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Contributions to the ecology of common beech as derived from tree-ring analyses

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Introduction

Tree rings are used in a wide range of scientific fields. Dendrochronology is one of these fields to which dendroecology can be assigned as important discipline. Its intention is to get environmental and physiological information about the various growth influences from tree-ring sequences, structures or other signals storied in tree rings. Forest scientists use dendroecological tools in order to get information, for instance, about:

- the growth potential of trees under different site and climatic conditions;
- former or recent environmental influences – biotic or abiotic, natural or anthropogenic – which have a distinct effect on trees growth, vitality or ecological fitness;
- range of site specific reactions to these influences or, as derived from this, the ecological range of a certain tree species.

Concerning the latter point, the presented contribution focuses on following questions:

- How distinctly reflect tree-ring widths of Common beech (Fagus sylvatica L.) environmental influences?
- What kinds of climatic influences mainly control radial increment of beech in Central Europe?
- What kinds of environmental changes will mainly affect growth and vitality of Common beech in Central Europe?

Data background and analyses

Background of the following evaluations are tree-ring data of more than 43 beech stands in Southern Germany and around 20 beech stands at sites on the eastern, western, northern and southern part of Europe (Dittmar et al. 2003a/b). To avoid effects of competition and suppression, only dominant trees (tree class 2 according to Kraft 1884) were sampled at each site. Normally, at each of 20 sample trees, 2 increment cores were taken. Measurement, synchronisation, dating and the analyse of climate-growth-relationships were carried out according to Dittmar & Elling (1999) and Dittmar et al. (2003a/b), respectively. In order to characterize the temporal variation of site specific water supply, water-balance calculations were carried out according to Rötzer et al. (2004).

Sensitivity of Common beech tree-ring series

Typical for beech is a high sensitivity of ring widths at most of the investigated sites. While measuring ring widths in mixed stands, one will usually find a higher sensitivity at beech series compared to other tree species, e.g. coniferous trees (Figure 1). The mean sensitivity is a degree of the intensity of growth fluctuations from year to year and of the frequent occurrence of particular narrow or wide rings. Typical for beech are also sharp reactions in single years without lag effects, that means: extreme narrow up to even missing rings, and a complete recovery of increment in the following year. A high sensitivity in ring widths reflects a sensible reaction to environmental factors. This characteristic makes beech highly suitable for dendroecological analyses.

Sensitivity is especially high, if one factor with a high variability from year to year limits growth. Depending on the site, however, beech can be sensitive to very different influences as shown be the climate-growth relationships described below. Beside a high sensitivity, another repeated observation is remarkable: Beech has an underestimated high growth potential on warm and dry sites (cf. Elling & Dittmar 2003). Compared to spruce, for example, beech is much more drought resistant.

Climate-growth relationships

In southern Germany climate-growth relationships were studied along an altitudinal gradient between around 300 and 1450 m a.s.l. (Dittmar & Elling 1999, Dittmar et al. 2003a/b). At low altitude sites, ring widths of beech are strong related to water availability. High temperatures, because they are normally accompanied by low precipitation, reduce ring widths. By contrast, at high altitude sites, above around 800 m, temperatures and ring widths are positive correlated. There, even negative correlations between water availability and increment were often found. Under this site conditions temperature, radiation and the length of the vegetation period are the main growth limiting factors.

