JOURNAL OF NORTHERN STUDIES Vol. 8 • No. 2 • 2014, pp. 89–102

SHEILA HICKS

Who Is Responsible for Today's Northern Landscapes, Climate or Human Beings?

ABSTRACT The present-day landscapes of northern Fennoscandia are the end result of a process of evolution. Mountains and valleys have scarcely altered during the last 10,000 years, whereas coastal areas have slowly but constantly changed. The nature of the vegetation that covers the landscape and is driven primarily by climate, has changed at a faster rate, but fastest of all have been the changes resulting from human activities. Steps towards the present-day situation are briefly reviewed on different temporal and spatial scales and on each the impacts of climate and people are weighed one against the other. Environmental reconstructions are made on the basis of pollen analysis and historical/archaeological records, while a quantified basis for their interpretation is provided by present day reference situations. Examples from palaeoecological research projects provide illustrations. On the coarsest spatial and temporal scales the bigger driving force is climate, but if the focus is on a small area and the time considered the last 100 years, then it is people who have played the bigger role in producing what we see. Two important questions for the north are: which impact will have the bigger effect in the future, the climate or human beings, and will future changes be reversible or not?

KEYWORDS temporal scale, spatial scale, summer temperature, human impact, landscape development, pollen accumulations rates

Introduction

When we think of landscapes we need to consider the elements that determine what we see, namely the bedrock, the overlaying glacial deposits, the positions of rivers and lakes, the type of soil that has developed and the vegetation cover. The latter is very much determined by climate, is the result of a relatively slow evolution and is more or less consistent over a wide region. We also see, however, the effect of human interference in terms of settlement, agriculture and industry (Fig. 1). People can cause big landscape changes and cause them rapidly but usually only over a small area. These changes are often, but not always, reversible. In fact, how we understand what we see is all a question of scale, both in space and in time. Within a circle with a radius of 1 kilometre around the present village of Svensbyn in Northern Sweden, the landscape is almost entirely man-made but within a circle of 1,000 kilometres the landscape is primarily forested and developed in response to climate (Fig. 2a). Already on a scale of 10 kilometres the man-made proportion of the landscape has shrunk to some 60 per cent and at 100 kilometres the situation approaches that of 1,000 kilometres. On the temporal scale we can easily remember changes over the past 10 years and, within the family, over the past 100 years. We can also follow changes through documentary records over the past 600–700 years but when we consider the time over which our present landscape has evolved—some 10,000 years—then we can only piece together snapshots on the basis of scattered archaeological finds (Fig. 2b). This means that the landscape will look different at different points in time and will change through time at different speeds.

Reconstructing the Last 10,000 Years by Means of Pollen Analysis

Pollen is incorporated and preserved in accumulating peat deposits and lake sediments (Fig. 3). The source of this pollen varies from being very local to up to hundreds of kilometres distant, so the pollen assemblage that is preserved reflects a mixture of both local and regional vegetation. By coring peat and lake sediments, dating selected horizons in their development and identifying the pollen content along a time series it is possible to reconstruct the vegetation that has produced the pollen and see how that vege-

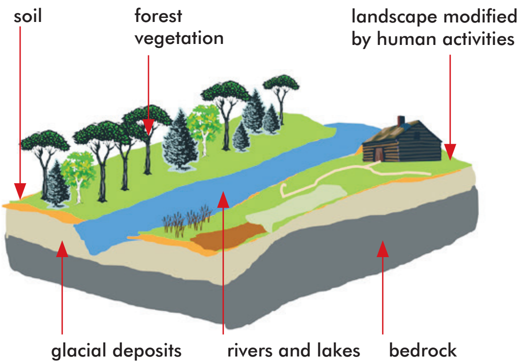


Fig. 1. Elements of the landscape. The man-made changes to the forest aspect of the landscape can happen quickly but are usually also reversible.

