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Building of the oak standard chronology for the Czech Republic

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Introduction

The correct dating of a sample depends on the used standard chronologies. These are created for each tree species individually by continuous overlapping of tree ring sequences towards the past. Individual standard chronologies differ by the area and by the time interval for which they are usable. The created standard chronology reflects the climate of the certain period at maximum and the local growth conditions of individual included trees at minimum (Rybníček 2007).
The overwhelming majority of historical wooden constructions in the Czech Republic are made of soft wood; hard wood (almost exclusively oak wood) appears only rarely. However, there are some types of constructions (e.g. bell stools, bridge piers and harbour equipment, well timbering and waste traps) in which oak wood dominates. Oak wood is more often found in archaeological findings. The availability of the standard chronology for oak wood dating is as important as the already created standard chronologies for coniferous tree species (Rybníček et al. 2004).

Material and methods

The taking, processing and dating of samples have been carried out in accordance with the standard dendrochronological methods (Cook & Kairiukstis 1990). The data used to create the Czech oak standard chronology were obtained from subfossil trunks, archaeological findings, historical constructions and living trees from the entire area of the Czech Republic (Fig. 1).

Figure 1: The map of locations of samples used to create the standard chronology.

We can divide them into three groups. The base of the oak standard chronology for the CR was created in 1998–2001 by Jitka Vrbová-Dvorská in the Institute of Archaeology of the Academy of Sciences of the CR. The standard chronology was named CZGES 2001 and it includes the data from archaeological excavations – especially the data obtained through the archaeological research in Mikulcice, at Prague Castle and during the research of the Breclav castle tower (Dvorská 2001). The second group consists of the data provided by the Institute of Botany of the Academy of Sciences of CR (Tomáš Kyncl, Josef Kyncl). These data come from the material from historical constructions and ruins of significant castles (e.g. Karlstejn, Ryzmburk, Buchlov, Bezdez, Valdek). The last part of the data used to create the standard chronology comes from the

Dendrochronological Laboratory of the Department of Wood Science of Mendel University of Agriculture and Forestry Brno (Michal Rybníček). The data were mainly obtained in archaeological findings in the area of Brno and its surroundings (e.g. houses in Mecova street, Namesti svoboty, Cacovice weir and Modrice).

Tree-ring curves of individual trees are influenced by the growth trend. The trend is to a certain extent individual for each tree and that is why it weakens the demanded common signal (Schweingruber 1996). Therefore, the individual tree-ring curves have been detrended. To create the standard chronology, they were exported from PAST 32 to ARSTAN application (Grissino–Mayer et al. 1992), where they were detrended. 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 interventions of foresters were balanced using the cubic spline function (Cook & 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 & Kairiusktis 1990). The resulting index tree-ring series shows relatively high values of autocorrelation (the dependence of a tree-ring width on the widths of the previous tree-rings).

Then, the data were exported from Arstan to PAST 32 and the oak standard chronology for the CR was created out of well-synchronizable curves.

Four locations were chosen to evaluate the necessity of detrending or non-detrending of tree-ring series and the creation of standard chronologies out of detrended tree-ring series. The tree-ring sequences of samples taken in these locations were measured. Then the tree-ring curves, both detrended and non-detrended, were created and compared with the detrended and non-detrended standard chronology in PAST 32. As the next step, the regression analysis of the data sets was carried out in the Statistica 7.1 application and the results were compared, especially the correlation coefficient, the confidence and prediction intervals. For the comparison normed values were used. The norm was defined by the highest value of the selected file.

Results

191 average tree-ring series were used to create the oak standard chronology, which was named CZGES 2005. It covers the period from 462 A.D. to 2004 A.D. (Fig. 2).