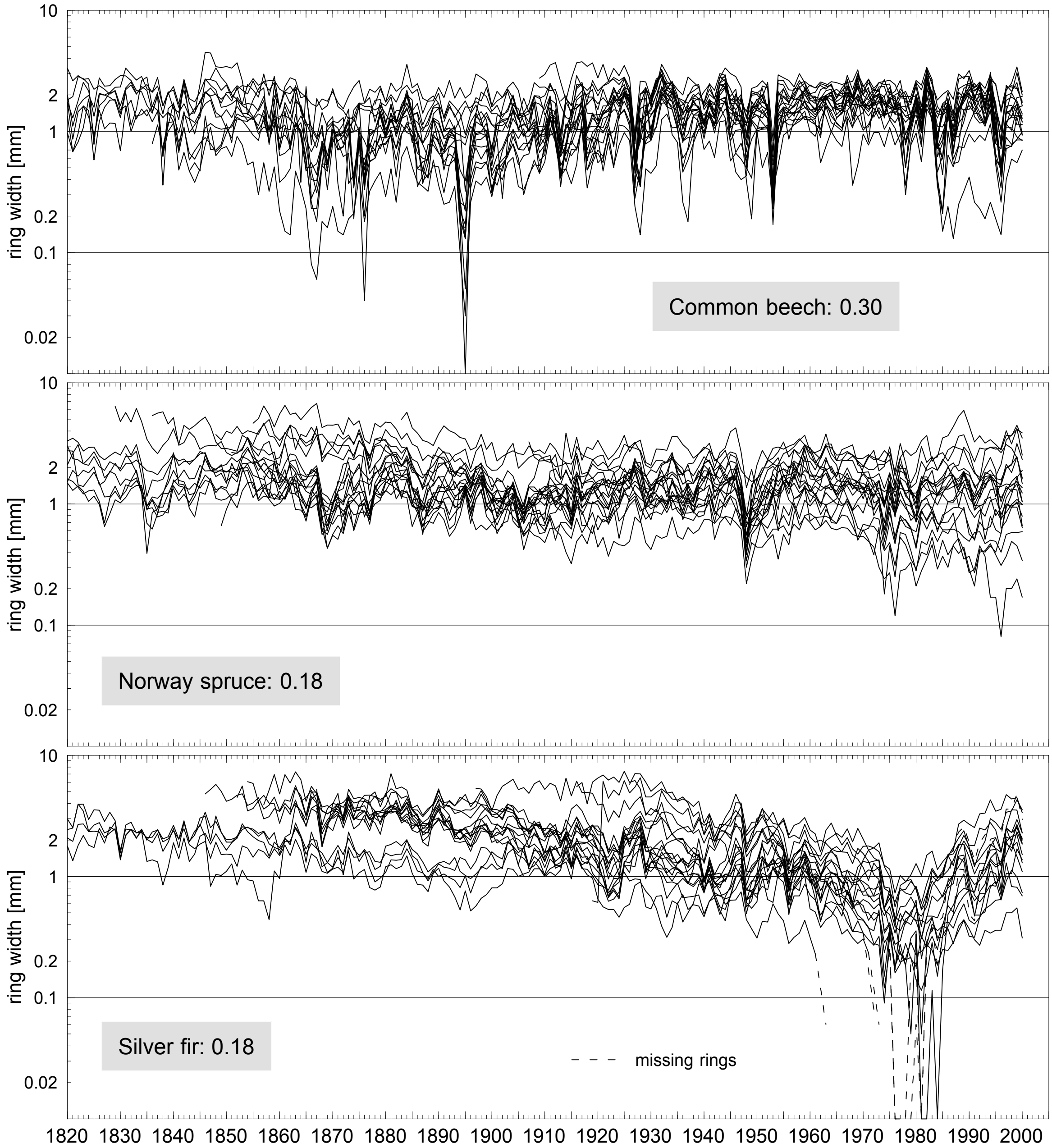

Figure 1: Tree-ring widths of Common beech, Norway spruce, and Silver fir at the mountain Brotjacklriegel (Bavarian Forest, 965 m a.s.l.). For each tree species radial increment of 20 dominant trees (tree class 2 according to KRAFT, two radii per tree) are plotted in semi-logarithmic diagrams. Plotted with dotted lines are series after the occurrence of missing rings. The sensitivities of tree-ring data were calculated for comparable time spans excluding the growth depression of Silver firs around 1980: 1775 – 1970 for Common beech, 1793 – 1970 for Norway spruce, and 1797 – 1970 for Silver fir. (tree-ring data according to RIFFESER and AMBROS 2001, REISCHL 2002).

