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THE BENEFITS OF TREE-RING CURVES DETRENDING FOR DATING ARCHAEOLOGICAL WOOD

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Abstract: During the process of developing the standard chronology for oak for the Czech Republic, two versions of standard chronology were determined: the standard chronology developed using detrended tree-ring series and the standard chronology developed using non-detrended tree-ring series. These standard chronologies were applied to date detrended and non-detrended average tree-ring curves obtained from dendrochronological samples from selected archaeological locations. The highest values of the t-test were achieved when comparing the detrended or non-detrended average ring curves only and exclusively with the detrended standard chronology. Similarly, the highest percentage of the curve parallelism was always obtained in comparison with the detrended standard chronology. The confidence and, more importantly, the prediction intervals of the detrended ring curves are considerably smaller than those of the non-detrended ones. The regression curves of the detrended standardised values of the ring curves are more similar to the calibration curve than the non-detrended ones. The significance level of the regression models in the detrended ring curves is notably higher, than in the case of the non-detrended ring curves. The differences established between the detrended and non-detrended standard chronology have highlighted the importance to develop detrended standard chronologies.

Keywords: tree-ring, standard chronology, dendrochronology, detrending, oak

1. INTRODUCTION

Average tree-ring curves can be calculated directly from individual tree-ring curves of measured tree-ring widths. Subsequently, these average tree-ring curves can be used to establish a standard chronology. However, tree-ring characteristics are not only the result of the effect of climatic factors; the conditions at the location, the age of the tree, competition, etc. also play a role (Rybníček, 2007). Their influence usually results in a slow change in the growth trend with time. To a certain extent the growth trend is individual for each tree and thus weakens the common signal that is being searched for (Schweingruber, 1996). That is why it is vital to identify this non-climatic noise and remove it, so that the remaining signal represents the influence of climatic factors on growth as accurately as possible (Shiyatov *et al.*, 1989).

Standardization is thus a process of modelling and removing the age trend from a time series, which together with other procedures has the objective of creating a stationary series. In the process of standardization, a non-stationary tree-ring series is transformed into a stationary series of tree-ring indices, usually fluctuating around a value of zero. The non-standardized series show a strong interdependence between the average values of the rings and their standard deviation. This relationship is considerably weaker after standardization (Cook and Kairiukstis, 1990). Therefore, in many dendrochronological applications it is necessary to remove the trend in order to detrend the curves before the average series is established (Rybníček, 2007).

The main purpose is to find an answer to the question as to whether it is necessary to remove the trend of tree-ring curves for dendrochronological dating, and thus whether one should form standard chronologies using detrended tree-ring curves.

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Table 1. *The results of the correlation of the detrended and the non-detrended average tree-ring curves with the detrended and the non-detrended Czech oak standard chronologies CZGES 2005.*

Standard chronology	t-value according to Baillie & Pilcher	t-value according to Hollstein	Gleichläufigkeit (%)	Overlap (years)	End year
		Namesti Svobody Square non-det.			
CZGES 2005 non-det.	6.94	7.35	66	121	1241
CZGES 2005 det.	7.13	8.03	67	121	1241
		Namesti Svobody Square det.			
CZGES 2005 non-det.	6.99	7.4	66	121	1241
CZGES 2005 det.	7.21	8.08	66	121	1241

2. MATERIAL AND METHODS

During the process of developing the oak standard chronology for the Czech Republic two versions of standard chronologies were established: the standard chronology developed using detrended tree-ring series and the standard chronology developed using non-detrended tree-ring series (Rybníček, 2007).

To evaluate the necessity of detrending or non-detrending of tree-ring series and the development of standard chronologies out of the detrended tree-ring series four locations were chosen. The tree-ring widths of samples taken in these locations were measured. Then, the average tree-ring curves, both detrended and non-detrended, were formed and compared with the detrended and the non-detrended standard chronology in PAST4 (©Sciem) software. As the next step, the regression analysis of the data sets was carried out in the Statistica 7.1 (©StatSoft) application and the results were compared, especially the correlation coefficient, the confidence and the prediction intervals. For the comparison normed values were used. The norm was defined by the highest value of the research sample.

