Stand Dynamics of Prehistoric Oak Forests Derived from Dendrochronologically Dated Subfossil Trunks from Bogs and Riverine Sediments in Europe

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ABSTRACT. There are some 7000 oak trunks from German river gravels and Irish, English, Dutch and German bogs, covering the period 8400 BC - AD 1000. Their replication varies through time with clear germination and dying-off (GDO) phases. The distribution of riverine oaks shows a general change at c. 3000 BC, after which there are clearly separated GDO phases. Bog oaks distributions show a more complex picture with some germination and dying-off occurring at the same time. We use mean age curves to allow regional GDO comparisons. Regionally mean age curves contain similar elements, sometimes over long periods suggesting common climate forcing.

KEY WORDS: bog oaks, climate, dendrochronology, riverine oaks, stand dynamics.

Introduction

From 1970, European tree-ring laboratories have studied oaks from bogs, river gravels and marine/brackish sediments. This material has provided absolutely-dated tree-ring chronologies back to a maximum of 8400 BC (Spurk et al., 1998; Leuchner, 1992; Pilcher et al., 1984). Widespread sampling of sub-fossil oaks shows that frequency varies with time, with discrete phases of germination and dying-off. In view of the marginal ecological cond-itions that existed at the ancient tree-ring sites (on the surface and margins of peat bogs and on river margins liable to flooding), it is likely that these phases were caused mostly by changes in local hydrology driven by climate or anthropogenic activity.

Some 7000 sub-fossil oaks have now been examined. River gravel material from the Main and Danube are shown in Fig 1. The north European bog-oak sites are categorised according to (1) German inland high elevation sites (Fig 2a) (2) German coastal low elevation sites (Fig 2b) and (3) Dutch coastal sites (Fig 2c). Fig 2 shows that the German oaks can be divided into three episodes dominated respectively by inland (c. 6000–3000 BC), coastal (c. 3000–500 BC) and inland (c. 500 BC–AD 900) assemblages.

Results and interpretation

Riverine oaks

Early suggestions concluded that after 3000 BC human activity resulted in changes in fluvial activity (Becker and Schirmer, 1977; Delorme and Leuschner, 1983). With greater numbers of oak records, with some revised Hohenheim dating (Spurk et al., 1998) and with the addition of Goettingen material, we now have the overall picture of the oak record as shown in Fig 1. This shows clear, temporally separated, GDO phases after 3950 BC with very distinct germination phases around 2750 BC, 2200 BC, 1700 BC, 380 BC, 130 BC and AD 400. This clear succession behaviour is essentially absent c. 8000–3950 BC.

Possible forcing factors for this distribution would be climate-induced changes in fluvial activity in the earlier part of

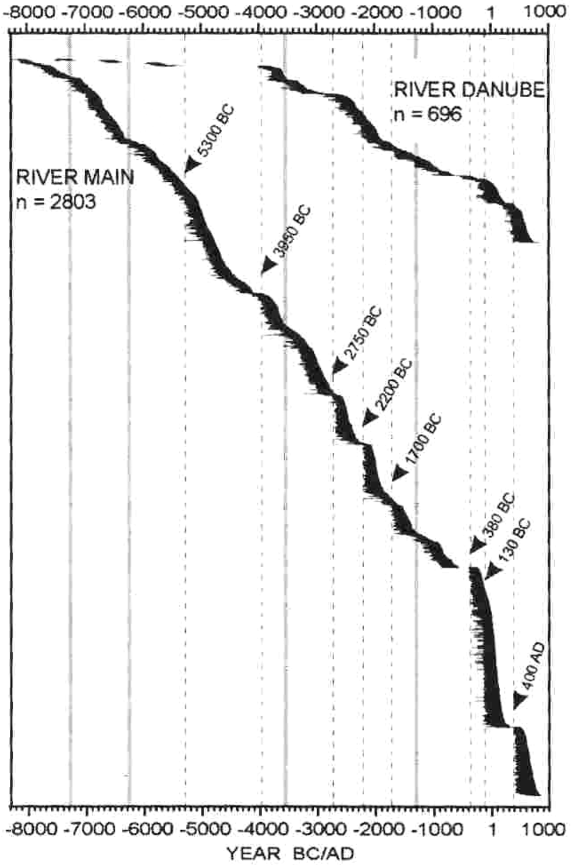

Fig. 1. The life spans of sub-fossil trees from the river Main and Danube gravels. Clear germination events are marked by vertical dotted lines; less distinct germination events are marked as grey bars.

