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Human impact and climate changes—synchronous events and a causal link?

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Abstract

Interaction between cultural development and the natural environment is generally accepted. Holocene climate change is described as one of the main environmental factors behind a step-wise development of the cultural landscape in Northwest Europe. Seven periods of human impact changes—5900, 5500, 4500, 3800, 3000–2800, 1500 and 1100 cal. BP—are defined and compared with reconstructed climatic scenarios, based on insolation, glacier activity, lake and sea levels, bog growth, tree line, and tree growth. There is a positive correlation between human impact/land-use and climate change, although precise correlations are difficult because of weaknesses in the chronology. Future studies of annually laminated (varved) lake sediments and wiggle-matched radiocarbon sequences are emphasized, as well as a combination of palaeoecology and archaeology. It is hypothesized that agrarian society and the landscape developed step-wise, dependent on the interaction between the technological/social complex and the ecological capacity of a region, highly influenced by climate.

1. Introduction

Expansion and decline of human cultures are caused by a complex set of factors. The interaction between people and nature is obvious (cf. Messerli et al., 2000). As a result of this interaction environmental archaeology is now an established university subject all over the world. Climate has been acknowledged as one of the main factors behind cultural development (Lamb, 1981, 1982; cf. Jäger, 1999), although the absolute extent is debatable (Barker, 1985; Mannion, 1991; Bell and Walker, 1992; Roberts, 1998). Among archaeologists it is regarded as determinism, which often has a poor reputation. However, it is of considerable interest to explore the pattern of human expansion and its possible relation to climate change. On a global scale, this was done by Wendland and Bryson (1974), who statistically compared radiocarbon dated Holocene environmental changes with cultural changes and found an approximate synchroneity, with a delay of 50–100 years for the cultural changes. However, the dating accuracy was not so good at that time. For Northwest Europe, a broad-scale, long-term deforestation/regeneration pattern has been recognized on the basis of numerous pollen diagrams (Berglund, 1969, 1985, 1986, 1991; Berglund et al., 1996; cf. Aalen, 1983; Pilcher et al., 1971). In some recent projects such a pattern has been compared with regional archaeological information, which demonstrates agreement between palaeoecological and archaeological data (e.g. Berglund, 1991; Molloy and O'Connell, 1991, 1995; Andersen, 1992–93; Rösch, 1992; Behre and Kučan, 1994). The multicausal, society and environment, background for the expansion of the cultural landscape was emphasized in the South Swedish "Ystad Project" (Berglund, 1991).

In this overview, seven time slices have been selected as important periods during the development of the cultural landscape, since 6000 years cal. BP, particularly in marginal settlement areas: (1) 5900, (2) 5500, (3) 4500, (4) 3800, (5) 3000–2800, (6) 1500, and (7) 1100 cal. BP. This selection is based on a screening of pollen diagrams from Northwest Europe (cf. Berglund et al., 1996). These time slices represent dynamic periods in the landscape development, in most cases characterized by deforestation and expanding agricultural land-use. However, periods 2 and 6 represent times with forest regeneration and reduced human impact. The question raised is, did any climate changes occur during these periods? A compilation of palaeoclimatic records for the Late Holocene in Fig. 1 shows that there is a concordance between the climate dynamics and the major human impact events. However, one must bear in mind