The detrending of partial tree-ring curves was carried out in the ARSTAN application (Grissino–Mayer *et al.*, 1992). To remove the age trend, the detrending was carried out in two steps (Holmes *et al.*, 1986). First, the negative exponential function or linear regression curve, which best express the change of growth trend with age, were used in dependence on the value of the determination index (Fritts *et al.*, 1969; Fritts, 1963). Other possible deviations of thickness increment values conditioned not by the climate, but brought about by the competition or the interventions of foresters, were balanced using the cubic spline function (Cook and Peters, 1981). The chosen length of the spline function was 32 years. Thanks to the use of the spline function, the accidental variability in tree-ring sequences was removed (Cook and Kairiusktis, 1990).

3. RESULTS

To provide examples of comparing the detrended and the non-detrended average tree-ring curves with the detrended and the non-detrended standard chronologies, only the results from two archaeological locations are presented; the results from the other locations were very similar. The selected results concern dendrological samples from the archaeological research of Namesti Svobody Square and Orli Street in Brno.

Namesti Svobody Square

When the dated curve overlaps the standard chronology by at least a hundred and twenty tree-rings, the Student's critical value of t-division with 0.1% significance level is 3.373 (Šmelko and Wolf, 1977). Student's t–test statistics are of considerably higher values than 3.373, which proves the high reliability of the dating. The highest Students's statistics t-test values are achieved when the detrended average tree-ring curve is compared with the detrended standard chronology. The highest parallelism (Gleichläufigkeit) of curves is achieved when the non-detrended average tree-ring curve is compared with the detrended standard chronology **(Table 1)**. This confirms the natural assumption that even the data after detrending retain a sufficient amount of common features with the original non-detrended values. The correctness of dating is also confirmed by the agreement of the standard chronology with the average tree-ring curve at most extreme values **(Fig. 1)**.

The prediction interval of the detrended tree-ring curves is considerably narrower than of the non-detrended ones. The regression curve of the detrended normed values of tree-ring curves is of a highly similar character to the calibration curve. By contrast, the regression curve of the non-detrended normed values of tree-ring curves is of a very different character in comparison with the calibration curve. The regression curve of the non-detrended normed values shows a considerable deviation from the calibration curve, which steadily increases. This deviation is the highest of all the presented examples. The regression curve of the detrended normed values also shows a deviation but this deviation increases slightly, and the maximum value of the deviation is negligible when compared to the non-detrended data **(Fig. 2** and **Fig. 3)**. The significance level of the regression model of the detrended tree-ring curves is considerable higher than of the non-detrended curves **(Table 2)**.

Orli Street

The overlapping of the dated curve with the standard chronology is again higher than a hundred and twenty tree-rings. Student's t-test statistics reaches values higher than the critical value with 0.1% significance level. The highest Student's t-test statistics values, and the highest curve parallelism (Gleichläufigkeit) are achieved when the detrended and the non-detrended average tree-ring curves are compared with the detrended standard chronology. When the average tree-ring curve is compared with the non-detrended standard chronology, the values

