Source: Elferts D, Brumelis G, Gärtner H, Helle G, Schleser G (eds.) (2008) TRACE - Tree Rings in Archaeology, Climatology and Ecology, Vol. 6: Proceedings of the DENDROSYMPOSIUM 2007, May 3rd – 6th 2007, Riga, Latvia. GFZ Potsdam, Scientific Technical Report STR 08/05, Potsdam, p. 77 - 82.

Various factors influencing the pointer year analysis

Sz. Bijak

Department of Dendrometry and Forest Productivity, Faculty of Forestry, Warsaw Agricultural University
Email: Szymon.Bijak@wl.sggw.pl

Introduction

Cross-dating is considered as a key target and one of the most important procedures in dendrochronological studies (Fritts 1976). In general, it is based on matching a certain calendar year with an individual tree-ring or linking a ring from one series with a corresponding ring from the other. However, constantly changing environmental conditions affect the formation of a ring by favouring or limiting tree growth. This results in the variety of the tree-ring widths, which hinders the process of cross-dating. Especially wider or narrower tree-rings are the witnesses of extreme growth conditions (Schweingruber 1996). Such events do not occur very often and thus can be easily placed in time. Therefore tree-rings of significantly bigger or smaller dimension become particularly important as potential linkages in the cross-dating process. Analysis of the tree-ring width series that leads to ferreting out those extraordinary increments enables also to determine the most or the least favourable conditions for tree growth. This information, in turn, may play an important role in silviculture and other utilisation of trees. The concept of pointer year as an individual calendar year when tree growth was significantly different than in other years has its roots in the pioneer dendrochronological studies. However the term itself was defined much later (Schweingruber et al. 1990). At the beginning, the identification of pointer years was based on the 'skeleton plot' method (Douglass 1939) and applied visual assessment of individual tree-rings in comparison with neighbouring increments. Scientific and statistic foundations of the pointer year analysis were introduced by Huber (1943, 1951) as well as Eckstein and Bauch (1969). Since then several methods of pointer year assignment were developed and the analyses were carried out for various regions and species. However, this variety of methods as well as different, very often mutually exclusive, approaches of individual scientists make any attempts to compare the results of pointer year analyses very difficult and complicated (Meyer 1998/1999).

The present paper aims to investigate how the number of pointer years changes when different criteria or methods are applied as well as whether and when the results obtained from dendrochronological analysis correspond to those from the climatological analysis. In the following an 'event year' is defined as, adopting the definition presented by Schweingruber et al. (1990) and Kaennel and Schweingruber (1995), a specific year when a single tree has formed a conspicuously wider or narrower ring. And thus, following the same basis, the term 'pointer year' describes a certain year when the majority of the investigated tree-ring series shows the same kind of extreme growth reaction. Using the terms 'threshold' or 'threshold value' we understand the certain values applied in utilised methods that allow determining either the 'event' (tree threshold) or 'pointer' (stand threshold) years.

Data

The study utilises a set of raw tree-ring measurements taken from lowland Norway spruce (*Picea abies* (L.) Karst.) stands located in the Borecka Primeval Forest in north-eastern Poland. We sampled 43 trees growing on three different site types of different moisture content. Since the distance among these sampling plots was relatively small (ca 1-1,5 km), all sites were assumed to represent the same mezo-climate conditions and therefore considered as a whole. The dendroclimatological description of that data can be found in Bijak (2007). In order to provide the maximum synchronisation of the samples included in the set, the most similar tree-ring series were chosen based upon the *Gleichläufigkeit* (GLK) criterion. The index was calculated according to the concept presented in Kaennel and Schweingruber (1995). Only series that showed the GLK coefficient with the master chronology higher than 65% were accepted. After this selection, in total 24 series remained for further analysis. We used data on mean monthly and annual temperature and precipitation from meteorological station in Suwałki (approximately 60 km eastwards from the Borecka Primeval Forest) to present the climate characteristics for the investigated area.