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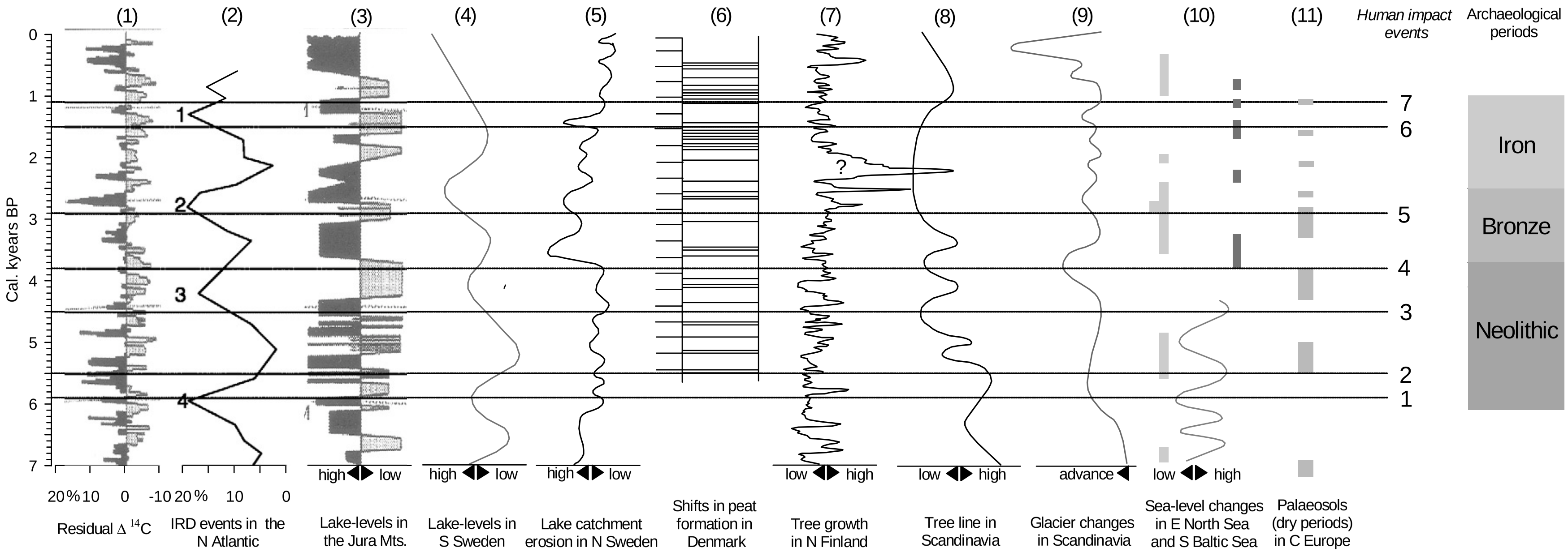

Fig. 1. Comparison of eleven palaeoclimatic records covering the last 7000 years with the human impact events discussed in this paper: (1) solar variability (Stuiver and Braziunas, 1993), (2) ice rafted debris (IRD) in N Atlantic with numbered events (Bond et al., 1997; Alley et al., 1999), (3) lake levels in the Jura Mts, E France (Magny, 1999), (4) lake levels in S Sweden (Digerfeldt, 1988), (5) lake catchment erosion in N Sweden (Snowball et al., 1999), (6) peat growth/humification changes in Danish bogs (Aaby, 1976); horizontal lines indicate dry/moist change, occurring with 260 years intervals, (7) Scots pine tree-ring record in N Finland (Eronen et al., 1999, Eronen et al., in press; cf. Briffa, 1999, 2000), (8) tree-line in Scandinavia (mainly from Karlén and Kuylenstierna, 1996; cf. Barnekow, 1999; Kullman, 2000), (9) glacier advances (Nesje et al., 2000), (10) sea-level changes, assumed to be temperature dependent, in S Baltic Sea (sea-level curve based on Berglund, 1971; Christensen, 1995), in SE North Sea (low sea-levels as filled bars based on Streif, 1989, and high sea levels as open bars based on Jelgersma et al., 1979), (11) Palaeosols correlated with dry periods in Central Europe (Jäger, 1999).

that these climatic records are heterogenous, comprising long-term climatic trends as well as high-frequency climatic changes, such as those based on the annual records of laminated lake sediments (Fig. 1:5) or tree rings (Fig. 1:7).