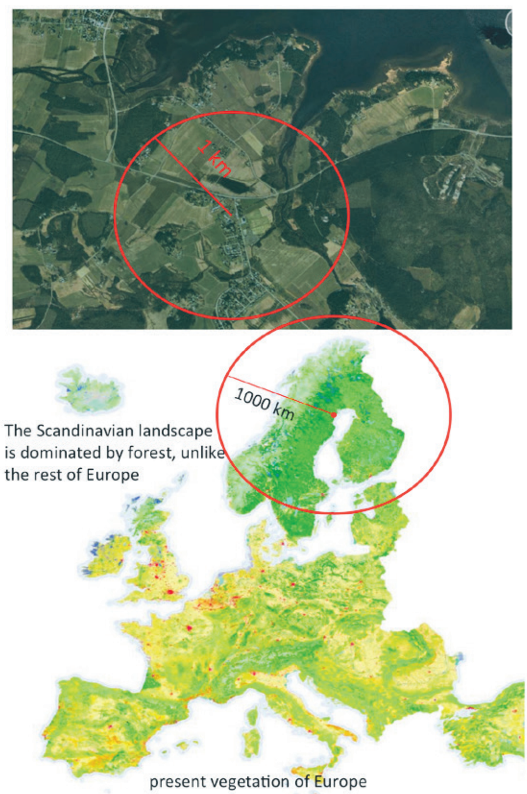


Fig. 2a. Satellite view of the landscape around the village of Svensbyn (Google Earth). Within a circle of radius 1 km the landscape is predominately man-made while with a 1,000 km view (Corine vegetation map of Europe) scarcely any man-made environment is visible.

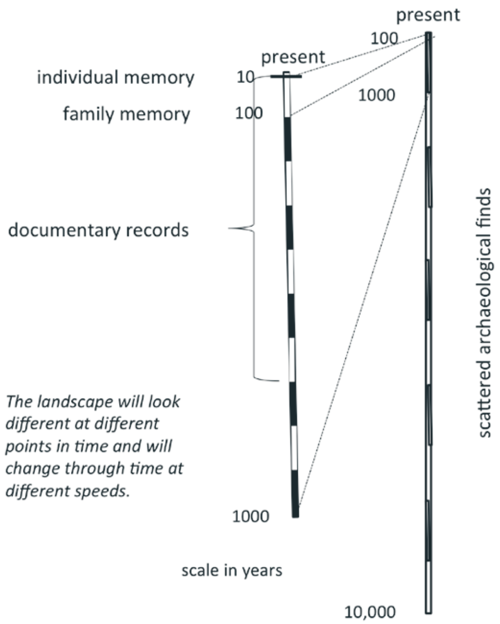


Fig. 2b. Clarity of the record of past landscapes at different temporal scales: 10, 100, 1,000 and 10,000 years.

tation has changed through time. We can then deduce the climate and the degree and nature of any human interference.

In order to make a quantified reconstruction and distinguish between the local and regional elements, it is useful to have a modern reference to compare with. Such a reference has been produced by using a network of "pollen traps" that collect the pollen falling on the land surface year by year (Fig. 4; Hicks 2001). This annual reference data from 1982–2009 illustrates two features. We take here the situation of the tree, pine (*Pinus sylvestris*), which is the most common tree in the north of Fennoscandia. We see that the amount of pine pollen varies dramatically from year to year but that the coincidence of high and low years is virtually the same over the whole of Northern Finland, and that there is a gradual trend towards greater quantities of pollen (Fig. 5a). We interpret this as being a response to July temperature and an earlier start to the growing season respectively. If, however, we take the average value for pine pollen deposition over the 28-year monitoring period, then we see that the quantity reflects quite clearly the abundance and closeness of pine trees relative to the monitoring point (Fig. 5b). Depending upon the temporal scale of the record the absolute amount of pine pollen tells us of summer temperature (plus partly length of growing season) or tree density, or a combination of the two.