Methods

Two methods, statistical and visual, were applied to assign the pointer years. Low-pass filtering based on running means and standard deviations of ring-width measurements, the so-called 'normalisation in a moving window' method, proposed originally by Cropper (1979) was used to determine pointer years statistically. The procedure consists of three steps, that is: (i) normalisation of the measurements, (ii) calculation of the event years series and (iii) establishment of the pointer year series. The standardisation was carried out within windows of 5, 7 and 9- years' length according to the following formula:

$Z_i = (x_i – M_w)/SD_w$

where: Zi is standardised tree-ring width for i-th year, xi is raw measurement for i-th year, Mw is mean ring width within a window (i-t ,..., i+t, where f=2t+1 is a window length) and SDw is standard deviation of ring widths within a window.

A given year was considered an event year when its z-transformed ring width exceeded a certain tree threshold value. Threshold values for event year determination were applied in 0,05 intervals starting from 0,05. When the ratio of trees showing an event year in a certain calendar year was higher than the stand threshold value, this year was assigned as pointer year. Applied stand threshold values changed from 0,50 to 1,00 (majority criterion) with 0,02 interval. The visual method of the pointer year determination was carried out with the intention to be possibly similar to the statistical method in the procedure mechanism. It included two stages, that is: (i) assessment of the outstanding increments in the ring-width series which allowed to establish event years series and then (ii) application of the stand threshold in order to receive the set of pointer years. An individual year increment was compared with its neighbours within ca 3 years distance both back- and forward in time. Again, in order to meet the majority criterion the stand threshold values ranged from 0,50 to 1,00 and the analysis was carried out in 0,02 intervals. An individual year was considered a pointer year when the share of trees revealing an event year exceeded the given threshold value. In both cases pointer years were determined for the period 1951-2000. This provided that the investigation considered only mature trees that are not affected by juvenile growth and intensive silviculture treatment. The character of the individual pointer years (negative or positive) was not considered and they were counted in total.

Meteorological pointer years were determined in a two-staged procedure. Firstly we calculated pointer years separately for mean annual temperature and annual sum of precipitation. These calculations were based on the comparison of the mean annual temperature and precipitation for individual years with the average values for the period 1931-2003. This allowed dividing both features into five classes. The thermal classification included division into normal, warm/cold and very warm/very cold years. An individual year was classified as a normal when its mean annual temperature was within the range of +/- 0,5 SD (standard deviation) from the mean (M) calculated for the period 1931-2003. Years characterised by the mean annual temperature in the range M+0,5 SD to M+1,25 SD and M-1,25 SD to M-0,5 SD were classified as warm and cold respectively. When mean annual temperature exceeded the value of M+1,25 SD or M-1,25 SD, then the year was classified as very warm or very cold respectively. The pluvial classification assumed division into normal, wet/dry as well as very wet or very dry years and was based on the calculation of the ratio between individual year annual sum of precipitation and the mean calculated for the 1931-2003 period (later referred to as M). When annual precipitation was within the range 0,9 M to 1,1 M the respective year was considered normal. Values between 0,75 M and 0,9 M and between 1,1 M and 1,25 M were classified as dry and wet year respectively. The annual sum of precipitation higher than 1,25 M or lower than 0,75 M meant that the year was classified as very wet or very dry. In the next step, each class was given a rank, which for normal years equalled 0, for warm, cold, wet or dry – 1, and for very warm, very cold, very wet or very dry – 2. Then summing up the ranks combined these results. A year with total rank higher than 3 was considered meteorological pointer year e.g. a year with extreme climate conditions.

