

Increased sensitivity in ring width series of common beech after 1990 – climatic impact or normal patterns due to ageing?

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Motivation – problem situation

During the last three decades many beech stands in Germany show a conspicuous growth pattern (Beck 2009, 2011). Tree ring width series show a dramatic increase of sensitivity beginning in the 1980s. This changed growth pattern, compared to the period before 1980, may be associated with the increased number of years with an unfavourable climate, especially warm and dry summers. This pattern appears even more distinct if the series of ring width data are transformed into a series of basal area increment (BAI). For illustration, a typical example (beech sample plot Chorin, North-eastern German lowlands) is shown (Fig. 1 and 2).

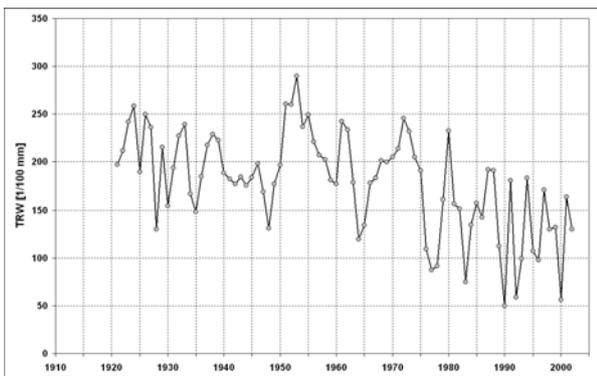


Figure 1: Course of mean radial increment

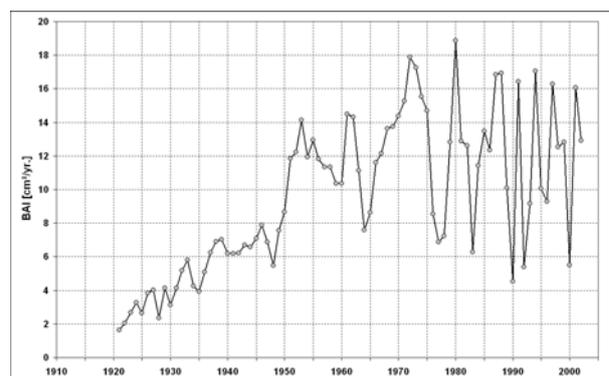


Figure 2: Course of basal area increment

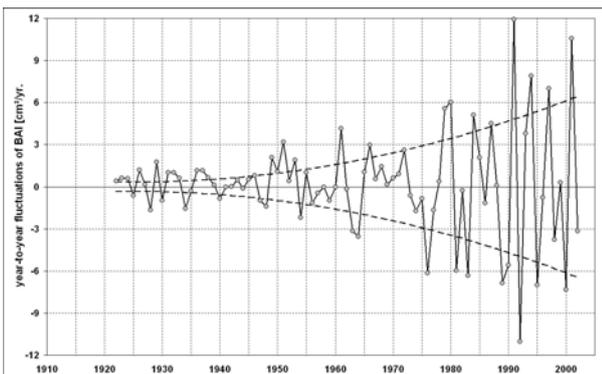


Figure 3: First order differences of BAI together with trend estimation

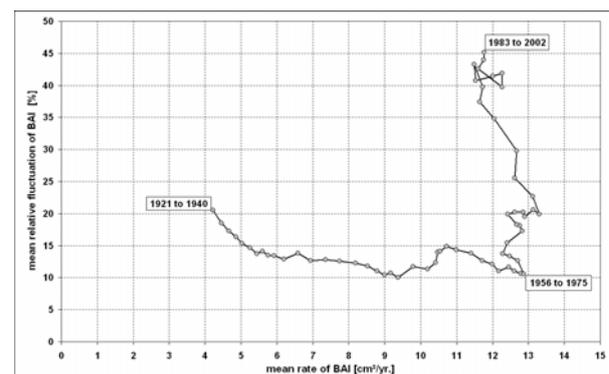


Figure 4: Relation between mean relative fluctuation of BAI and mean rate of BAI; calculations within moving time spans of 20 years