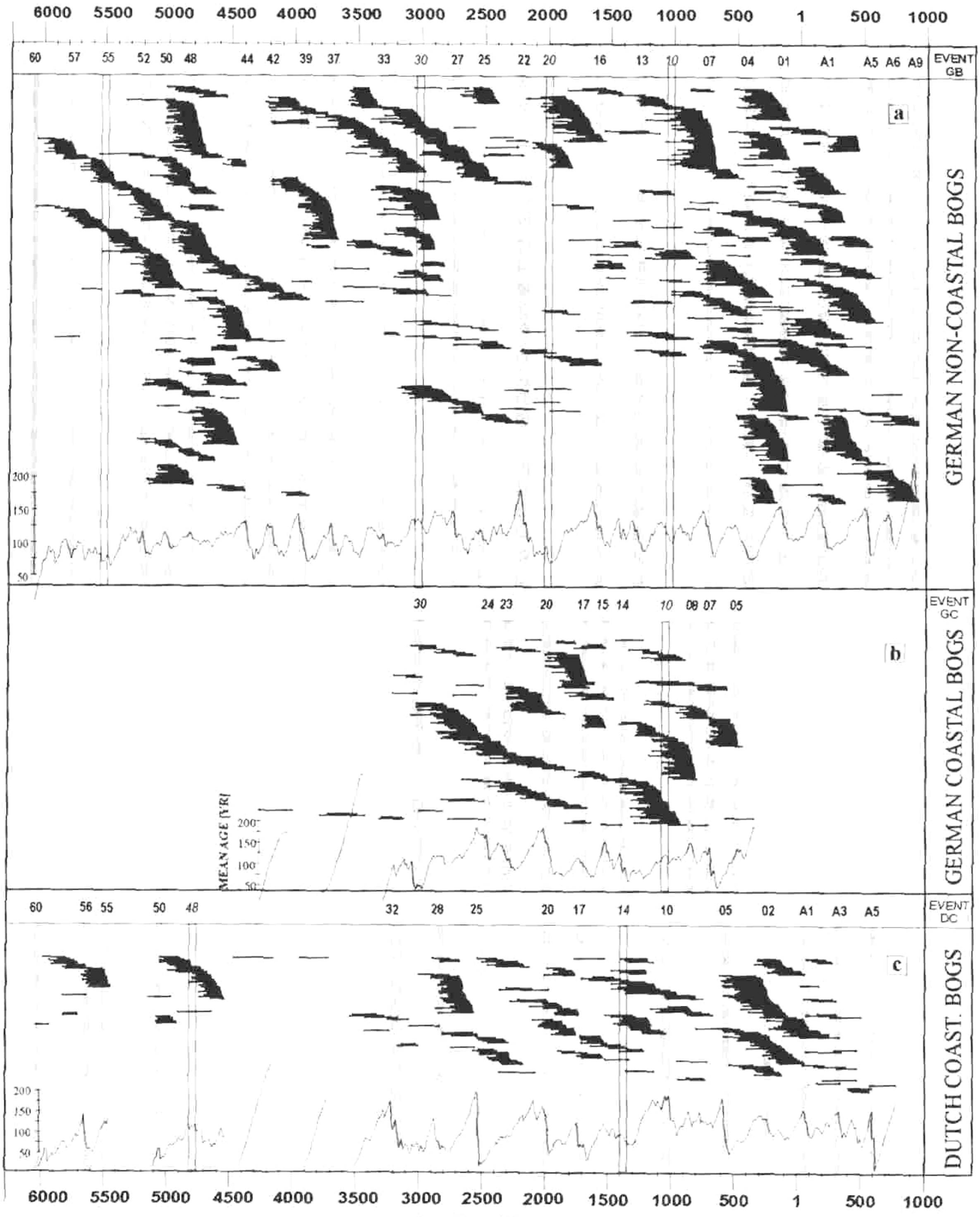

Fig. 2. The life spans of German and Dutch bog oaks. (a) Germany: non coastal n = 1291, 87 sites; (b) coastal a = 263, 14 sites; (c) the Netherlands: n = 301, 43 sites, clustered according to their site provenance. The wiggly curves at the bottom of each plot represent the mean age of the trees in time. Obvious decreases in the mean age (determined optically) are marked by grey bars. Periods of interrupted forest growth have been labelled in two digits according to their date (i.e. 52 = 5200 BC, A4 = AD 400).