Results and Discussion

Influence of window length

Authors that used the 'normalisation in a moving window' method in pointer year analyses, applied different lengths of the window within which tree-ring widths are standardised i.e.: 5 years – e.g. Cropper (1979), Neuwirth et al. (2007a), 7 years – e.g. Koprowski and Zielski (2002), or 13 years – e.g. Neuwirth et al. (2007b). However, they give no explanation of the reasons for such choice of this parameter. Application of the various window lengths in the statistical determination method resulted in slightly different numbers of received pointer years. In general, none of the applied window lengths gave constantly higher or lower number of pointer years for the same tree or stand threshold values. For example, application of the 9-year window resulted in the highest number of received pointer years when the stand threshold values were low (0,5-0,6) or high (0,9-1). However, for stand threshold values between 0,6 and 0,7, the number of determined pointer years was the lowest among all applied window lengths (Fig. 1a). Similar relationships can be observed for other window lengths and tree threshold values (Fig. 1b).

a)

b)

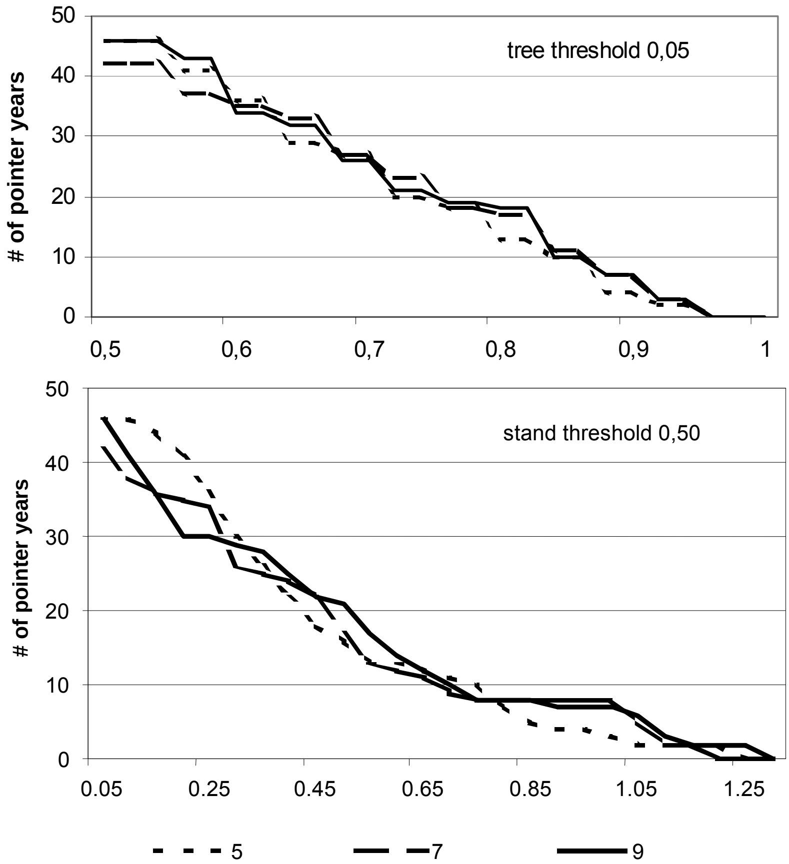

Figure 1: Number of pointer years in period 1951-2000 in the dependence on, the presented at x- axis, a) stand threshold and b) tree threshold value for various lengths of normalisation window (line type).

No obvious pattern in combination of the threshold values was observed during the investigation of the occurrence of a certain number of pointer year either. By analysing the threshold values required for the occurrence of a single pointer year one can see that the application of a certain window length may result in both strict and soft conditions (Fig. 2). Received results do not suggest which window length to choose as the number of obtained pointer years does not differ obviously with respect to that parameter.