The course of BAI (Fig. 2) shows an additional change in trend within the 1970s. In order to evaluate these changes, first order differences of BAI were calculated and its temporal trend were estimated (Fig. 3). The non-linear increase of the year-to-year fluctuations suggests a really dramatic change and leads to the expectation of a collapse. On the other hand, there may be a dependence of the size of fluctuations from the size of the increment level itself. Therefore, mean rates of BAI as well as mean relative fluctuations of BAI were calculated within 20-year moving

windows. These two parameters were compared to detect temporal changes of their relationships (Fig. 4). Here, a clear temporal change is obvious. Up to the 1956 to 1975-interval the relative fluctuation declines slightly while mean BAI is increasing. Exactly at that moment when the year 1976, with its very small BAI, is added to the calculation interval, the fluctuations start to increase dramatically, connected with a slight decrease in mean BAI. This pattern shows, that the magnitude of BAI fluctuation is not controlled by the mean level of BAI. Moreover, one can assume, that most likely external driving forces cause this special pattern. Because such growth patterns in beech stands are found currently in many cases, this contribution tries to formulate some scientific questions:

- i. Is increased sensitivity in ring width series a normal pattern due to ageing effects? Is it an indication of senescence?
- ii. Is there a relationship between tree age and annual sensitivity?
- iii. Is the climate warming over the last couple of decades the main cause of an increase in sensitivity in ring width series?
- iv. Are beech trees able to overcome periods with increased sensitivity and return to normal growth patterns if climatic conditions become more suitable?

Material and methods

A comparative investigation of growth patterns in recent and medieval beech-chronologies was seemed appropriate to answer the above questions. In the case that senescence is the cause of increasing sensitivity with higher tree age, this relation should appear in the historical material as well. Similarly, periods of increased sensitivity should be detectable in the past as well if climatic stressors are the cause. In a sufficiently long chronology, alternating periods of increased and lowered sensitivity should appear. The mediaeval beech chronology from Greifswald situated at the north-eastern Baltic Sea coast, spans from 960 AD to 1296 AD. During these times the nearly virgin forests were unmanaged in the sense of regular thinning practice and scheduled stand treatment. Forests were only used sporadically to provide construction timber and fuel. For the latter use thin and young trees were preferred. At this time the forests were not affected by long-lasting air pollutants. From all series of this chronology only series exceeding 150 years were selected, in order to look for possible effects due to senescence. The sample material for tree ring measurements consists of split-planks, frequently containing the pith. In most cases, the last ring before felling was present. Therefore, the complete life spans of 53 beech trees were available for investigation. Within this chronology a replication of at least 20 per year exists between 1045 and 1259 AD.

The other side of this comparative investigation is formed by 12 recent beech chronologies sampled in northern Germany (from Schleswig-Holstein, Mecklenburg-Vorpommern up to Brandenburg) and northern Poland (Czajkowski 2006; Fig. 5) which consist of 320 sample trees all together.



Figure 5: Geographical positions of the investigated beech chronologies; fat point: Greifswald chronology

We used moving time spans of 21 years wherein mean sensitivity (Douglass 1936) and first order autocorrelation were calculated. The corresponding procedures are implemented into the computer program "LINDWORM" which enables a series by series search for changing patterns of sensitivity and AR(1). Among all possible combinations between these parameters some distinctive cases can appear:

- (1) High autocorrelation and low sensitivity: High AR(1)-values indicate invariable growth trends together with a slight environmental effects This combination may be seen as attributes of stable growth conditions.
- (2) High autocorrelation – high sensitivity: Compared to (1), this combination seems to be harmless as long as a high autocorrelation is accompanied by stable growth trends.
- (3) Low autocorrelation – low sensitivity: Compared to (1), this combination also seems to be harmless as long as sensitivity is remaining at a low level.
- (4) Low autocorrelation – high sensitivity: Contrary to (1), combinations in which a stable trend is lost and simultaneously growth rate fluctuations increase are an indication of stressed conditions.

The LINDWORM program determines these time spans where:

- a) the most rapid change of the AR(1)-sensitivity relation (increasing sensitivity and decreasing AR(1)),
- b) the lowest autocorrelation occurs,
- c) the highest sensitivity occurs and when,
- d) the strongest increase of sensitivity appears.

These four criteria (a to d) are used to calculate the relative amount of all included series which show the same pattern in each year of the chronology. The program was applied to the Greifswald-chronology and to the recent beeches. Within the program run the consecutive stepwise results are shown in movie-like animation. Here, only an example of the final investigation of a single series can be shown (Fig. 6).