Water balance and radial growth

In dendrochronology and dendroecology, normally precipitation data are used in order to establish relationships between water availability and tree-ring growth. Sometimes also the climatic water balance is applied. But despite of an often overestimated evapotranspiration (Laatsch 1969), the climatic water balance takes no stand and site specific properties into account. In the presented investigations, a site and soil dependent water balance model was established for a more realistic estimation of water supply (Elling et al. 1990, Rötzer et al. 2004). The model HyMo (for details see Rötzer et al. 2004) provides long-term daily values of different water balance parameters. As input data the meteorological parameters temperature, precipitation, air humidity, wind speed and radiation are used. These parameters, measured at climatic stations, were transformed with regional and time specific transfer functions in order to obtain site specific conditions. A second set of input data are soil and stand properties carefully evaluated at each site. Additionally, HyMo takes snow smelting, fog precipitation and phenology into account. As continuous records daily data of climatic stations can be used, HyMo enables the retrospective calculation of water balance data. In this way, it is a valuable tool for dendroecological analyses as shown by the example in Figure 2.

At one site in Northern Bavaria near Würzburg, climatic and soil conditions cause a distinctly water limited growth (Figure 2a). A strong correlation between the actual available water content of the soil and the ring widths was obtained (stronger than between precipitation and radial growth: $r = 0.42$, $p < 0,01$). By contrast, at the high altitude site of the Bavarian Alps, no – even an almost significant negative – correlation between soil water content and radial growth was found. There, water availability is not restricted in most of the years, but the vegetation periods are often to cold, to wet and to cloudy. Hence, tree-ring widths correlate with temperature (Figure 2b).