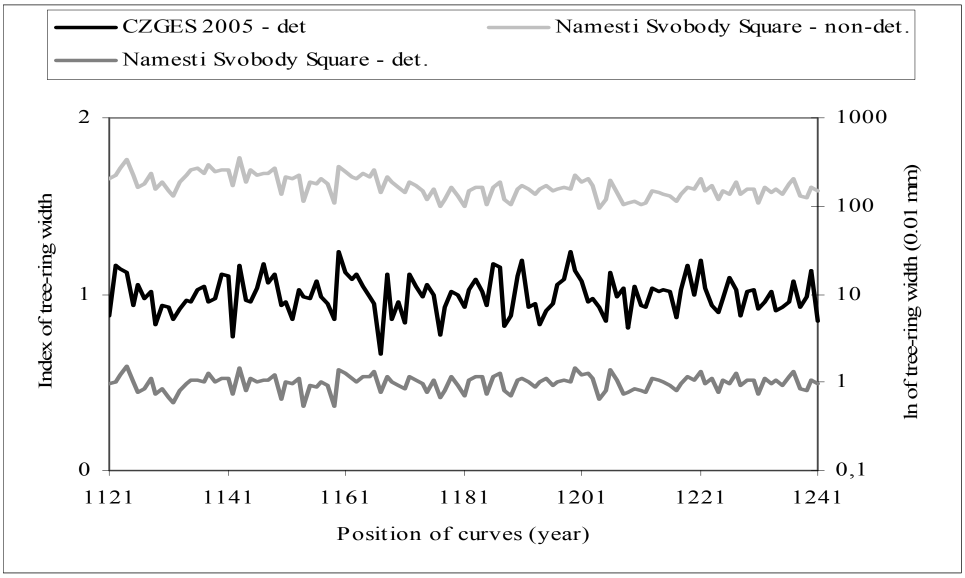

Fig. 1. *Synchronization of the average detrended and the average non-detrended tree-ring curves with the detrended Czech oak standard chronology CZGES 2005.*

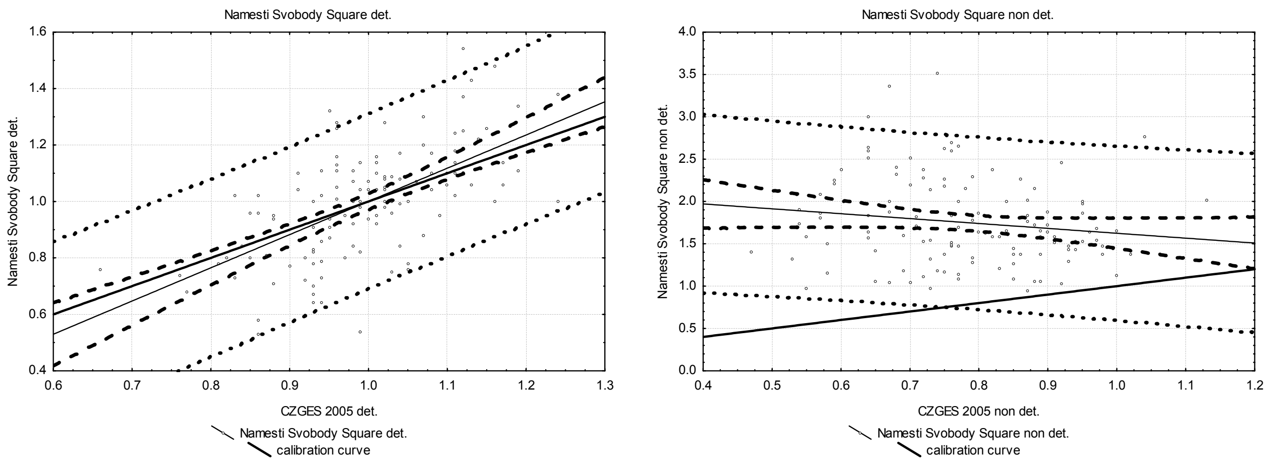

Fig. 2. *The comparison of the dependence of the detrended and the non-detrended average tree-ring curve regression functions progress on the detrended and the non-detrended standard chronologies with the calibration curve (the prediction and the confidence intervals of the function are marked).*

