

Dendrochronology of oak (*Quercus* spp.) in Slovenia – an interim report

K. Čufar¹, M. Zupančič¹, L. Krže¹, M. de Luis² & D. Eckstein³

¹ University of Ljubljana, Biotechnical Faculty, Dept. of Wood Science and Technology, Rozna dolina, Cesta VIII/34, SI-1000 Ljubljana, Slovenia

² University of Zaragoza, Dept. Geografía y O.T., C/Pedro Cerbuna 12, E-50009 Zaragoza, Spain

³ University of Hamburg, Dept. of Wood Science, Division Wood Biology, Leuschnerstr. 91, D-21031 Hamburg, Germany
E-mail: katarina.cufar@bf.uni-lj.si

Introduction

The aim of our contribution is to survey the present state and future challenges of oak dendrochronology in Slovenia, a region that was until recently considered sub-optimal for the assembly of an oak reference tree-ring chronology and for using it for various purposes such as climate reconstruction and dating historical buildings or archaeological wood.

Oak - mainly represented by pedunculate (*Quercus petraea*) and sessile oak (*Q. robur*) - is the most important wood in European cultural heritage and dendrochronology. Currently, several multi-millennial chronologies of different tree species are in existence but the Central European oak chronology, reaching back to 8480 B.C. (Friedrich *et al.* 2004) is, for the time being, the longest tree-ring chronology in the world (for recent reviews see Čufar 2007, Haneca *et al.* 2009).

Recently, we assembled a 548-year long regional oak chronology for SE Slovenia which covers the period A.D. 1456-2003 (Čufar *et al.* 2008c). It is based on wood from living trees and historic constructions and proved to correlate significantly with local and regional oak chronologies up to 700 km apart in Austria, Hungary, Serbia, Czech Republic and South Germany. It also showed a good heteroconnection (agreement with chronologies of other tree species) with beech (*Fagus sylvatica*), ash (*Fraxinus excelsior*), and silver fir (*Abies alba*) in SE Slovenia.

A dendroclimatic analysis showed that tree-ring width variations in Slovenian oaks are highly significantly correlated with June precipitation (positive) and temperature (negative) (Čufar *et al.* 2008b, 2008c). That is why this chronology was used to reconstruct June climate conditions over the last five centuries by applying the De Martonne aridity index (Čufar *et al.* 2008b). The reconstructed past climate anomalies in terms of negative and positive deviations from the long-term mean helped us to identify 50 years with a likely dry and hot June, as well as 40 years with a likely wet and cool June. Historic sources and chronicles used to validate the reconstruction in the pre-instrumental period (before 1896) confirmed that ten years with a strong negative deviation of the aridity index coincide with years of drought, extremely hot summers or crop failures. In contrast, five years with strong positive deviations of the aridity index correspond to years with cool and rainy summers (Čufar *et al.* 2008b).

Significant teleconnections of the Slovenian oak chronology with chronologies of remote sites indicate that oak growth in Europe is driven and controlled by a common factor - climate. On the other hand, the positive and negative deviations from the average tree-ring width, identified in the Slovenian oak tree-ring chronology, do not exactly coincide with corresponding deviations in central and western Europe, expressed for instance by the pan-European signature years of oak (Kelly *et al.* 2002).

Since we consider tree-ring chronologies as 'living organisms', we continue to improve and prolong the Slovenian oak chronology with the aim to use it for various purposes. In this contribution we present recently investigated and dendrochronologically dated wooden objects of the Slovenian cultural heritage. We discuss the importance of these objects to improve the Slovenian regional oak chronology and on the likelihood to prolong it and to use it for the development of dendrochronological research in neighbouring countries.

Material and Methods

We investigated 16 wooden rural buildings, mainly hay racks and houses in the Dolenjska region, around Novo mesto in SE Slovenia (approx. 45°48'N, 15°11' E) in co-operation with the Institute for the Protection of Cultural Heritage, Basic Unit Novo mesto.