2. Human impact and climate change events

2.1. 5900 *cal. BP, Early Neolithic*

This is a well-dated period because of the regional and synchronous elm decline in Northwest Europe (Nilsson, 1964). In many areas the introduction of agriculture in forest areas, followed by an expansion named the ''landnam period'' (Iversen, 1941), resulted in multicausal deforestation (Birks, 1986, and others). Climatically, this was a very dramatic period, with a short-term wet/cool event with low solar intensity around 6000 cal. BP followed by ca. 300 years of dry/cold conditions with high solar intensity. During these centuries, glacier activity increased, as also reflected in increased ice-rafting (IRD) in North Atlantic sediments during Bond's event 4 (Bond et al., 1997). The chronological precision for these climatic events is rather weak. It is generally accepted that climate had an important role behind the first agricultural expansion in Northwest Europe (Birks, 1986; Karlén and Larsson, in press) and possibly also globally (Sandweiss et al., 1999).

2.2. 5500 *cal. BP, Early/Middle Neolithic*

This is a rather well-dated level, often named the regeneration phase following the landnam phase, with the contraction of agricultural areas locally and regionally, e.g. in Scandinavia (Gräslund, 1980; Berglund, 1986) and Ireland (Molloy and O'Connell, 1995). Climatically, a change to more wet/cool conditions is demonstrated by raised lake levels, increased bog growth, and lowered tree line.

2.3. 4500 *cal. BP, end of Middle Neolithic*

This event was marked by expanding agriculture, in central settlement areas as well as in marginal areas of North Scandinavia. Climatically, it was a period with rather wet/cool conditions with raised lake levels in southern Sweden and Central Europe, expanding bogs on Ireland, and glaciers in the Scandinavian mountains. Increased glacier activity is also reflected in the North Atlantic sediments by Bond's event 3 (Bond et al., 1997). It is also important to note that dendroclimatic data from North Scandinavia reflects a climatic trend change from stable to more variable around 5000–4500 BP (Eronen et al., 1999).

2.4. 3800 *cal. BP, beginning of Bronze age*

Expanding agricultural settlement, particularly pastures in Scotland and Scandinavia, resulted in increased deforestation, especially along the western Scandinavian coast, which led to a large-scaled heath expansion (Kaland, 1986; Odgaard, 1994; Prösch-Danielsen and Simonsen, 2000). Climatically this period was one of dramatic change from more continental to oceanic, which lead to raised lake levels (particularly in Central Europe), expanding bogs, lowered tree limit and increased glacier activity. The frequency of lake catchment erosion events increased distinctly from this time onwards. Peat humification data in northern Scotland indicate a main change from dry to wet conditions 3900–3500 cal. BP (Anderson et al., 1998).

2.5. 3000–2800 *cal. BP, Late Bronze age*

Expanding agriculture occurred in central settlement areas as well as in marginal land areas, particularly involving expanding pastures all over Northwest Europe. This expansion led to one of the main prehistoric deforestation periods. Climatically this period was complex, with cool/wet conditions just before 3000 cal. BP, followed by a warm/dry phase ca. 3000 BP, and then a change to cool/wet conditions again around 2800 BP. There is a general trend of raised lake levels and increased glacier activity around 3000 cal. BP. The last phase around 2800 BP corresponds to Bond's event 2 in the North Atlantic (Bond et al., 1997). It is also concordant with one of the most pronounced insolation drops during the Holocene, which has been much debated recently (van Geel et al., 1996, 1998). However, the chronological precision in the correlations between the climate changes and the settlement/land-use development is still rather weak. The main increase of the agrarian land-use has been dated to 3100–2900 cal. BP, but a ^{14}C reservoir effect may be involved in some studies, causing ages ca. 200 years too old (Kilian et al., 1995). This error means that the agrarian expansion possibly occurred after 2800 cal. BP. However, the most detailed studied sequence, with high-precision chronology, is from Lake Gosciaz in central Poland where pollen analysis of the annually laminated sediments shows a human impact maximum (mainly pasturing) 3400–2700 cal. BP, with brief minima around 3100 and 2800 cal. BP (Ralska-Jasiewiczowa et al., 1998).