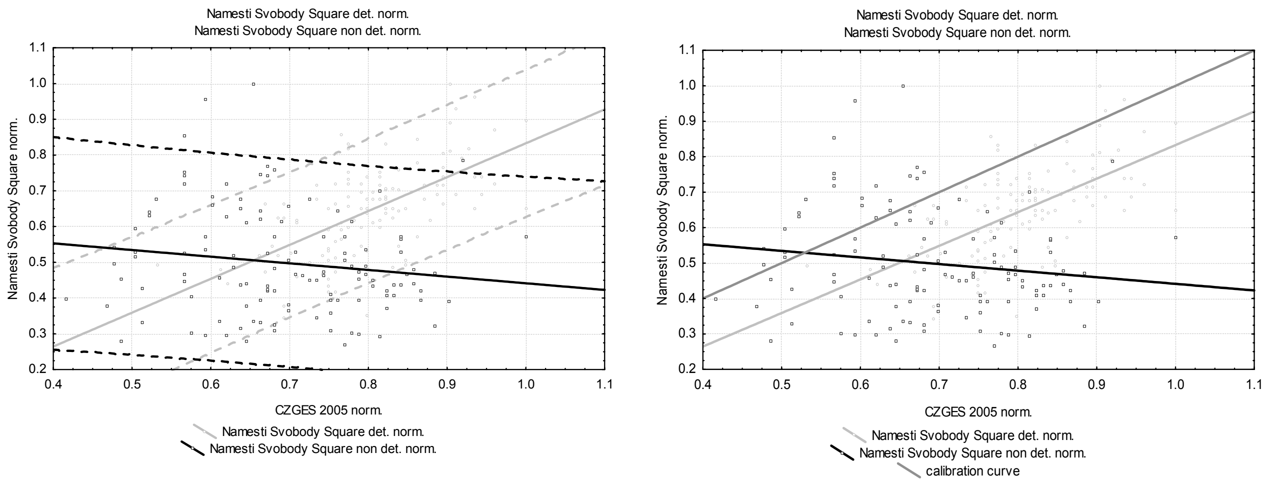

Fig. 3. *The comparison of the regression functions progress of the detrended tree-ring curve dependence on the detrended standard chronology with the dependence of the non-detrended tree-ring curve on the non-detrended standard chronology. The prediction intervals of the regression function (right) and the calibration curve (left) are marked.*

Table 2. *The results of the regression analysis of the values of the detrended and the non-detrended average tree-ring curves with the detrended and the non-detrended Czech oak standard chronology CZGES 2005 (R – correlation coefficient, p – model – regression model significance level, β – regression model linear dependence slope).*

		R	p – model	β
CZGES 2005 non-det.	Namesti Svobody Square non-det.	0.146	0.107	- 0.150
CZGES 2005 det.	Namesti Svobody Square det.	0.614	0	0.615

are lower **(Table 3)**. The standard chronology agrees with the average curve at most extreme values, which again shows the correctness of dating **(Fig. 4)**.

The confidence interval and mainly the prediction interval of the detrended tree-ring curves are considerably narrower, than of the non-detrended ones. The regression curve of the detrended normed values of tree-ring curves is of a more similar character to the calibration curve than the regression curve of the non-detrended normed values. The deviation of the regression curve of the detrended normed values of tree-ring curves increases slightly and the maximum value of the deviation is considerably lower in comparison with the non-detrended data **(Fig. 5** and **Fig. 6)**. The correlation coefficient of the detrended tree-ring curves is higher than of the non-detrended ones **(Table 4)**.

4. DISCUSSION AND CONCLUSIONS

The t-test results always considerably exceeded the critical value of Student's t-division with 0.1% significance level. The highest t-test values were achieved when the detrended or the non-detrended average tree-ring curves were compared with the detrended standard chronology. When these were compared with the non-detrended standard chronology, the t-test values were lower. The highest curve parallelism (Gleichläufigkeit) was achieved when the detrended or the non-detrended average tree-ring curves were compared with the detrended standard chronology. The correctness of the dating is also confirmed by the agreement of the standard chronology with the average tree-ring curves at most extreme values.

The confidence interval and mainly the prediction intervals of the detrended tree-ring curves are considerably narrower than of the non-detrended ones. The regression curves of the detrended normed values of tree-ring curves are of a similar character to the calibration curve. By contrast, the regression curves of the non-detrended normed values of tree-ring curves are of a very different character in comparison with the calibration curve. The