We collected data on these objects, evaluated the stand of their preservation and characteristics of wooden constructions, identified the wood species, and performed dendrochronological analyses. The samples for dendrochronology were collected by coring or sawing. The number of samples per building varied in accordance with the availability and characteristics of the timbers.

The wood samples were then polished and the tree-ring widths measured to the nearest 0.01 mm. The tree-ring series were visually and statistically cross-dated and compared with each other. We then established non-detrended, raw-data chronologies for each building and cross-dated them with the oak chronology of SE Slovenia (Čufar et al. 2008c) using standard dendrochronological procedures.

Results and Discussion

Oak (*Quercus petraea* and *Q. robur*) was the dominant wood in all buildings. For each of the buildings we constructed a tree-ring chronology based on 2 to 9 tree-ring series. The time spans of these object-chronologies, their 'sample depth', and the parameter of cross-dating (t-value after Baillie and Pilcher 1973) with the SE Slovenian oak chronology are presented in Figure 1a.

The length of the chronologies of buildings was 54 to 219 years; altogether they span the period from 1655 to 1966. The oldest building is dated to 1788 and the youngest to 1966. The end dates of the object-chronologies in most cases represent a *terminus post quem* since at least few outermost tree rings were usually missing.

The dating shows that some wooden constructions are still original whereas others have been thoroughly renovated. The determined age of the buildings helped to evaluate their importance and to include them into the list of monuments of cultural heritage of the Republic of Slovenia.

The tree-ring chronologies of all buildings investigated fall within the time span covered by the Slovenian regional chronology (1456-2003) and do not contribute to extend it further back into the past. Nevertheless, they can help to improve its replication. Our work in the last years showed that wood having grown before 1500 is extremely rare in rural buildings. Therefore, other sources of old wood should be found to prolong the chronology. Such older timbers seem to be preserved in castles. The constructional timber in the castle Pišce (located near the border with Croatia), for instance, already helped to extend the Slovenian regional oak chronology, even if only for some years, to A.D. 1442 (Čufar et al. 2008c).

Since the building timbers originated from local forests, the chronologies assembled are local in nature. Such local chronologies are important for dendro-provenancing studies – a new sub-field of tree-ring research (Eckstein & Wrobel 2007). The dating of a ship wreck found near Venice (Fig. 1b, white circle SW from Ljubljana) confirmed the possibility of dating and dendroprovenancing (Martinelli & Čufar, unpubl.)

The map (Fig. 1b) shows the location of the buildings in the area which corresponds with the area of the Slovenian oak chronology (black squares) and locations of chronologies in Austria, Hungary, Italy (white circles), and Serbia (black spot near Beograd) that could be successfully cross-dated with the Slovenian oak chronology (Čufar et al. 2008c, Grabner, Grynaeus, Morgos personal communication).

Until recently there was nearly no information on tree-ring characteristics of oaks from Croatia but co-operation with Croatian archaeologists, where during an initial study no wood appropriate for dendrochronological dating was found (Čufar et al. 2006), lead to first encouraging results. There were successfully dated timbers in the Varaždin Old Castle (Čufar & Šimek 2008) and in Torečec gradić (Čufar et al. 2008a)(Fig. 1b, black spots NE of Zagreb). The dating of these timbers in Croatia to 1415 and 1263 (*terminus post quem*) was only possible in co-operation with the

dendrochronological laboratory of the University of Natural Resources and Applied Life Sciences, Vienna, Austria where an over 800-year long oak chronology has been assembled (Wimmer & Grabner 1998). Since this Austrian chronology and the Slovenian regional one cross-date well ($t_{BP}=9.7$), in future both of them could act as powerful reference chronologies for establishing a chronology network in the area south and southeast of the Alps.