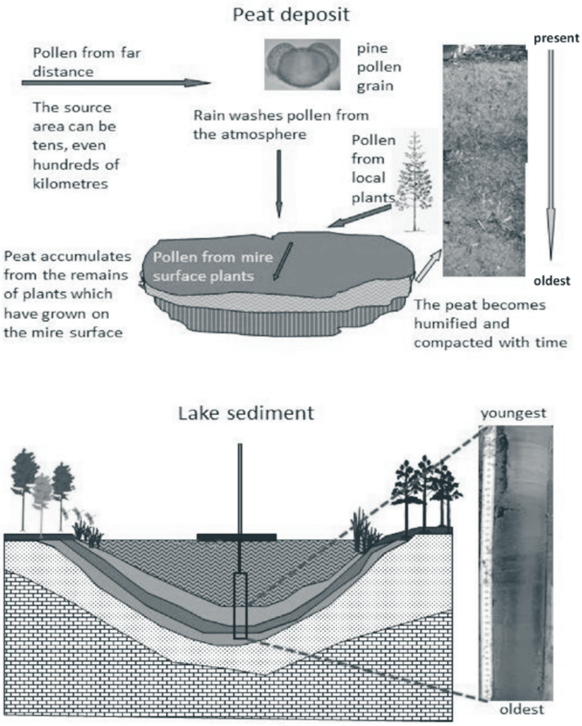


Fig. 3. The way in which pollen is incorporated in peat deposits and lake sediments.

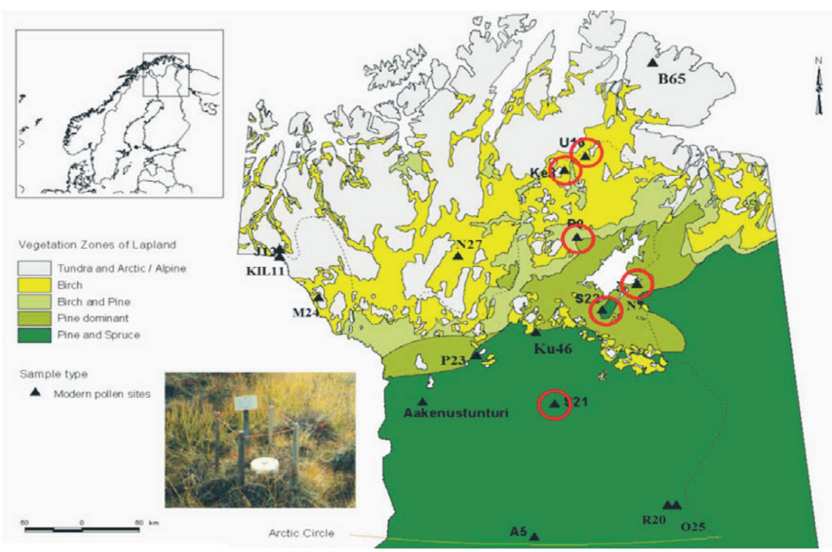


Fig. 4. Network of "pollen traps" used for collecting modern reference data. The insert shows a "pollen trap" in the field.

