compile global data bases, consider the many constructive suggestions of the Bern workshop and prepare a new prototype database. This will be discussed at a meeting linked to a Symposium entitled "Past land cover, human activities and climate variability: future implications" to be held at the Fall meeting of the American Geophysical Union in San Francisco, December 15–19. Shortcomings will be reviewed and further improvements suggested. The months thereafter will be used to develop the final fast-track database, which will be released during the IGBP Open Science Meeting in July 2001 in Amsterdam.

The second objective is to begin the task of building a community for a longer-term effort to reconstruct and understand human impacts on the landscape over the past several millennia. This effort included discussions of the methods that should be included, the data sources available in the various regions, and the perceived gaps in data coverage and interpretive methods.

A steering group for this longer term research agenda, growing out of the BIOME 300 meeting, was established at the end of the workshop, that includes: Frank Oldfield (PAGES), Emilio Moran (LUCC), Carol Crumley (USA), Marie-Jose Gaillard (Sweden), Rik Leemans (the Netherlands), Charles Redman (USA), Shinya Sugita (Japan), and Bob Thompson (USA). Most of the members of this group will also hold a meeting at the Fall AGU (see above).

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