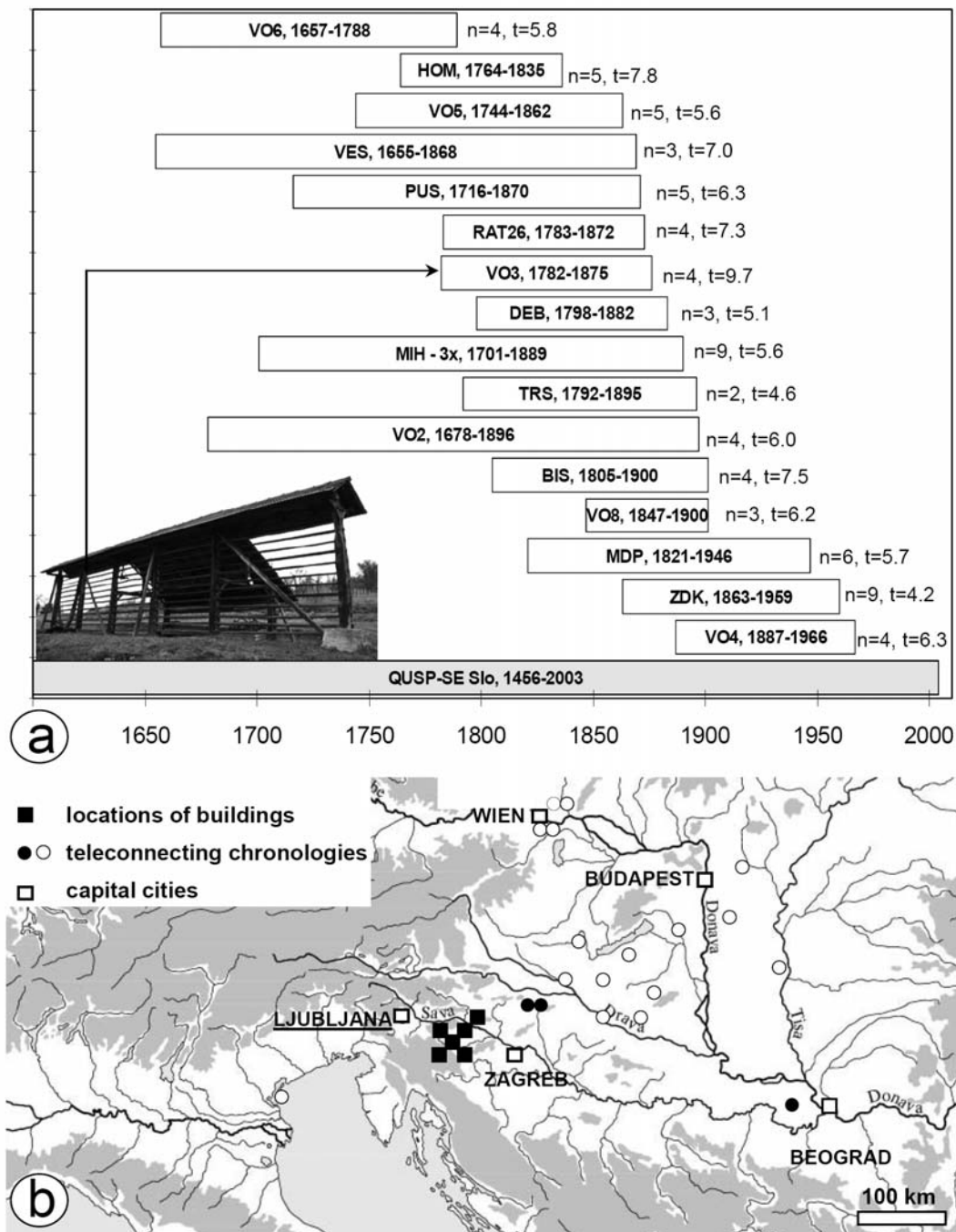


Figure 1: (a) Time spans of the object-chronologies of 16 wooden buildings in SE Slovenia dated with the Slovenian oak chronology. For each of the buildings the following information is given: code of the building, time span of the chronology, number n of samples included in the chronology, and t -value after Baillie and Pilcher for comparison with the Slovenian oak reference chronology (QUSP-SE Slo). The inset shows a typical hay rack dated 1875. (b) Map of the sampling area with locations of buildings (black squares) and chronologies constructed by the laboratories in Austria, Hungary, Italy (white circles) and Slovenia (black circles) that were teleconnected significantly to the Slovenian regional chronology. Map ZRC SAZU.