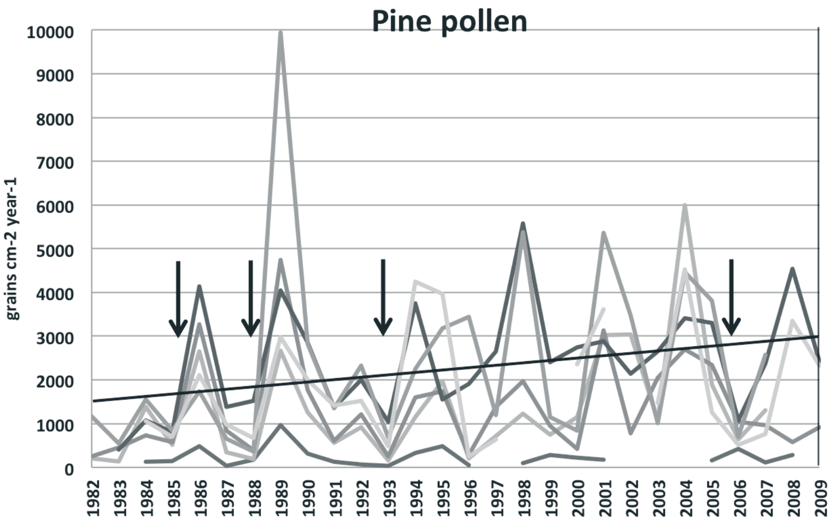


Fig. 5a. Pine pollen deposition at 6 points on a north-south transect in northernmost Finland over the period 1982–2009. The solid black line shows the trend in pollen quantity. The arrows indicate years where pine produced virtually no pollen at all sites—mostly those years when July temperature of the year before pollen emission (T July-1) did not rise above 12°C.

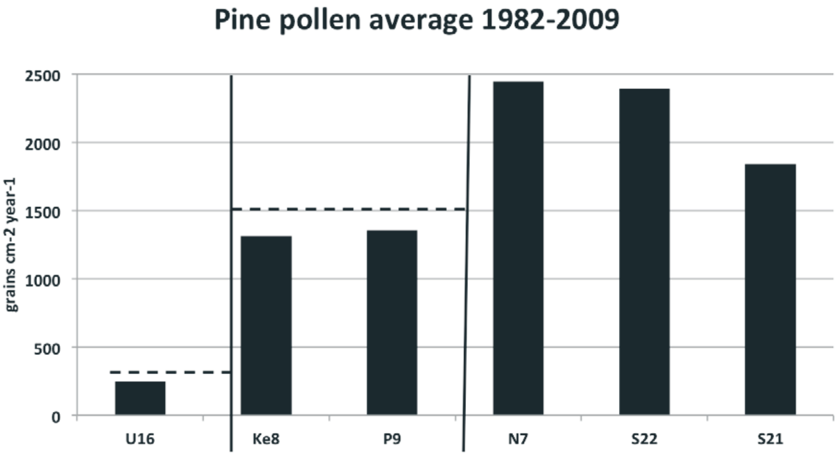


Fig. 5b. Average *Pinus* pollen deposition for the same period with respect to the presence and abundance of pine forest. The most northern site, where pines are absent, is at the left hand side and the southernmost sites, where pine is abundant, at the right hand side. The dotted horizontal bars indicate the threshold values of the number of pine pollen grains being deposited on a square metre of land surface in 1 year that indicate pine being present (250) and pine being dominant (1,500), respectively.

In addition to the record of forests the pollen can reveal changes in other types of vegetation, particularly in association with human presence. The people who were first present in the north were nomads who existed by hunting and gathering; activities which cause almost no change to the natural vegetation and are, therefore, usually invisible in the pollen record. Other ways of life, however, do leave a record; slash and burn cultivation is seen by the presence of charcoal and a decrease in trees, keeping livestock with the use of meadows and pastures is seen through an increase in grasses and the presence of dung fungi, cultivation in fields leads to the presence of crop weeds and, of course, the crops themselves, while permanent settlement encourages plants that can survive in trampled yards and areas where the nitrogen content of the soil is increased. Mostly the vegetation changes caused by people are seen through the increase or decrease of plants that are, in any case, part of the natural flora, so the interpretation requires auxiliary evidence but when the record contains non-naturally occurring plants (e.g. cereals), the evidence is much clearer.

The Situation in the Northernmost Areas of Fennoscandia

On a temporal scale of thousands of years and a spatial scale of hundreds of kilometres