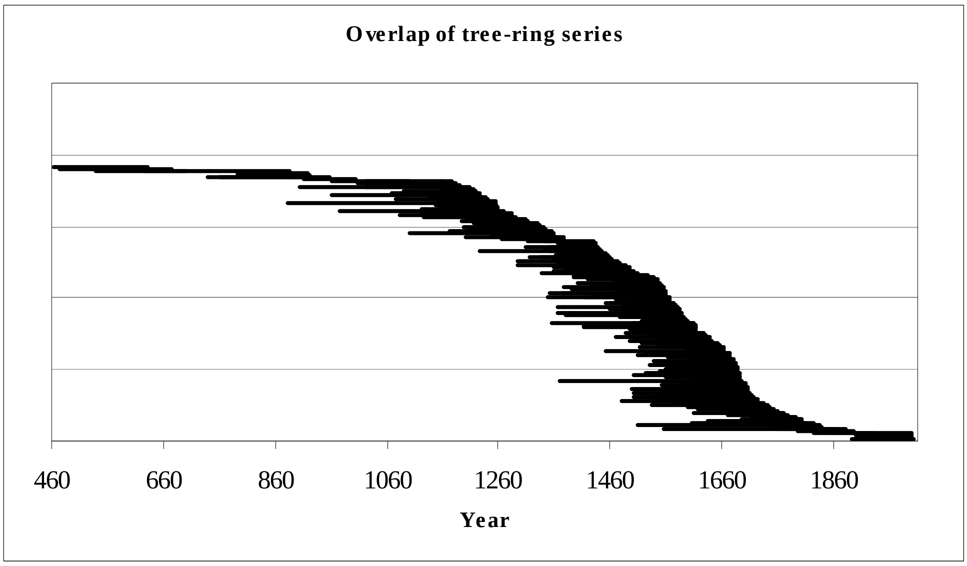

Figure 2: The range of individual average tree-ring series used to create the standard chronology of oak CZGES 2005

Two versions of the oak standard chronology CZGES 2005 were created – the standard chronology created out of detrended tree-ring series and the standard chronology created out of non-detrended tree-ring series (Fig. 3).
When these two versions of standard chronology were compared, the t-test values proved to be higher than ninety; however, there are some differences, especially in the areas where the standard chronology consists of a lower number of average tree-ring series. This is also confirmed by the value of Gleichläufigkeit being 91 %.

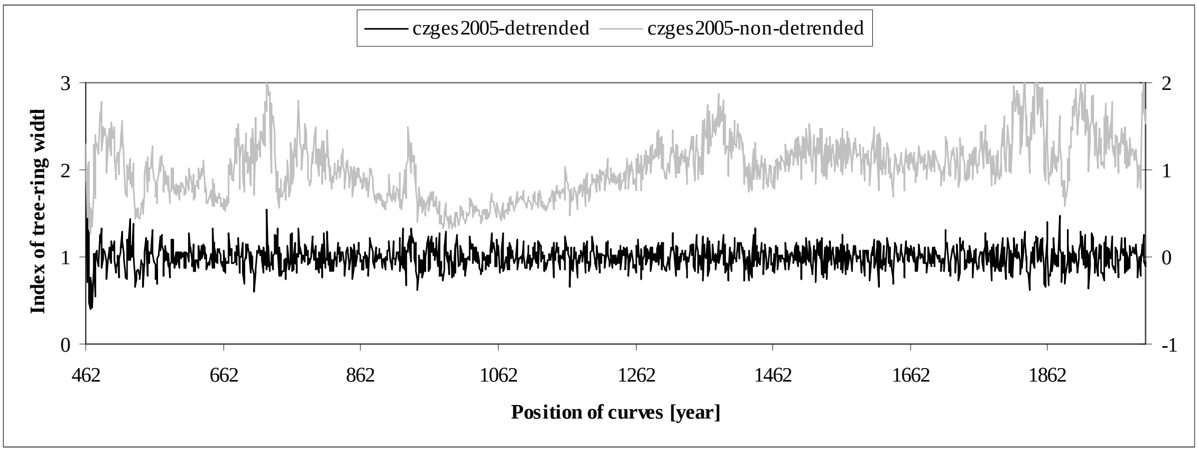

Figure 3: The synchronization of the detrended standard chronology CZGES2005 (black) with the non-detrended standard chronology CZGES 2005 (grey) for the period from 462 A.D. – 2004 A.D.

There were used oak standard chronology for Brandenburg (Heußner & Westphal 1998), oak standard chronology for South Germany (Becker 1981), oak standard chronology for Eastern Austria (Wimmer & Grabner 1998) and oak standard chronology for Silesia (Krapiec 1998) for comparison with the newly created standard chronology CZGES 2005. The statistical data show very high values. The highest values of statistical indicators appear when the standard chronology CZGES 2005 is compared with the East-Austrian standard chronology OstOestQP, the t-values being 24 and 25 and the Gleichläufigkeit 75 % with the overlap of 807 years for the detrended standard chronology and the t-values being 23 and 24 and the Gleichläufigkeit 73 % for the non-detrended standard chronology. The lowest values of statistical indicators appear when the standard chronology CZGES 2005 is compared with the Brandenburg standard chronology Branges, the t-values being 14 and the Gleichläufigkeit 65 % with the overlap of 1529 years for the detrended standard chronology and the t-values being 13 and the Gleichläufigkeit 64 % for the non-detrended standard chronology (Tab. 1).