In search to prolong the Slovenian oak chronology we found considerable amounts of wood in the Ancient Roman period (Horvat, Tolar & Čufar, unpubl.) and in prehistoric pile dwellings that mainly existed from 3500 to 2500 B.C. (Velušček & Čufar 2002); these hitherto 'floating' tree-ring chronologies are for now dated by radiocarbon only.

In future, co-operation between laboratories in a wider region would be necessary to fill the spatial and chronological gaps and to establish a network of regional oak chronologies.

Acknowledgements

The work was coordinated by Dušan Strgar and Dušan Štepec, conservers of the ZVKDS OE Novo mesto (=Institute of the Republic of Slovenia for the Protection of Cultural Heritage, Basic Unit Novo mesto). Investigations were part of the graduation theses of students. The authors would like to acknowledge the Slovenian Research Agency for financial support within the framework of the P4-0015 programme.

References

- Baillie, M.G.L., Pilcher, J.R. (1973): A simple cross-dating program for tree-ring research. *Tree-Ring Bulletin* 33: 7-14.
- Čufar, K. (2007): Dendrochronology and past human activity- A review of advances since 2000. *Tree-Ring Research* 63 (1): 47-60.
- Čufar, K., Šimek, M. (2008). Dendrochronological investigation of wood from Varaždin Old Castle. *Podravina* 7 (13): 22-29.
- Čufar, K., Korenčič, T., Trajković, J. (2006): Drvo s tri arheološka nalazišta u Hrvatskoj i mogućnosti njegova istraživanja (= Wood from three archaeological sites in Croatia and its research potential). *Drvna industrija* 57 (2): 67-73.
- Čufar, K., Sekelj Ivančan, T., Grabner, M. (2008a): The dendrochronological dating of wood from the site of Torčec–Gradić in northern Croatia. *Podravina* 7 (13): 30-40.
- Čufar, K., de Luis, M., Eckstein, D., Kajfež-Bogataj, L. (2008b): Reconstructing dry and wet summers in SE Slovenia from oak tree-ring series. *International Journal of Biometeorology* 52: 607-615.
- Čufar, K., de Luis, M., Zupančič, M., Eckstein, D. (2008c): A 548-year long tree-ring chronology of oak (*Quercus* spp.) for SE Slovenia and its significance as dating tool and climate archive *Tree-Ring Research* 64 (1): 3-15.
- Eckstein, D., Wrobel, S. (2007): Dendrochronological proof of origin of historic timber – retrospect and perspectives. Proc. of the Symposium on Tree Rings in Archaeology, Climatology and Ecology, April 20-22, 2006 in Tervuren, Belgium. *Schriften des Forschungszentrums Jülich, Reihe Umwelt/Environment* 74: 8-20.
- Friedrich, M., Remmele, S., Kromer, B., Hofmann, J., Spurk, M., Kaiser, K.F., Orcel, C., Küppers, M. (2004): The 12,460-year Hohenheim oak and pine tree-ring chronology from Central Europe - a unique annual record for radiocarbon calibration and paleoenvironment reconstructions. *Radiocarbon* 46(3):1111–1122.
- Haneca, K., Čufar, K., Beeckman, H. (2009): Oaks, tree-rings and wooden cultural heritage: a review of the main characteristics and applications of oak dendrochronology in Europe. *Journal of Archaeological Science* 36: 1-11.
- Kelly, P.M., Leuschner, H.H., Briffa, K.R., Harris, I.C. (2002): The climatic interpretation of pan-European signature years in oak ring-width series. *Holocene* 12:689–694.
- Velušček, A., Čufar, K. (2002): Dendrokronološke raziskave kolišč na Ljubljanskem barju - stanje 2001(=Dendrochronological investigation into the pile-dwelling settlements of the Ljubljana Marshes - the situation in 2001). *Arheološki vestnik* 53: 59-67.
- Wimmer, R., Grabner, M. (1998): Standardchronologien in Österreich als Basis für die dendrochronologische Datierung. *Archäologie Österreichs* 9(2):79–85.