At the last glacial maximum, some 20,000 years ago, the area we are considering was under the Weichselian ice sheet (Svendsen *et al*. 2004). By 11,600 years ago this ice sheet had shrunk but still covered most of Fenno- scandia with, in the north, only a narrow strip of the Norwegian coast and the Kola Peninsula being ice-free, but by 10,000 years ago there was only a small fragment of the ice sheet left in Northern Sweden. The land area, however, was less extensive than today because the sea level was much higher as a result of the depression of the land due to the weight of the ice sheet (slow to rebound) combined with the presence of a huge amount of water from the melted ice (Björck 1995). It was a rapid rise in temperature that caused the melting of the ice sheet, culminating in a temperature maximum around 6,000 years ago, since when, in the long term, the temperature has been decreasing but, on shorter temporal scales, fluctuations have been considerable. Pollen diagrams from lake deposits that reveal how the vegetation of the north has changed over the last 10,000 years show a succession in response to this increasing temperature. At Svartkälstjärn in Northern Sweden, for example (Barnekow *et al*. 2008), the open treeless tundra-like vegetation that first invaded the mineral land surface that emerged from beneath the melting ice was gradually invaded by birch and pine, with alder establishing in the wetter areas. With the establishment of forest, soil developed and deepened. The pine-birch forest persisted at Svartkälstjärn until around 3,000 years ago, when it was invaded by spruce, which was spreading westwards through Fennoscandia (Giesecke & Bennett 2004).

People have been present in the region from the earliest time as indicated by a Mesolithic site from Aareavaara dated to 9,600 years ago and located at the very edge of the land emerging from the ice sheet (Möller *et al.* 2012). The site is interpreted as a short-stay hunter-gatherer camp on an island in the Ancylus lake, an earlier stage of the Baltic (Björck 1995). The pollen evidence shows that the landscape at this time was in the treeless open tundra-like/coastal meadow stage.

On a temporal scale of hundreds of years and a spatial scale of tens of kilometres

It is only during the last 1,000 years or so that more permanent settlement centres have developed in connection with the evolution of a pastoral and agricultural economy. Naturally the landscape changed dramatically in the immediate vicinity of the settlements, but many of the early sites were later abandoned and returned to forest. Långrumskogen is just such an example (Segerström *et al.*1994; Renberg *et al.* 2009). The pollen record clearly shows forest clearance followed by rye cultivation, haymaking and cattle grazing, the actual cultivation phase lasting for some 200 years between AD 1500 and 1700. The present forest, which recovered after the cattle-grazing phase, has only existed for 300 years and yet it is considered to be "one of the most valuable swamp forest refugia in the country"! (Renberg *et al.* 2009: 2797). The long term driving force of climate was able to reverse the landscape changes induced by people.

On an annual temporal resolution and a spatial scale of a few kilometres

When considering the landscape over small areas and for short periods of time, the balance between the impact of climate and of humans can be quite different. We can consider two examples from the Millennium project (EU-FP6 Project "MILLENNIUM—European climate of the last millennium," contract no. 017008 [GOCE]). These are both mire sites (peat profiles); one, Palomaa, in Finland, is located at the northernmost limit of continuous pine forest and the other, Kiruna, in Sweden, located at the northernmost limit of continuous spruce forest. Both sites have been subjected to pollen analysis at a nearly annual resolution to produce a continuous record for the last 1,000 years. In both cases the pollen record is available as pollen accumulation rates (PARs), which show how the actual quantity of pollen of all the plants in the vegetation have changed through time, as opposed to the more classical approach of expressing each pollen type as a percentage of the total assemblage, which shows not "absolute" but relative changes. From the modern reference material it is known that PARs best reflect both the presence and abundance of trees and summer temperature, which is why this means of illustration is used. The Finnish site is in a nearly natural landscape (only one road crosses the area), while the Swedish site, being close to the open-cast mining area, is in a completely man-made landscape.

