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Coppice fingerprints in growth patterns of pedunculate oak (*Quercus robur*)

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Introduction

Coppice is an ancient form of sustainable woodland management which provides both fuel wood as well as small-dimensional timber. The technique has been described as early as the Roman Era, amongst others by Cato and Columella (Meiggs 1982), but might be in use ever since the Neolithic age (Rackham 2003). It is a silvicultural system which relies on trees that are able to resprout after being cut periodically. With the decline in wildwoods over the ages, coppice management gained more importance, especially in the densely populated areas of North-Western Europe (Buis 1985, Vera 2000, Rackham 2003). Two important coppice systems are simple coppice and coppice with standards. In simple coppice, trees are grown as a single storey even-aged crop and cut after a certain period, defined as coppice cycle - the remaining stools form new sprouts which eventually replace the harvested poles. In the coppice with standard system there are different storeys. Next to the even-aged underwood there are taller trees - the standards - which are allowed to grow for several coppice cycles to provide timber. Coppice cycles normally differ between four and twenty-five years, depending on product, growth and demand (Boer 1857, Harmer & Howe 2003, Rackham 2003). One of the most important species used in coppice systems in North-Western Europe was pedunculate oak (*Quercus robur*) as it provided valuable tanbark as well as fuel wood and timber.
Nowadays, the reconstruction of past-woodland utilisation has become an interesting topic, especially in archaeology and landscape history. Different studies have been conducted on ancient wooden artefacts to derive information on past forest management (e.g. Billamboz 1990, 2003, 2008, Haneca et al. 2005). Small dimensional, even-aged wood with a limited number of annual rings (Fig. 1) is frequently found in excavations (e.g. Billamboz 2008, Haneca et al. 2005, 2006). Growth patterns in these wooden remains often reflect vigorous juvenile growth - wide rings around the pith – followed by a steep decline a few years later. Based on these observations, these wood remains are frequently categorised as originating from coppice systems (Spurk 1992, Haneca et al. 2005, 2006). If such growth characteristics are indeed indicative for coppice management, interesting information can be retrieved on past forest usage. However, no systematic study has yet been conducted to prove significant differences in growth patterns between trees from coppice systems and trees evolving from seeds. On the contrary, there are indications that the age trend in oak is not a reliable indicator of (past) forest management as climate, stand density and other environmental variables can have an overriding influence on the tree-ring pattern at least after some years (Copini et al. 2007a, b).
In this study, multiple generations of contemporary oak coppice (*Quercus robur*) in two nearby woodlands with similar soil types are systematically investigated, considering stem and stool densities and the social status of the stems, with a view to validating whether coppice management can be detected from juvenile growth patterns.

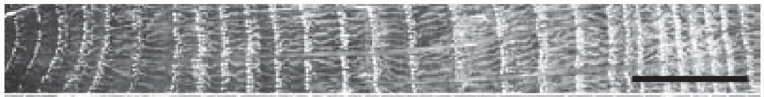

Figure 1: Ring-width pattern of a cross-section from an archaeological excavation. The growth pattern shows wide rings and possibly reflects a coppice origin. The scale bar represents 1 cm (Source: Haneca et al. 2006).

Material and methods

Study sites and sampling

The two selected woodlands Laarsenberg and Noordberg are located in the centre of The Netherlands at a distance of 12 km from each other and are both located on sandy soils (Fig. 2). In October and November 2008, different generations of coppice were selected in both woodlands – at the Laarsenberg three and at the Noordberg two generations (Tab. 1).

Figure 2: Location of the woodlands Laarsenberg (L) and Noordberg (N) in The Netherlands.

The number of coppice stools and sprouts per site (living and dead) was estimated by recording all stems and coppice stools in at least five randomly located 5-meter radius circles. Stem disks were taken at a height of 40 cm from 10 randomly selected dominant stems per site - only dominant stems were sampled to decrease variation due to different social positions. Furthermore, it is expected that dominant stems are more frequently used as timber and therefore more frequently found in excavations. The DBH and height of the selected stems were recorded. The stem disks were prepared using Stanley knives and razor blades. Ring width and earlywood (EW) width of two radii were measured and analyzed with a precision of 1/100 mm (LINTAB: Rinntech) in combination with TSAP software (Rinn 1996). To examine the age trends, the average radial growth was computed chronologically and according to cambial age.

Table 1: Site characteristics of the coppice sites at the Laarsenberg and at the Noordberg.

Coppice Site	Age/year of resprouting	Coppice stools per ha	Sprouts per ha living / dead	DBH ± SD (cm)	Stem height (m)	Ave. ring width ± SD (mm)	Ave. ring width first 5 yrs ± SD (mm)
Laarsenberg 1	8 / 2001	1298	8225 / 0	3.5 ± 0.7	4.82 ± 0.33	2.47 ± 0.44	2.50 ± 0.35
Laarsenberg 2	27 / 1982	1591	1957 / 2626	10.8 ± 2.3	12.22 ± 1.06	2.08 ± 0.86	2.59 ± 0.39
Laarsenberg 3	32 / 1977	1564	1837 / 1601	16.6 ± 4.3	14.59 ± 1.86	2.76 ± 0.64	2.92 ± 0.20
Noordberg 1	22 / 1987	1167	1655 / 2653	9.8 ± 2.4	9.77 ± 1.43	2.69 ± 0.81	2.13 ± 0.93
Noordberg 2	29 / 1980	1167	1994 / 1528	13.8 ± 2.6	12.13 ± 1.31	2.31 ± 0.58	2.15 ± 0.47

Results and Discussion

Characteristics of oak coppice in the woodlands Laarsenberg and Noordberg.