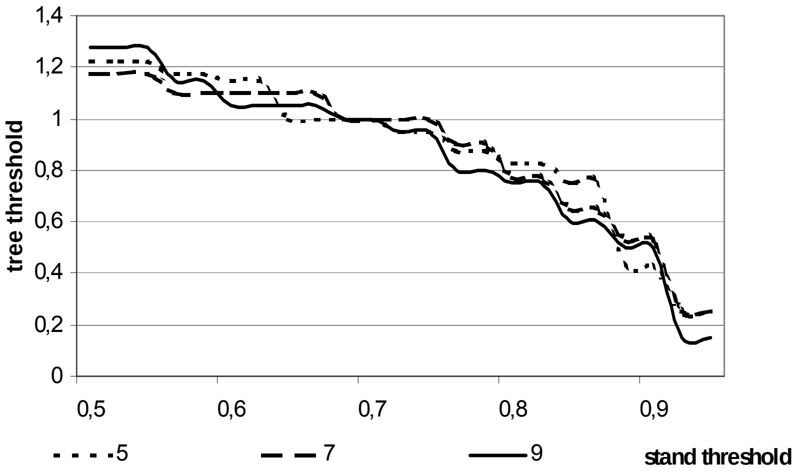

Figure 2: Combinations of tree and stand threshold values required for the occurrence of a single pointer year for various lengths of normalisation window (line type)

Influence of threshold values

Expected results were received when analysing the relationships between number of pointer years and tree or stand values. Application of the more strict conditions in pointer year determination (i.e. higher values of the threshold) resulted in smaller numbers of received pointer years (Fig. 3).

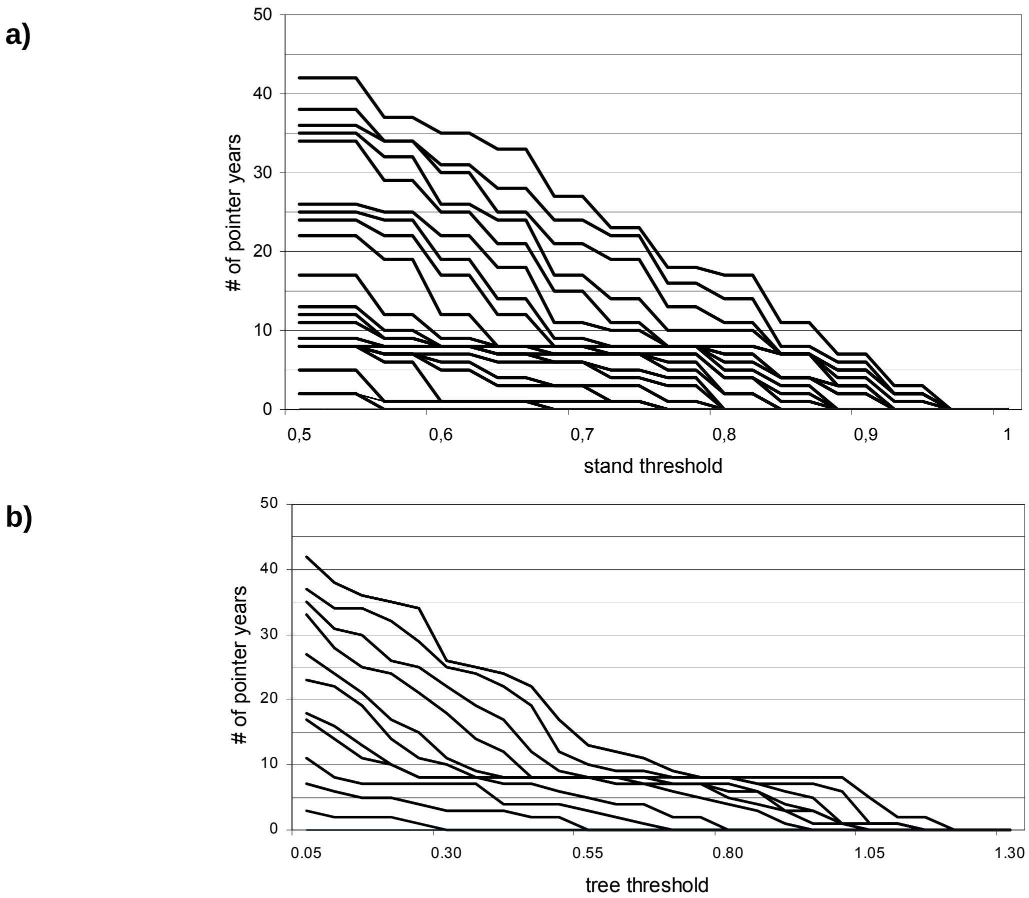

Figure 3: Number of pointer years in the dependence on a) stand threshold and b) tree threshold values for normalisation in 7-year windows.