Palomaa

The Palomaa pollen record shows that pine forest has dominated the landscape for the past 1,000 years (Fig. 6), so we deduce that climate is the driving force throughout. The only clear evidence of people is the building of the road, which took place in AD 1959. The temporal resolution of the record is such that for the period AD 1960 to 2005 it is easy to see the similarity between the *Pinus* PAR curve and the July temperature record from Sodankylä, 250 kilometres to the south of the site. There is some evidence that between AD 1500 and 1600 the surface of the mire was much drier than at present and that animals, presumably reindeer (the spores of dung fungi become abundant), frequently crossed the mire (Finsinger *et al*. 2013). Although some plant species that are known to expand when people are present are recorded throughout, there is no clear peak in these that could be interpreted as indicating more intensive human presence. The *Pinus* PAR curve, which dominates the record, has been interpreted as reflecting changes in pine tree volume over the last 1,000 years (Mazier *et al*. 2012), changes which are initiated by changes in summer temperature but which, because of the time that it takes for seedlings to germinate and trees to obtain maturity (and begin producing pollen), are seen in the diagram with a time-lag when compared with the summer temperature curve reconstructed from dendroecological evidence (McCarroll *et al*. 2013).

It is possible to distinguish 5 climate-driven landscape phases:

AD 1080–1170, June-July-August (JJA) temperature was as high as today and the pine forest flourished;

AD 1170–1340, JJA temperature was lower than in the previous period but the tree volume was at its maximum, better tree growth and movement of the forest northwards being the result of the earlier very favourable temperature conditions;

AD 1340–1630, JJA temperatures increase but the tree volume is clearly lower suggesting that following the previous colder period the pine forest had begun to retreat southwards;

AD 1630–1810, both JJA temperature and tree volume are at the lowest for the whole 1,000-year record. This is the time of the "Little Ice Age."

The pine trees had not necessarily disappeared (we have evidence that many existed), but July temperature was so low that they were unable to produce pollen (see the 12°C July temperature situation referred to above);

AD 1810–1950, both JJA temperature and pine tree volume are increasing in response to the temperature rise following the "Little Ice Age."

Kiruna

The section of the Kiruna pollen diagram from AD 1880 to 2005 reflects the development of the mine and of the city. This is seen not only from the pollen record of plant species which increase in abundance in connection with settlement and disturbed ground, but also from the record of other microparticles, namely charcoal fragments greater than 40μ and spheroidal