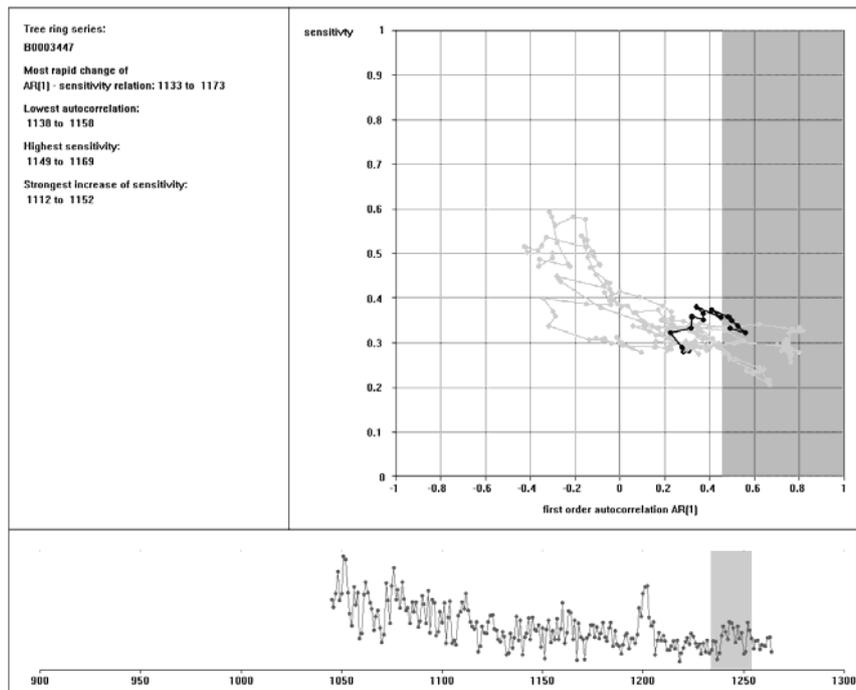


Figure 6: Example of a complete investigation of a single ring width series by the LINDWORM-program; upper graph: relation between $AR(1)$ and sensitivity; temporal changes of this relation are shown as a grey trace; grey shaded area: range of significant correlation; lower graph: ring width time series; grey shaded area is the time span currently under investigation; results of this current time span are shown in the upper graph as black trace.

Results of the investigation of the Greifswald-chronology and of the recent beeches

The time range between 1045 and 1259 wherein replication is at least 20 per year, is used to evaluate the temporal appearance of the criteria a to d as relative percentages of all included series. From these criteria only b and c presented here, because they are the most important ones (Fig. 7 and 8).

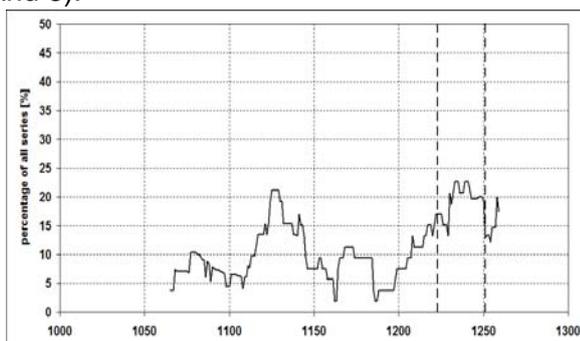


Figure 7: Greifswald chronology; criterion b): lowest autocorrelation

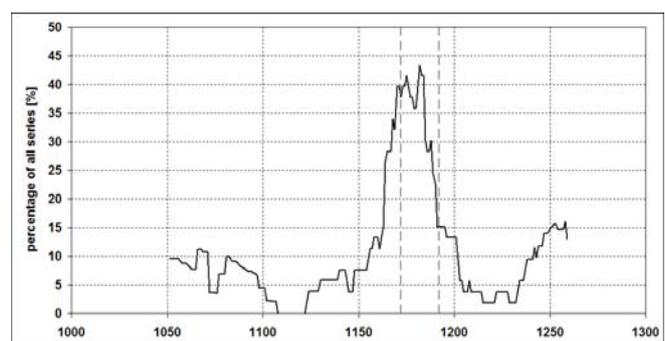


Figure 8: Greifswald chronology; criterion c): highest sensitivity

Concerning the collection of recent beeches from stands in northern Germany and northern Poland the range between the years 1895 and 2007 was used where at least 100 series are present (Fig. 9 and 10).