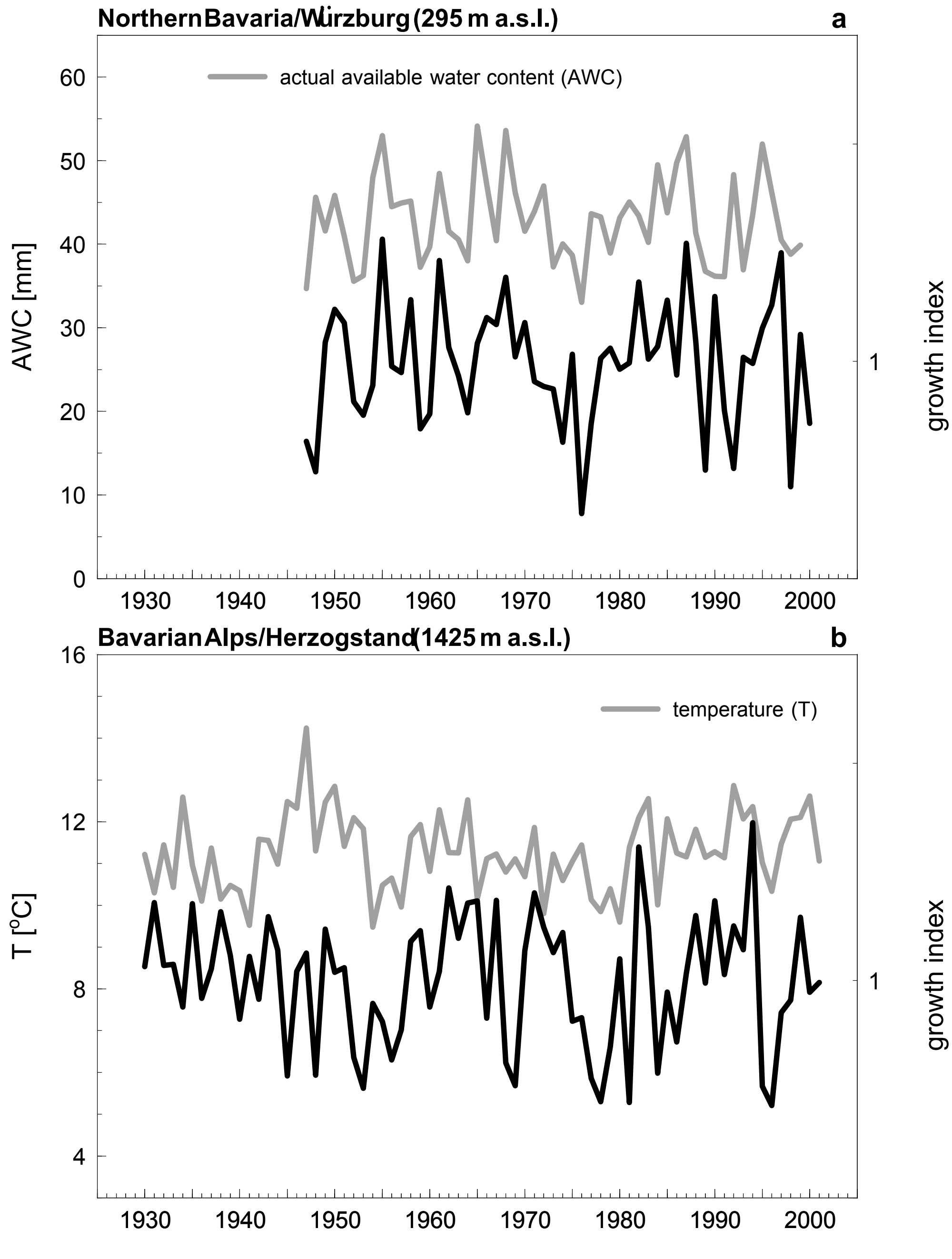

Figure 2: Relation between (a) the actual available soil water content (AWC, averaged for the vegetation period) and the radial growth of beech in Northern Bavaria (correlation: r = +0.49, p < 0.001, 1947-1999) and (b) the temperature (T, measured at 2 pm, averaged for the vegetation period) and radial growth of beech at the Northern Alps (correlation: r = +0.23, p < 0.05, 1931-2001). The AWC was calculated with the water balance model HyMo (RÖTZER ET AL. 2004). The average growth index (residual chronology) was derived from 20 trees (40 radii) at each site (tree-ring data according to SCHRAUDER and REITHMEIER 2002 and ELLING and DITTMAR 2003, respectively).

Impact of late frosts

At mountainous sites, an additional important and temperature related factor was found: the impact of late frosts. This factor, however, cannot be detected in continuous climate-growth relationships, but can be the reason of weaker dependences of growth on average weather influences. Sudden cold spells caused by advective transport of cold air at the beginning of the vegetation period can strongly damage the foliage, if temperatures fall below – 3 °C and fresh leaves are affected. In tree-ring records, we found signals of late frost events especially pronounced, if they occurred during the days around or immediately after leaf unfolding.

Forest sites investigated by dendroecological analyses usually are not located directly nearby meteorological and phenological stations. For the investigation of relations between late frost and pointer years, therefore, the site specific minimum temperatures and the site specific timing of leaf unfolding have to be considered. If corresponding data sets are available, impacts of late frost events on radial growth in certain years can be recognized. One example is shown in Figure 3.

Despite of a high deviation of leaf unfolding data in 1952, until the late frost at 21th of May, leaves of beech at all altitudes at the northern fringe of the Alps should be unfolded. Minimum temperatures, however, only fell below the threshold value for frost damage (- 3 °C) at altitudes above around 1100 m a.s.l.. Accordingly, only at altitudes above 1100 m signals in tree rings of beech can be expected. Radial series of several stands in different altitudes confirm this expectation (see Figure 4): At lower altitude sites, no reaction – sometimes even a maximum – was found in the year 1952. By contrast, at high altitudes, strong increment reductions occurred and can be related to late frost impacts. In May 1953, many beech trees at sites above around 800 m a.s.l. were affected by a further late frost.