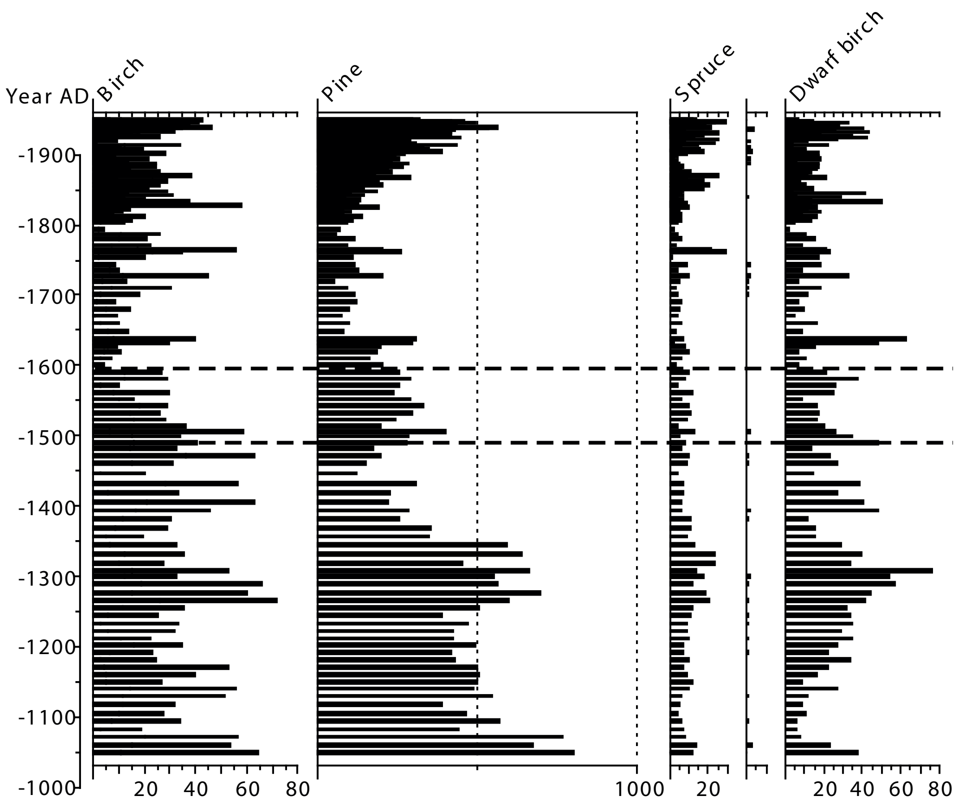
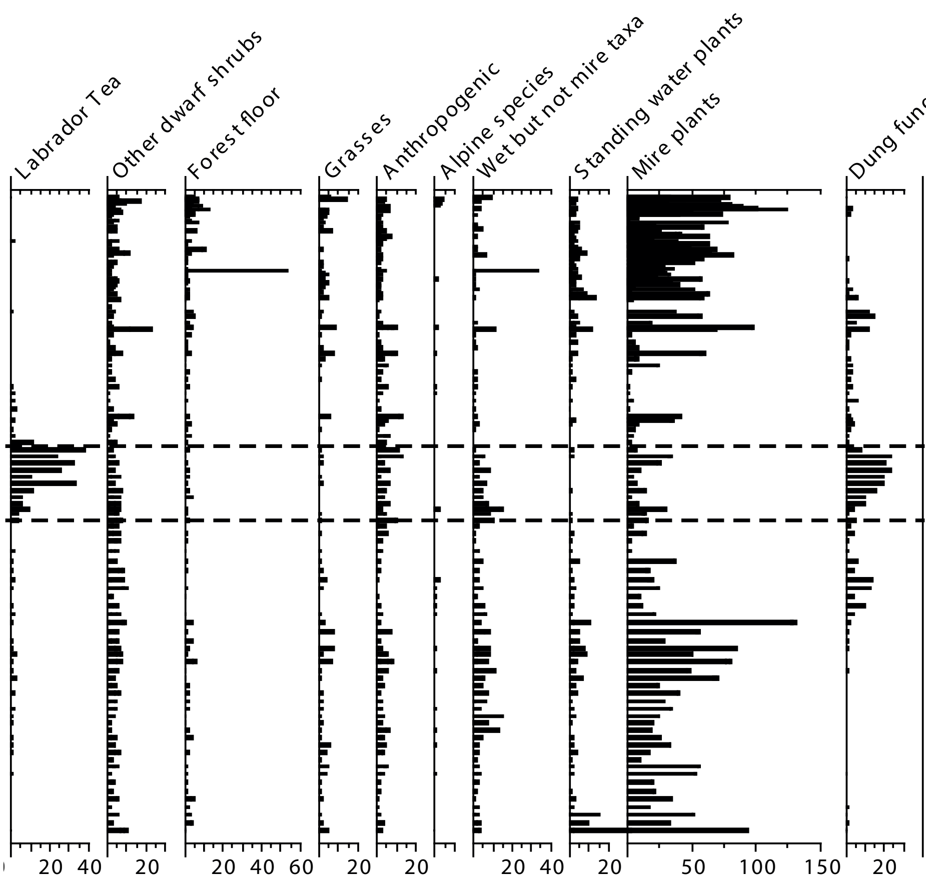


Fig. 6. A pollen accumulation diagram from Palomaa covering the last 1,000 years and showing the changes in the quantity of pine pollen which has been interpreted as being caused by both changes in tree volume and in July temperature.

carbonaceous particles (SCPs). These latter are particles that are emitted when fossil fuels are burnt at high temperatures. The PARs of the tree taxa are low in the early part of the twentieth century when there is a great need for timber in the region and the city is being founded, but increase from AD 1960 onwards in exactly the same way as they do at Palomaa. Pollen from the "human impact" taxa increases from AD 1950 onwards and large charcoal particles begin to increase from AD 1965 around the time of maximum population for the city. The curve for SCPs begins in the early 1960s, reaches a maximum in AD 1975 and declines to zero values by 1985 when the city incinerator is built in conjunction with the need to control emissions and the clean air movement (WHO 1987). Overlying the record of the development of the human landscape the tree taxa still reflect changes in summer tem-



perature such that the *Picea*, *Pinus* and *Betula* pollen records of the past 135 years can be calibrated with the instrumental summer temperature record (Barnekow *et al*. 2007), again showing a similar situation to that at Palomaa.