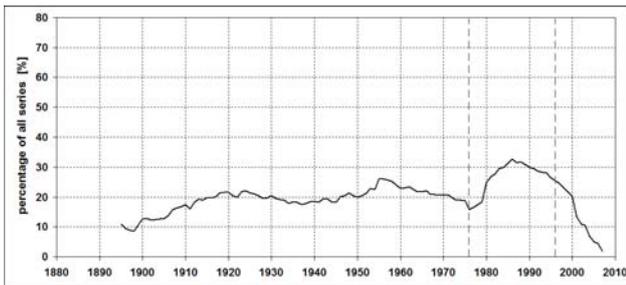


Figure 9: Recent beeches; criterion b): lowest autocorrelation

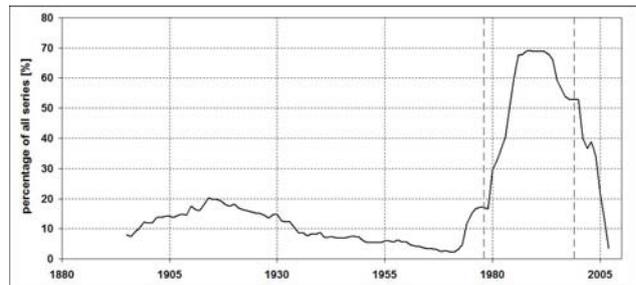


Figure 10: Recent beeches; criterion c): highest sensitivity

In order to ask to the question whether tree age affects sensitivity or not, the annual sensitivities of all series were compared with the corresponding tree ages (figures 11 and 12).

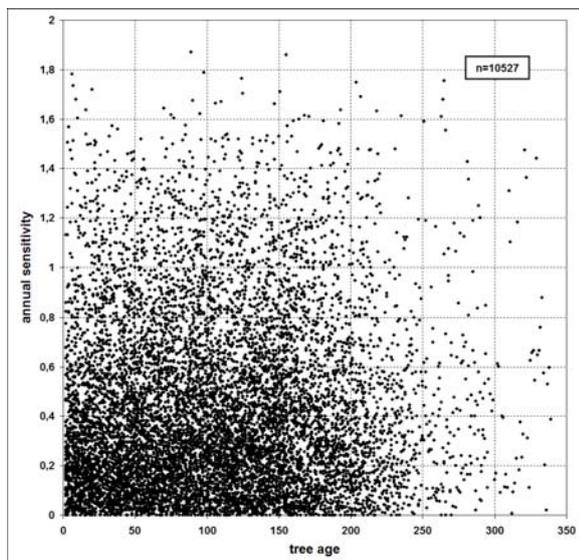


Figure 11: Greifswald chronology; age related annual sensitivities

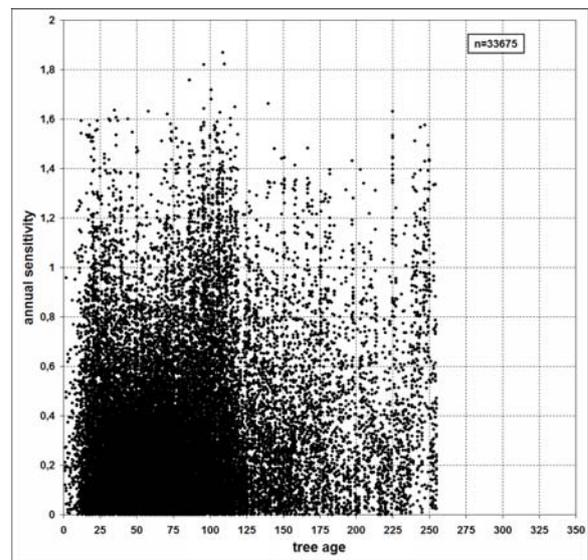


Figure 12: Recent beeches; age related annual sensitivities

Evaluation of results and discussion

Dramatic increases of sensitivity, accompanied by low autocorrelation, accumulate during specific periods. This pattern relates to both the medieval and the recent chronologies (Fig. 7 to 10). Periods with unfavourable changes in ring width series, i.e. the increase of sensitivity and the decrease of autocorrelation, do not appear at the end of the series. Therefore, such changes cannot be associated with increasing age or senescence. There is no apparent relationship between tree age and annual sensitivity (Fig. 11 and 12). This is contrary to the questions (i) and (ii), formulated in the motivation section. The advancing tree age cannot explain rapid changes and the return to normal growth patterns. Therefore, the hypothesis of senescence does not appear to be supported by these tests. It is supported by the historical as well as the recent chronology.

After periods of stressful conditions even old beeches are able to recover to normal growth patterns if growth conditions turn for the better. The simultaneous growth reactions between the series of the respective chronologies is likely driven by exogenous forces, because the changes are independent of tree age. So, question (iv) has to be confirmed. Otherwise, the repeatedly observed recent occurrence of increased sensitivity and lowered autocorrelation of beech chronologies (Fig. 1 to 4) can be seen as a momentary condition of these age stands. It has to be

assumed, that these changes are driven currently by the climatic conditions which corresponds to the confirmation of question (iii). Their future development depends on the direction of further climatic changes.