Table 1: The statistical comparison of CZGES 2005 with the surrounding European standard chronologies of oak (black values for the detrended standard chronology and grey values for the non-detrended standard chronology)

	Standard chronology							
	Brandenburg (Branges)		South Germany (Sued2ges)		Eastern Austria (OstOesQP)		Silesia (DSL1)	
t-value according to Hollstein	14	13	17	16	24	23	20	18
t-value according to Baillie & Pilcher	14	13	18	17	25	24	19	18
Gleichläufigkeit [%]	65	64	66	65	75	73	68	67
Overlap [years]	1529		1489		807		1215	

To verify the validity of the newly created standard chronology CZGES 2005 and to compare the detrended and the non-detrended standard chronologies, samples from four locations were chosen – two archaeological locations in Namesti svobody in Brno (A30/05 and A93/05), research at 16 Orlí street and the construction of the Olsovec pond outlet in Jedovnice. Only the results from the first archaeological location in Namesti svobody (A30/05) are presented as an example; however, the results from the other locations were very similar.
When the dated curve overlaps the standard chronology by at least sixty tree-rings, the Student's critical value of t-division with 0.1 % significance level is 3.46 (Šmelko – Wolf 1977). Values of t–tests are much higher than 3.46, which proves the high reliability of the dating. The highest t-test values are achieved when the detrended and 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 of t-tests are lower. The highest curve Gleichläufigkeit is achieved when the non-detrended average tree-ring curve is compared with the detrended standard chronology (Tab. 2). 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. 4).

Table 2: 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 chronology CZGES 2005.

Standard chronology	*t*-value according to Baillie & Pilcher	*t*-value according to Hollstein	Gleichläufigkeit [%]	Overlap [years]	Year
Náměstí svobody A30/05 – 400 non-det.					
CZGES 2005 non-det.	6.37	7.6	72	94	1241
CZGES 2005 det.	6.93	8.53	75	94	1241
Náměstí svobody A30/05 – 400 det.					
CZGES 2005 non-det.	6.39	7.71	65	94	1241
CZGES 2005 det.	6.92	8.62	69	94	1241

Figure 4: The synchronization of the average detrended and non-detrended tree-ring curves with the detrended Czech oak standard chronology CZGES 2005

The confidence and mainly the prediction intervals of detrended tree-ring curves are considerable narrower than those of the non-detrended ones. The regression curve of detrended normed values of tree-ring curves is of a very similar character as the calibration curve. On the other hand, the regression curve of non-detrended normed values of tree-ring curves is of a very different character in comparison with the calibration curve. There is a significant, ever-increasing deviation from the calibration curve at the regression curve of non-detrended normed values. The increase of the deviation of the regression curve of detrended normed values of tree-ring curves is gradual and the maximum value of the deviation is negligible in comparison with non-detrended data (Fig. 5, fig. 6). The significance level of the regression model of detrended tree-ring curves is considerably higher than of non-detrended tree-ring curves (Tab. 3).

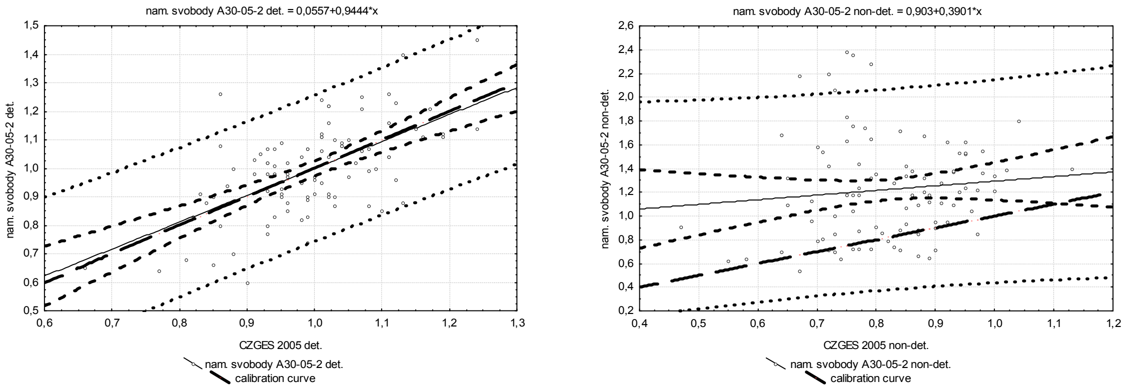

Figure 5: The comparison of the dependence of the progress of detrended and non-detrended tree-ring curves regression function on the detrended and non-detrended standard chronologies with the calibration curve (the prediction and confidence intervals of the function are marked in the graph).