Conclusions

In the far north of Fennoscandia the strongest driving force in moulding the landscape is climate, which determines the vegetation cover. We see this in terms of different vegetation zones either along a south-north gradient or an altitudinal gradient (coast to mountain top), which causes decreasing summer temperature. On top of this, people have dramatically changed the natural forest landscape but mostly over relatively small spatial areas and for relatively short periods of time. Even extensive and very visible changes, such as those caused by fire or clear felling, are relatively short lived when the whole 10,000-year history of the area is considered. To give an answer to the question posed in the title it is, therefore, necessary to define the temporal and spatial scale.

Considerations for the Future

Both climate and people will continue to shape the landscape of the north and the effects on the forest vegetation and the present man-made landscape patches will vary as they have done in the past. Those interactions that can be expected are summarized in schematic form in Fig. 7. Predicted changes in the climate of northern Fennoscandia towards warmer winters and longer growing seasons could potentially affect the position of the tree line and the composition and density of the forests and might also influence the quantity of snow at ski resorts and the risk of landslides. At the same time economic changes caused by people, changes in social trends or population density, might lead to a change in the land area used for cattle farming and hay production, an increase in settlement and increased pollution from industrial activity and mining etcetera. There is, however, an element which is very difficult to predict, and that is whether future changes may be such that they cause the crossing of a non-reversible threshold?

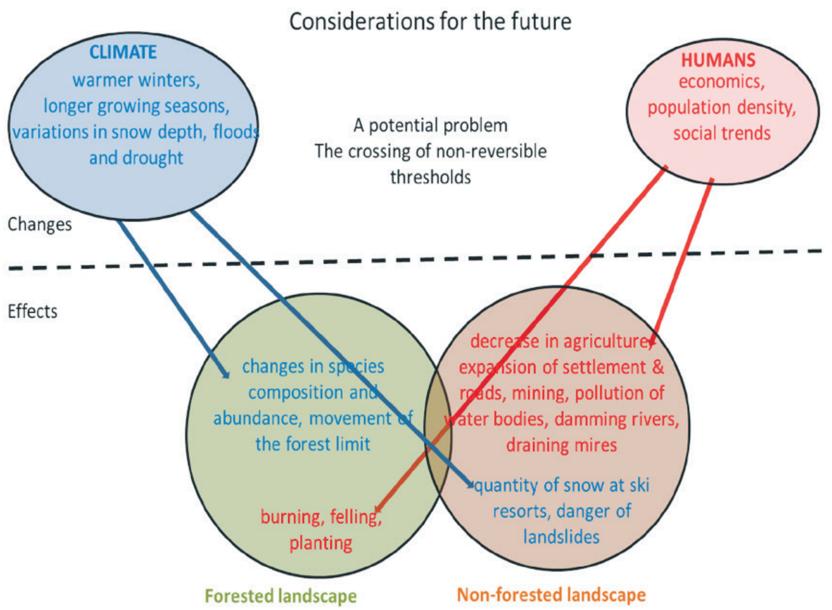


Fig. 7. Schematic diagram of aspects in the forest and man-induced landscapes that could change in the future due to changes in climate and/or the effect of people.

ACKNOWLEDGEMENTS

I would like to thank my friends and colleagues Lena Barnekow, Ulf Segerström and Phil Buckland for the help and support they provided during the preparation of the presentation on which this article is based.

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Sheila Hicks is Research Professor (emerita) at the University of Oulu. She uses the technique of pollen analysis to reconstruct landscapes of the past. Her 25-year long data set of modern pollen deposition enables the interpretation of quantitative changes in pollen at a near annual resolution.

hicks.sheilap@gmail.com