The mean sensitivity of all 320 recent beech series is 0.32. This value is comparatively high, but consistent and can be explained by the widely spread sandy soils of northern Germany and Poland. The calculation of the mean sensitivity of the 53 Greifswald beeches leads to the surprising value of 0,41. If sensitivity is an expression of the strength of fluctuating growth conditions, the question of the corresponding climatic conditions for this chronology (960AD to 1296AD) arises. Instrumental climatic data of this time range which is part of the Medieval Warm Period are not available; however historical chronicles exist (Glaser 2001; Tab. 1).

Table 1: conspicuous climatic characteristics within the time range of the Greifswald chronology

time range/year	precipitation and temperature conditions
1003 to 1047	many cold, enduring and snowy winters
1021 to 1040	summer heat periods with extreme heat and drought
1043	extremely cold summer
1049 to 1053	wet and cool summers
1088 to 1107	predominantly mild, rainy winters, dry springs, hot and dry summers
1124 to 1126	cold and snowy winters
1127 to 1137	dry and hot summers
1141 to 1146	wet and cool summers
1155 to 1158	dry and hot summers
1159 to 1168	predominantly cold winters
1161 to 1310	longest time span with warm and dry summers, however: 1182 frost in June !

These chronicle data suggests that not only heat and drought during the Medieval Warm Period could have caused the outstanding high sensitivity, but time spans with opposing and extreme weather conditions led to these strong fluctuations of ring width. Compared to today's climate, the conditions a thousand years ago must have been much more changing and much more extreme (Glaser 2001). These huge climatic changes did not only occur during the Medieval Warm Period, but came along with the complete remigration of beech after the end of the Pleistocene. Common beech arrived in Germany during the late Atlanticum, the so-called Beech Warm Age, 4800 years ago. This period was followed by colder conditions during the Bronze Age (2200 – 1200BC), the climate optimum of the Roman Expansion (30BC – 250AD) and again by the coldness during the Barbarian Migration (250- 450AD). The Medieval Warm Period was followed by the so-called Little Ice Age (1400 -1800). Current warming began around 1850 (Akasofu 2010). It is really noteworthy that the common beech was able to cope with all these partially harsh and changing conditions.

Conclusions

Common beech exhibits a strong resilience towards unfavourable climatic impacts. The survival of this tree species may not be challenged by the on-going climatic changes. In the fields of forest management and silviculture there does not appear to be a reason to start overhasty actions at present, such as replacing indigenous by more drought tolerant species or provenances. Practical measures should only be taken based upon trusted findings, such as the conversion of non-indigenous spruce forests at low elevations sites. The level of knowledge on the ranges and limits of climatic stress tolerance for all important indigenous and foreign tree species has to be widened by systematic studies. Nevertheless, cultivation tests of foreign species should be conducted with new intensity.

References

- Akasofu, S.-I. (2010): On the recovery from the Little Ice Age. *Natural Science*, Vol. 2, No.11, 1211-1224; [http://www.scirp.org/journal\(NS/1211-1224](http://www.scirp.org/journal(NS/1211-1224);
- Beck, W. (2009): Growth patterns of forest stands - the response towards pollutants and climatic impact [online]. *iForest* 2:4-6; <http://www.sisef.it/forest/search.php?action=displayFULL&type=search&n=0&abstr=on&start=06k=1&id=472>
- Beck, W. (2011): Impact of drought and heat on tree and stand vitality – results of the study commissioned by the Federal Ministry of Food, Agriculture and Consumer Protection. In: TRACE, Tree Rings in Archaeology, Climatology and Ecology, Vol. 9, Proceedings of The Dendrosymposium 2010 in Freiburg, Germany, GFZ German Research Centre for Geosciences; Scientific Technical Report STR11/07; 20 - 27
- Czajkowski, T. (2006): Zur zukünftigen Rolle der Buche (*Fagus sylvatica* L.) in der natürlichen Vegetation – waldökologische Untersuchungen zur Buchen-Naturverjüngung an der östlichen Buchenwald-Verbreitungsgrenze. Dissertation zur Erlangung des Doktorgrades der Fakultät für Forstwissenschaften und Waldökologie der Georg-August-Universität Göttingen, 69 pp
- Douglass, A.E. (1936): Climatic cycles and tree growth, Vol. III. A study of cycles, Carnegie Inst. Wash. Publ., 289 pp
- Glaser, R. (2001): Klimageschichte Mitteleuropas. 1000 Jahre Wetter, Klima, Katastrophen. Primus-Verlag Darmstadt, 227 pp.