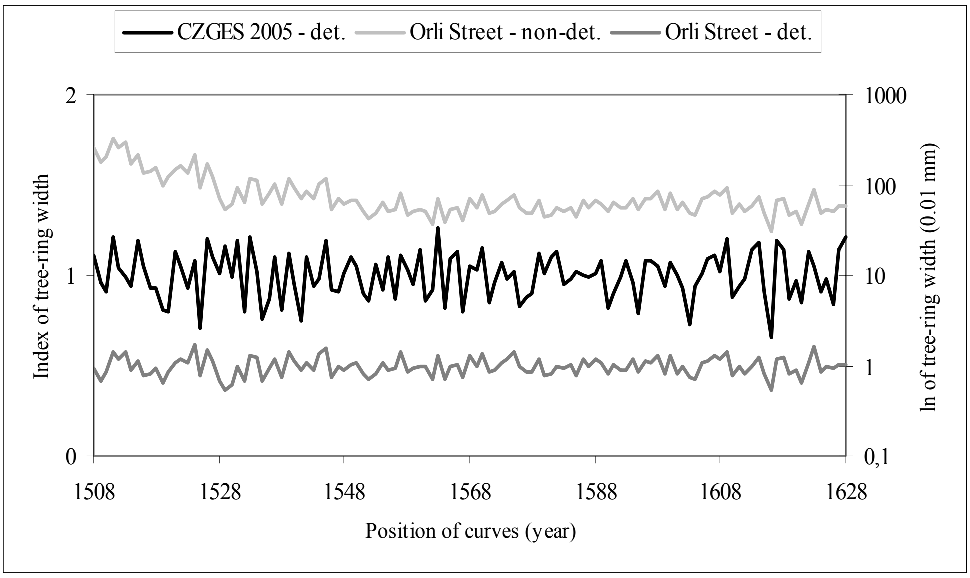

Fig. 4. *Synchronization of the average detrended and the average non-detrended tree-ring curves with the detrended Czech oak standard chronology CZGES 2005.*

Table 3. *The results of the correlation of the detrended and the non-detrended average tree- ring curves with the detrended and the non-detrended Czech oak standard chronologies CZGES 2005.*

Standard chronology	t-value according to Baillie & Pilcher	t-value according to Hollstein	Gleichläufigkeit (%)	Overlap (years)	End year
		Orli Street – non-det			
CZGES 2005 non-det.	11.92	11.9	73	121	1628
CZGES 2005 det.	12.11	12.28	74	121	1628
		Orli Street – det.			
CZGES 2005 non-det.	11.88	11.95	72	121	1628
CZGES 2005 det.	12.07	12.33	74	121	1628

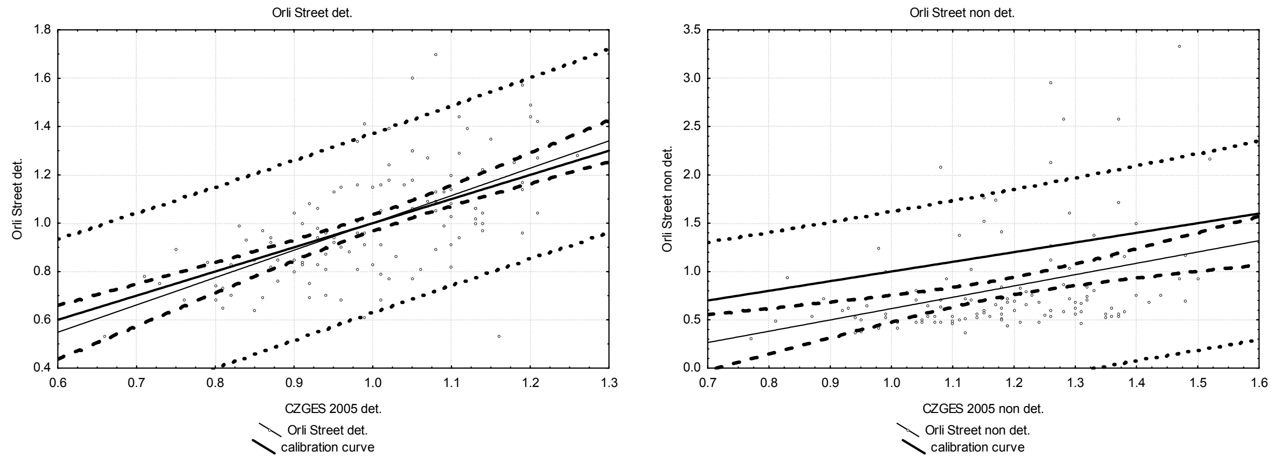

Fig. 5. *The comparison of the dependence of the detrended and the non-detrended average tree-ring curve regression function progress on the detrended and the non-detrended standard chronologies with the calibration curve (the prediction and the confidence intervals of the function are marked).*