2.6. 1500 *cal. BP, Migration period of the Late Iron age*

This period saw the retreat of agriculture, including pasturing as well as cultivation of crops, leading to reforestation in large areas of central Europe and Scandinavia (Andersen and Berglund, 1994). This period corresponds to the time following the Roman

Empire collapse around AD 480 and the Justinian plague ca. AD 540 (Lamb, 1982; Ambrosiani, 1984). Climatically this period was one of rapid cooling indicated from tree-ring data (Eronen et al., 1999) as well as sea surface temperatures based on diatom stratigraphy in Norwegian Sea (Jansen and Koç, 2000), which can be correlated with Bond's event 1 in the North Atlantic sediments (Bond et al., 1997). It is also a period of rising lake levels, increased bog growth and a peak in lake catchment erosion.

2.7. 1100 *cal. BP, Viking period of the Late Iron age*

Expanding settlement and agriculture occurred, with clearing of new areas for colonization, even involving remote areas such as Iceland and Greenland. This boom period covers several centuries from AD 700 to 1100. Climatically, it was a favourable period for agriculture in marginal areas of Northwest Europe, leading into the so-called Medieval Warm Epoch (Lamb, 1982). The climate was warm and dry, with high treelines, glacier retreat, and reduced lake catchment erosion. This favourable period lasted until around AD 1200, when there was a gradual change to cool/moist climate, the beginning of the Little Ice Age *s. lat.*, with severe consequences for the agrarian society. This change is well documented in geological archives as well as in historical sources (Lamb, 1977; Grove, 1988).

3. Discussion

This compilation of human impact events in Northwest Europe indicates that they are concordant with periods of climate changes. However, the chronology is too weak to enable a more precise correlation as a basis for a discussion of synchroneity, interactions, and time lags. In future research, we should pursue studies of annually laminated lake sediments (cf. Ralska-Jasiewiczowa et al., 1998; Zolitschka, 1998; Lotter, 1999; Snowball et al., 1999) or peat stratigraphy dated by means of wiggle-matched radiocarbon dates (van Geel et al., 1996). It is also probable that short-term, rapid changes impact more on survival than long-term trends. We have to use methods that can detect such changes. Climatic signals, as well as land-use signals, are probably easier to disclose in marginal areas, such as upland areas. Finally, interdisciplinary research on selected key study areas that combines palaeoecology and archaeology is a fruitful strategy aiming at a more profound knowledge on the interaction between environment and society (Berglund, 2000).

The relations between agrarian land-use and climate change are rather complex. "Improved" climate, i.e. warm summers with long growing season and moderate precipitation, will favour the cultivation of crops, particularly in marginal upland areas. A contrary climatic situation will disfavour cultivation and possibly change land-use towards extensive pasturing, which is reflected as deforestation and expansion of grasslands and meadows in pollen diagrams. A signal of increased human impact has to be interpreted carefully: a pollen-analytical "expansion phase" may reflect increased crop cultivation (intense agriculture) or increased pasturing (extensive land-use of marginal land). Climatic deterioration will lead to the abandonment of an area or a change of land-use towards animal production. Event 5 at the end of the Bronze Age involves such a complex situation. In future research, we should aim to discriminate and quantify various land-uses (cf. Broström et al., 1998).

The causality behind the development of the society, expansions or regressions of the cultural landscape, and land-use changes is complex. In the Scandinavian context, technology in relation to growing population has been emphasized (Welinder, 1975), followed by the interaction of social and environmental factors (Ambrosiani, 1984; Berglund, 1991) or a step-wise change of a technological/social complex, in harmony with environmental changes (Myrdal, 1997, 2000). For marginal settlement areas, it is a reasonable hypothesis that the development of the agrarian society was stepwise, depending on the interaction between the technological/social complex and the ecological capacity, where climate played a fundamental role. So far this hypothesis has some support in the palaeoecological and the archaeological/historical material, but it has to be rigorously tested by future interdisciplinary research.

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