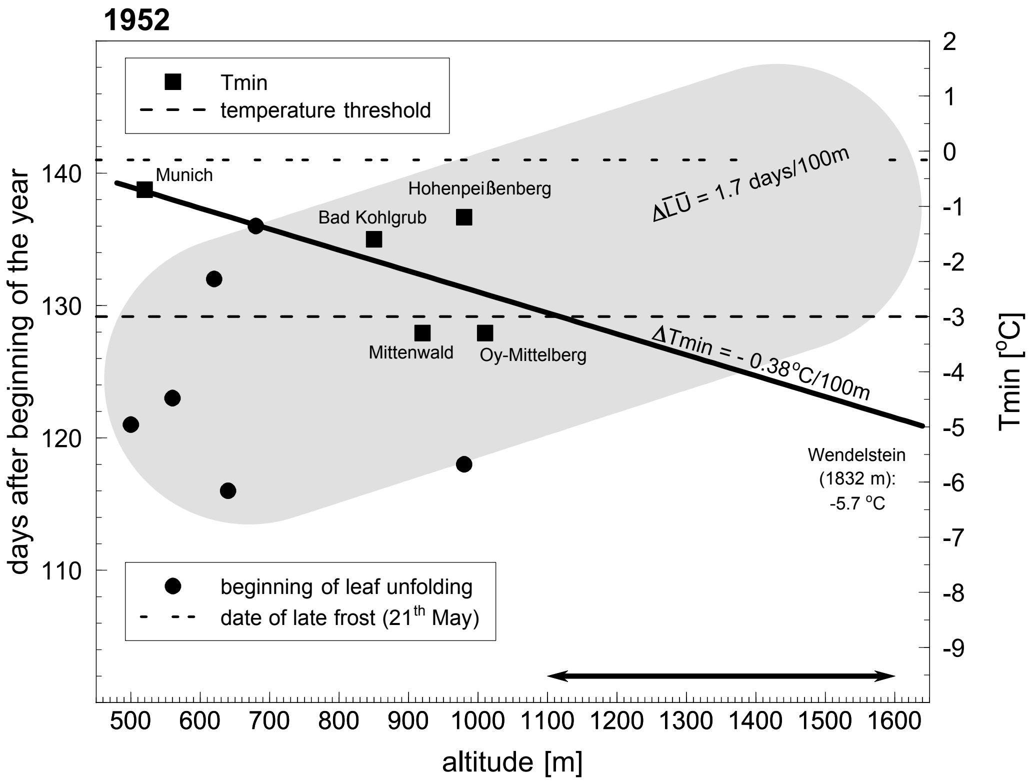

Figure 3: Minimum temperatures (Tmin, plotted as ■ on the right axis) during the late frost event at 21th May 1952 at different climatic stations and beginning of leaf unfolding (LU, plotted as ● on the left axis) in this year at different phenological stations at the northern fringe of the Alps. The grey area indicate the dispersion of LU data and the long-term average of the altitudinal gradient of LU. Tmin decrease with altitude during the day of late frost is plotted as regression line. Altitudinal belts, endangered by late frost impacts, are signed by an arrow.

Accordingly carried out investigations of late frost impacts on radial growth of beech for longer periods and at different sites revealed: With increasing altitude the frequency and intensity of late frosts at the beginning of the vegetations period increases and with it also an increasing number of negative pointer and event years can be related to late frost impacts (Figure 4).