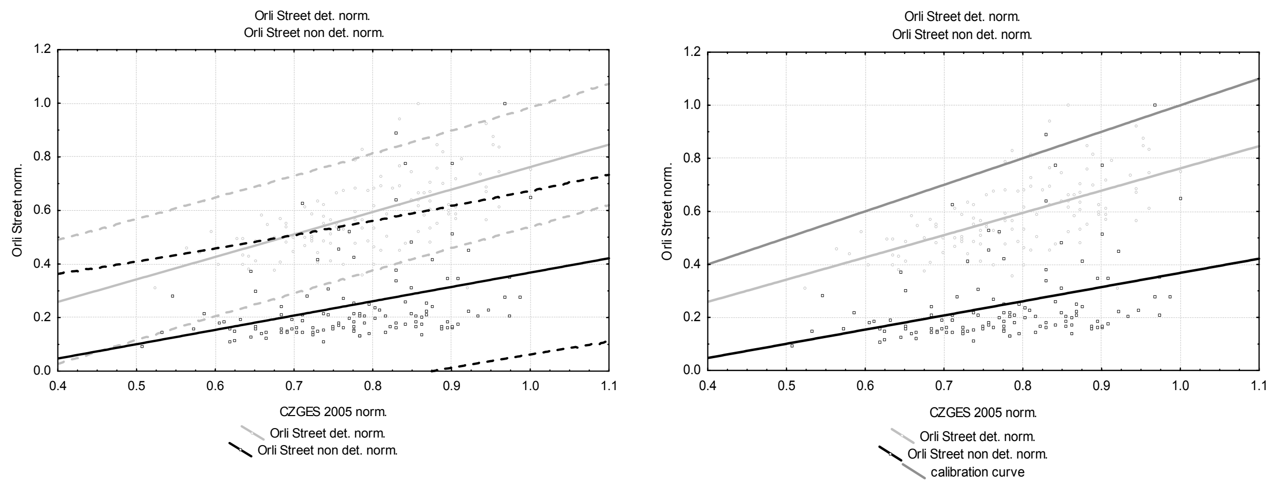

Fig. 6. *The comparison of the regression functions progress of the detrended tree-ring curve dependence on the detrended standard chronology with the dependence of the non-detrended tree-ring curve on the non-detrended standard chronology. The prediction intervals of the regression function (right) and the calibration curve (left) are marked.*

regression curve of the non-detrended normed values shows a considerable deviation from the calibration curve which steadily increases. The deviation of the regression curve of the detrended normed values increases slightly and the maximum value of the deviation is negligible when compared to the non-detrended data. The significance level of the regression models of the detrended tree-ring curves is considerably higher than of the non-detrended ones.

Table 4. *The results of the regression analysis of the values of the detrended and the non-detrended average tree-ring curves with the detrended and the non-detrended Czech oak standard chronology CZGES 2005 (R – correlation coefficient, p – model – regression model significance level, β – regression model linear dependence slope).*

		R	p – model	β
CZGES 2005 non-det.	Orli Street – non-det.	0.349	0.000086	0.349
CZGES 2005 det.	Orli Street – det.	0.608	0	0.609

The differences found between the detrended and the non-detrended standard chronologies have proved how important it is to develop the detrended standard chronologies.

The main benefit of using the detrended standard chronology is a higher information relevance of the detrended curves; this is due to lower variability of processed data according to measured dataset. Detrending is a way which affects the extent of variability and can extract the carrying signal (in statistical sense) essential for dendrochronological dating of archaeological finds from the data.

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