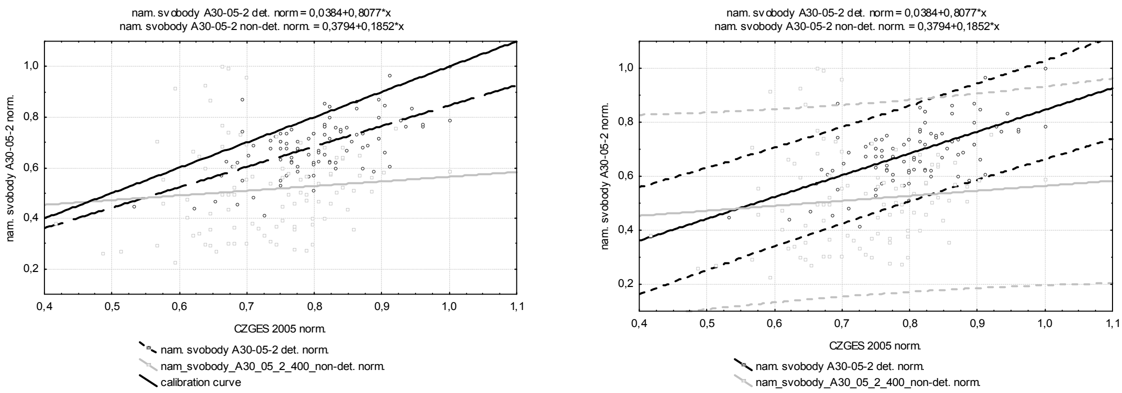

Figure 6: The comparison of the regression functions of the dependence of the detrended tree-ring curve on the detrended standard chronology with the dependence of the non-detrended tree-ring curve on the non-detrended standard chronology. The prediction intervals of the regression function (right) and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

Table 3: The results of the regression analysis of the values of detrended and non-detrended average tree-ring curves with the detrended and 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.	A30/05 – 400 non-det.	0.10617385	0.308439	0.106
CZGES 2005 det.	A30/05 – 400 det.	0.60490529	0	0.605

Discussion and Conclusions

The main aim of this work was to create a national oak standard chronology. The CZGES 2005 standard chronology, which functions as a oak standard chronology for the Czech Republic, has been made up on the basis of 191 average tree-ring series and covers the periods from 462 AD – 2004 AD. This standard chronology correlates perfectly with the standard chronologies developed in the surrounding countries. So far there has been no single national oak standard chronology that would encompass the oak data gathered all over the Czech Republic, and so it has been very difficult to process any oak sample files. Now that the oak standard chronology is available, dating of the oak samples collected on the territory of the Czech Republic can be done with a much greater precision. The standard chronology enables us to reflect - with the highest possible precision - the effects of the environment in which a particular tree has grown and which are typical of its particular location. Moreover, it will be possible to date those samples that due to the missing standard chronology have not been dated so far. Currently, the standard chronology enables dating of a vast majority of the oak wood found during the archaeological excavation and exploration works carried out in the historic buildings in the Czech Republic.

The CZGES 2005 oak standard chronology has filled a gap in the European network of oak standard chronologies. The standard chronologies should be used not only in the countries of their origin but also in the adjacent regions where the historic works of art were frequently exported (Krapiec 1998).

In addition to the aim stated above, the study was focused on the comparison between the detrended and non-detrended standard chronologies. The differences established between the detrended and non-detrended standard chronology have shown only too clearly how important it is to develop the detrended standard chronologies. 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 Gleichläufigkeit was always established in comparison with the detrended standard chronology. The confidence and, more importantly, the prediction intervals of the detrended ring curves are considerably shorter 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. 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.

All data used for the creation of the oak standard chronology are available in the database of dated objects, which is regularly updated and accessible on the web site www.dendrochronologie.cz.

There is only one way to prolong the existed standard chronology and that is dendrochronological dating of subfossil wood.

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