the record with increasing human activity in the later section. One suggestion is that a key factor may have been increased loam deposition in the river valleys. This factor will have been exacerbated by human activity with feedback through erosion leading to long-duration floods. Such floods could easily have prevented the rejuvenation of riverside forests.

Bog oaks

Early work in north Germany with oaks from only some ten sites was summarised by Leuschner et al. (1987). They interpreted instances where bog oaks showed dying-off episodes at more than one site as the result of increased wetness. The current German/Dutch situation, with much more material available, is displayed in Fig 2. This shows (marked by grey bars) that there are a number of episodes where we can observe dying-off coincident with germination phases. For example, there is particularly clear evidence of a widespread synchronous dying-off phase (GB 01) between 200–100 BC. Also displayed in Fig 2 is a graph of mean tree age through time. The mean age of a group of trees decreases when the older trees die while younger ones live on, or when young trees replace old trees. It increases when no population changes occur and the existing trees live on. In more general terms, this could be thought of as disturbed (mean age decreasing) and undisturbed (mean age increasing) populations. Note how in Fig. 2a the behaviour of the mean age curve reflects the distribution of ageing and regenerating trees; this is particularly clear at the 200–100 BC example. Mean age is therefore a robust way of conveying a lot of complex information which can be useful for comparison between regions.

Fig 3a shows one regional comparison between mean age plots for German and Dutch coastal material, originating from sites some 200 km apart. There is very clear agreement between the curves, especially between 2000–1300 BC. On a bigger spatial scale Fig. 3b shows a comparison between the mean age curve of all the continental bog-oak material with that from Irish bogs; the average distance in this case being c. 800 km. Here we see clear evidence for remarkably synchronous behaviour before 2000 BC . After 2000 BC, there are only episodic periods of agreement which may be no more than random.

From c. 5500 BC to c. 2000 BC not only the large scale regeneration/dying-off phases agree, for example those at 4000–3900 BC, around 2500 BC, and at 2000 BC, but much of the fine detail information in the mean age curves also agree. During this interval reduced mean age may then be interpreted as the result of increasing wetness, whereas intervals of increasing mean age may point to relatively dry conditions. Clearly something on a macro-scale changed around 2000 BC. In this context it is interesting that there is a widespread interest in climate change in the later third millennium BC (Dalfes et al., 1997). Moreover, there are suggestions that after 2000 BC some events are not climate related but may be due to intense human activity albeit probably driven by environmental conditions (Baillie and Brown, 1997). For example, the very notable drop in the Irish mean age curve at 1000–950 BC appears to be a purely Irish phenomenon. Thus it seems likely that the breakdown in agreement between the German/Dutch and Irish mean age curves, after 2000 BC, could be due either to climatic change or anthropogenic factors, or both.

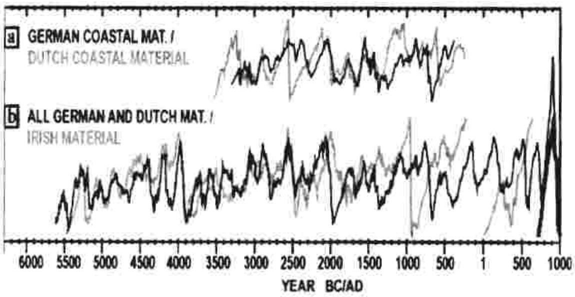

Fig. 3. (a) Comparison of a regional and macro-scale mean age plot for German coastal (heavy line) and Dutch coastal bog oaks; (b) A similar mean age comparison for all German/Dutch bog oaks (heavy line) and Irish bog oaks. For scale of mean age see Fig. 2.