The most crucial question that arises from this analysis is what the “right” values of the thresholds are. Neuwirth et al. (2007a, b) proposed application of the criteria based on normal distribution for assignment of what here is called tree threshold. However in the ‘normalisation in a moving window’ method mean and standard deviation are calculated within a window of the predefined length and that is why an extremely wide or narrow ring may not stand out so clearly as if these parameters were calculated for the whole series. On the other hand this latter calculation method requires prior indexing of the measurement series. Despite this fact, this proposal is the only attempt to apply objective criteria in determination of pointer years.

Literature review gives also wide range of stand threshold values applied. They varied from 0,4 (Neuwirth et al. 2007b) to 0,9 (Cedro 2007). Again, the reasons for the choice of the certain value were not explained. Of course, the objectives and the conditions of the study as well as individual author’s preferences were behind these subjective choices.

Statistical vs. visual method

Results of the statistical method of the pointer year determination were compared to those from the visual method. Residuals between number of pointer years received for particular tree thresholds in the statistical method and amount of pointer years from visual assignment were calculated for each of the applied stand threshold values. Correlation analysis pointed out that the results of the application of 0,95 (for 5-year window) and 1,05 (for 7- and 9-years windows) tree thresholds are the most similar to those achieved with the visual method. Pearson’s correlation coefficients equalled 0,974; 0,844 and 0,892 respectively. For the same stand threshold (0,5) not only the number of pointer years, but also individual years were similar. The visual method revealed positive pointer years in 1967 and 1974, and negative ones in 1964, 1979,1992 and 1998. Exactly the same results were received when the 9-year window was applied. Application of 5-year window missed the negative pointer years 1964 and 1979. When the 7-year long window was used, analysis did not reveal a positive year in 1974, nor a negative one in 1964, but an additional negative pointer year was detected in 1980. However, despite these small differences, the results of the two compared methods are very similar, which confirms observations of Weber (1995). Even though the described visual method of pointer years determination is time consuming, its great advantage is the fact that it requires application of only stand threshold, which decreases the subjectiveness of the procedure.

Comparison to meteorological data

The applied procedure resulted in total amount of 11 meteorological pointer years in the period 1951-2000. Only two of them (1970 and 1976) are pointer years with respect to both, extreme temperature and precipitation. The remaining ones were characterised only with either unusual precipitation (3 cases) or temperature (6 cases). The received pattern of pointer years does not resemble the results of the dendrochronological analyses. Even the years that are distinctively recognised in tree-ring width series e.g. 1967 or 1992 (Vitas 2002, Koprowski and Zielski 2002, Bijak 2007) were not present in the investigation of the meteorological data. Although climate influences the formation of tree-rings to a large extent, event and pointer years may have very different causes and are not only the result of extraordinary weather conditions (Schweingruber et al. 1990). Moreover, if climate impact is considered, these are conditions in particular periods (e.g. months) that cause formation of the conspicuously wider or narrower rings. This great difference in pointer years obtained from dendrochronological and meteorological method disables the utilisation of the latter one as a supporting tool in pointer year determination.

Conclusions

Although the term ‘pointer year’ is quite clear as far as its definition is concerned, the different aspects of the determination process seem to require more detailed specification. The phenomenon of extraordinary wider or narrower tree-rings is very complex. The causes include not only extreme climate conditions, but also insect outbreaks, fires or physiological conditions (e.g. defoliation). As extreme conditions occur from time to time it is very difficult to state or assume the "right" number of such events. That is why there is, and probably will be, no answer to the question about the proper number of pointer years. However the issue of subjective application of various criteria in the determination methods that results in great differences in number and character of obtained pointer years and hence in difficulty in comparison of pointer years detected for different areas should be discussed widely. Agreement on the same method and applied criteria based rather on statistical bases than on subjective preferences of researcher will make pointer years analyses more objective as well as comparable and therefore available for more comprehensive utilisation.

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