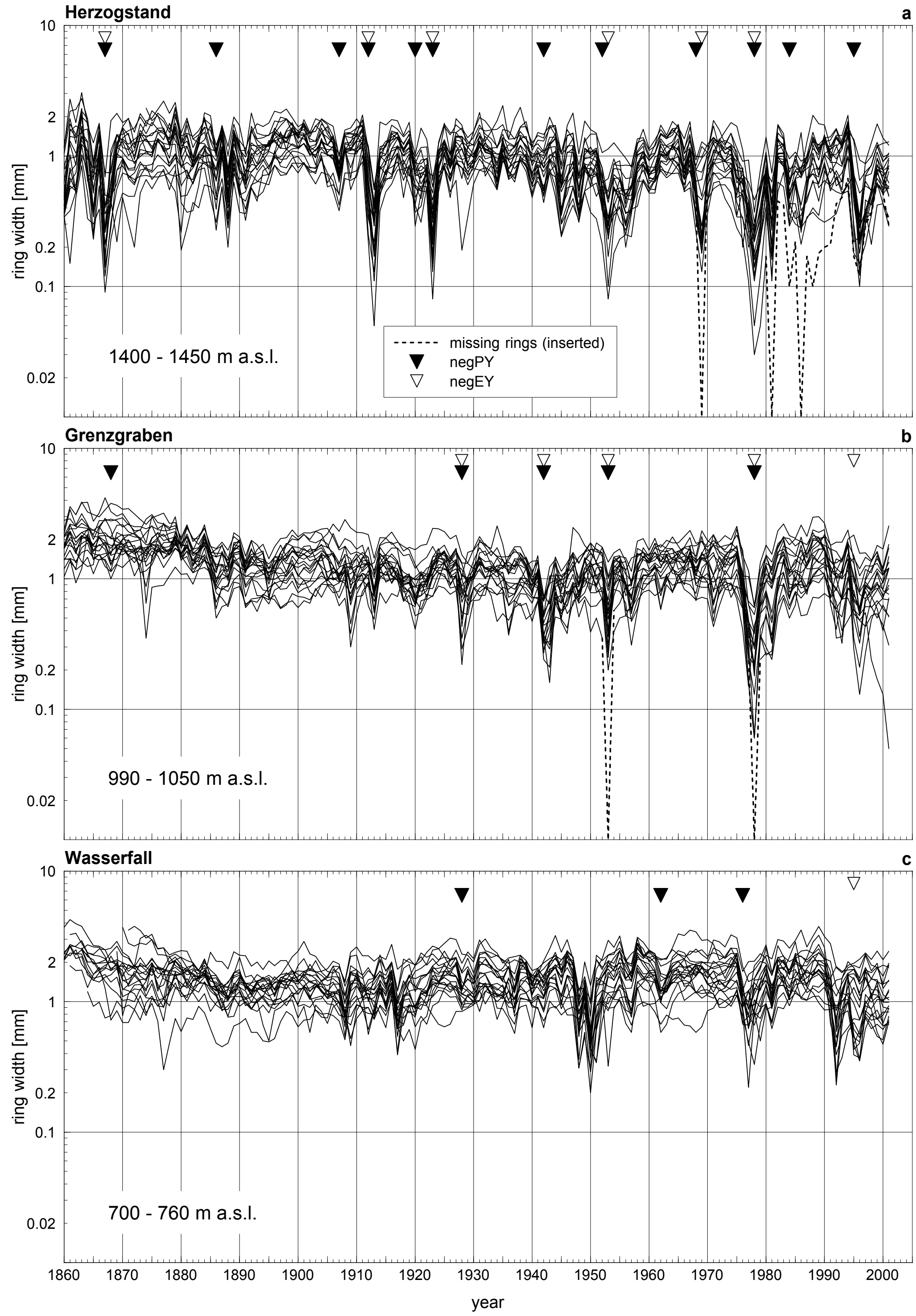

Figure 4: Tree-ring widths of 3 stands at different altitudes at the northern slope below the Herzogstand mountain (Bavarian Alps). For each site radial increment of 20 dominant trees (tree class 2 according to KRAFT*, two radii per tree) are plotted in semi-logarithmic diagrams. Missing rings are signed by dotted lines. Signed as triangles are negative pointer (negPY) and event years (negEY), respectively, according to* DITTMAR *and* ELLING *(1999) which can be related to late frost events in the same years.*

Conclusions and Summary

- On many sites in Central Europe, tree-ring widths of Common beech reflect a sensitive reaction to environmental influences. This feature favour the application of dendrochronological and dendroecological investigations.
- Depending on the site, however, growth influences are very different: On dry sites – normally at low altitudes – water availability is the main growth limiting factor. By contrast, on mountainous sites, temperature and radiation are the main growth controlling factors. With increasing altitude, the importance of late frosts increases.
- Comparing the increment on different sites, Common beech shows a high growth potential on dry sites in Central Europe.

Concerning the question, what kinds of environmental changes will mainly affect the growth of Common beech, following is concluded:

- Increasing temperatures will not be a serious problem for beech vitality at most of the forest sites in Central Europe. At high altitude sites, warming would even improve growth potential; on condition, however, that the frequency and intensity of late frost will not increase.
- Decreasing precipitation in summer months will only affect radial growth on dry sites and soils with a low water storage capacity. In Bavaria, only a small part of forest sites will be affected.
- The high and increasing input of nitrogen and the high ozone pollution in many Central European regions are considered as serious risk factors for Common beech. At the Northern Alps, growth disturbances since the late 1970s, preceding crown symptoms of a decreased vitality in the 1980s, were repeatedly found by dendroecological investigations in the last years (Elling & Dittmar 2003). During summer 2003, visible ozone symptoms at beech leaves at several sites above around 900 m a.s.l. indicating acute photooxidative stress were observed (Dittmar et al. 2004).
- Further investigations are required to answer questions about long-term impacts of nitrogen and ozone on the vitality and ecological fitness of Common beech in Central Europe. As shown by this contribution, tree-ring data should be more considered in this context by the application of suitable dendroecological tools.

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