Conclusions

The analysis of large dendrochronological data sets in terms of 'mean age' produces clear data about forest dynamics and climatic change in regions of varying size. The parallel continental/Irish forest dynamic in the period 5400–2000 BC must have been the result of a strong forcing by macro-scale environmental influence; probably expressed as hydrological changes. This period includes a particularly clear GDO phase between 4000 and 3900 BC when the climate in Northwestern Europe appears to have been relatively wet (Baillie, 1995). After 2000 BC the lack of agreement between the large scale continental/Irish mean age curves suggests either notable climate change or increased human influence. The agreement between the regional coastal curves (Fig. 3a) continues to about 1300 BC, so marine influence may play a role in the case of regeneration and dying-off in coastal continental oak forests.

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A 1105-Year Tree-Ring Chronology in Altai Region and Its Application for Reconstruction of Summer Temperatures

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ABSTRACT. There has been developed a 1105-year (AD 895 to 1999) regional tree-ring width chronology for Larix sibirica Ldb at upper timberline (the elevation is 1900 to 2200 m) in the South-East of Altai region (Russia). The standard statistical methods were used for the dendrochronological analysis. The statistical parameters of the chronology show a strong climatic signal to be contained in radial growth variability. The climatic response-function analysis reveals that up to 90% of radial growth variability is determined by climate. Such a climatic parameter as the mean temperature for the June-July explains 54% of tree-ring width variability. The reconstruction indicate significant year-to-year and long-term (century) variations of the parameter during the last millennium. These fluctuations coincide with increase and depression of glaciers. The main periods of temperature decrease were in the end of the 18th and middle of 19th centuries. Temperature increase occurred in the middle of the 14th and 20th centuries were the most significant during the last millenium in Altai region. Comparison of the reconstructed data on temperature regime for Altai region with the reconstructed data on temperature regime for the northern hemisphere shows the same periods with low and high temperatures (Colenul et al., 1995).

KEY WORDS: dendrochronology, regional chronology, temperature reconstruction.

Introduction

The intensive dendrochronological research in the South of Siberia Mountains was initiated from 1995 by Institute of Forest of SB RAS. The research area is located between 49°–52°N and 84°–89°E. One of the main goals of these investigations is to reconstruct summer temperature variations at the upper timberline in Altai Mountains for the last millenium. Tree-ring width chronologies are the best source of proxy climate data for the late Holocene, because tree-ring width indicates and contains the intra-annual and long-term variations of the environment. Several local chronologies were developed for the different altitudes. The chronologies reflect the radial growth features of *Larix sibirica* at the upper timberline. The regional chronology was developed by averaging indices of the local chronologies and used for the following analysis.

Methods and material studied

The objects of the investigation were cores and discs from living trees, dead trees and subfossil wood of Siberian larch (*Larix sibirica Ldb.*) from upper timberline in Altai Mountains. Larch trees are very sensitive to the climate changes. They are of old age and grow under extreme condition. We used two cores from every tree and not less than 8 trees for each site to build the local chronology. Ring-widths were measured to the nearest 0.01 mm and then all the cores were crossdated using plots of individual ring-width series. Program COFECHA (Holmes, 1983) was used for the best quality dating of every sample. The percentage of missing rings ranges from 0.13 to 0.49% for different sites. Tree-ring width series were standardized by negative exponent, trend line or 128-year spline (Fritts, 1976) using the ARSTAN program. Usual characteristics (standard deviation, mean sensitivity, autocorrelation) were used for the statistical and response function analysis.

Results and analyses

The statistical parameters of the chronology show a strong climatic signal to be contained in radial growth varaibility. The summary of statistical results is given in Table 1.

The correlation coefficients between the local chronologies are high (0.67–0.77) which helps to arrange them into the regional chronology presented in Fig. 1a. The most significant decrease of radial growth was found in the end of 17th and 18th and in the middle of 19th centuries. Improved growth occurred in the middle of the 14th and from the end of 19th to the middle 20th centuries. The climatic response-function analysis shows that up to 90% of radial growth variability is limited by climate (Fig. 2) and June-July temperature determines 54% of tree ring width variability. June temperature is a general limiting factor for radial growth at the upper timberline which is similar with