In November 2008 the number of coppice stools per hectare per site has been estimated between 1167 and 1591 and is slightly lower at the Noordberg than at the Laarsenberg (Tab. 1). In the most recently cut coppice site (Laarsenberg 1) the estimated number of sprouts per hectare reaches 8225, 8 growing seasons after the last harvest (in 2001) and no dead sprouts were detected. In the sites where the last cutting campaign took place between 22 and 32 years ago, less than 2000 living sprouts occur and many more dead stems were recorded (Tab. 1). The youngest, 8-year old, coppice sprouts of the Laarsenberg 1 site were on average 4.82 m high with an average diameter of 3.5 cm, while the oldest and highest stems (Laarsenberg 3) were 14.59 m in height and 16.6 cm in width (DBH). The average radial growth of the dominant stems in the coppice sites ranges from 2.08 mm (Laarsenberg 2) to 2.76 mm (Laarsenberg 3) and is not substantially different between both woodlands (Tab. 1). The average radial growth in the first formed 5 rings around the pith is slightly higher at the Laarsenberg sites, with 2.92 mm per year as the highest average ring width at the Laarsenberg 3 site (Tab. 1).

Is there a coppice fingerprint in ring-width patterns?

In figure 3, average ring-width patterns are shown for the three Laarsenberg and two Noordberg coppice sites. The year-to-year (high frequency) variation in growth is similar both within as well as between woodlands. When the time series are aligned and plotted according to cambial age (Fig. 4) it becomes obvious that no consistency in growth trends exists within and between woodlands. There are sites showing a strong decrease in tree-ring width, either instantly after the first year (nb2) or after about 10 years (lb2) and there are sites with relatively stable growth (lb1 & lb3). When growth patterns of individual stems are taken into account, the variation even increases.

Although the first rings surrounding the pith are on average quite wide (Tab. 1, Fig. 2 & 3) hence reflecting vigorous juvenile growth, the pattern in ring width proved to be highly variable and therefore not applicable as a fingerprint of coppice management. Even when trees are grown under similar conditions with regard to soil type, stem and stool density as well as social status, the patterns in ring widths during the first five to ten years - but also the growth trend in the whole time series - fail to reflect a common specific pattern that could be linked to the coppice origin of the stems. The similarity in high-frequency variation between the ring-width series within and between the two woodlands (Fig. 3) suggests that environmental factors such as climate, have a major influence on the tree-ring pattern.

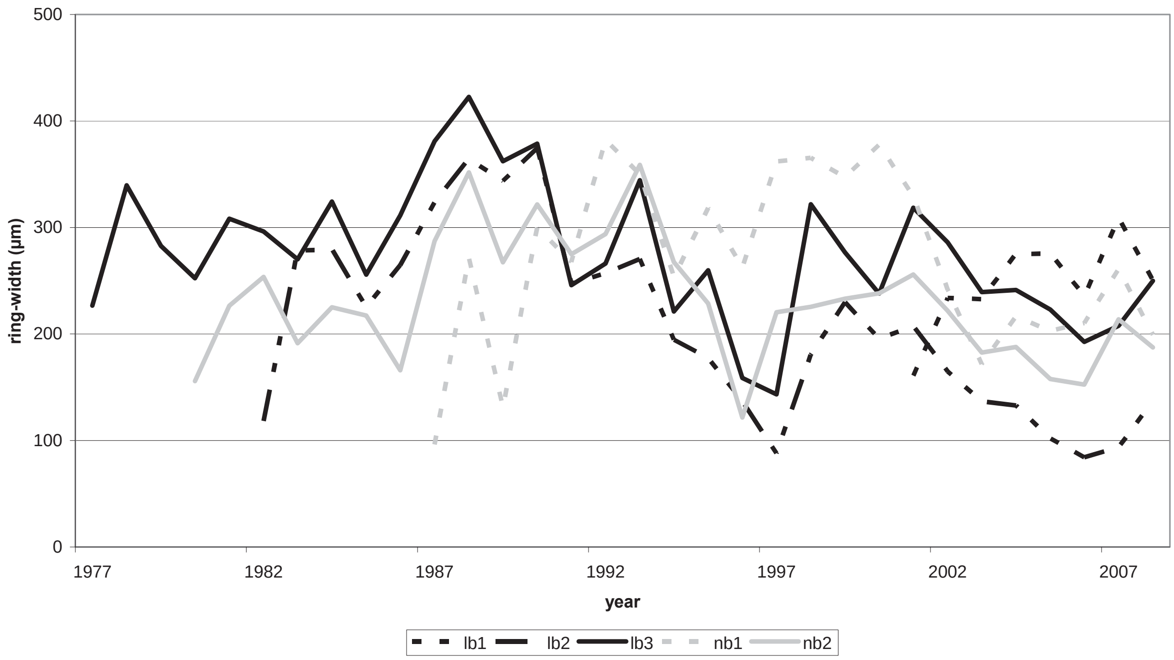

Figure 3: Patterns of average ring width for the three Laarsenberg (lb) and two Noordberg (nb) sites.

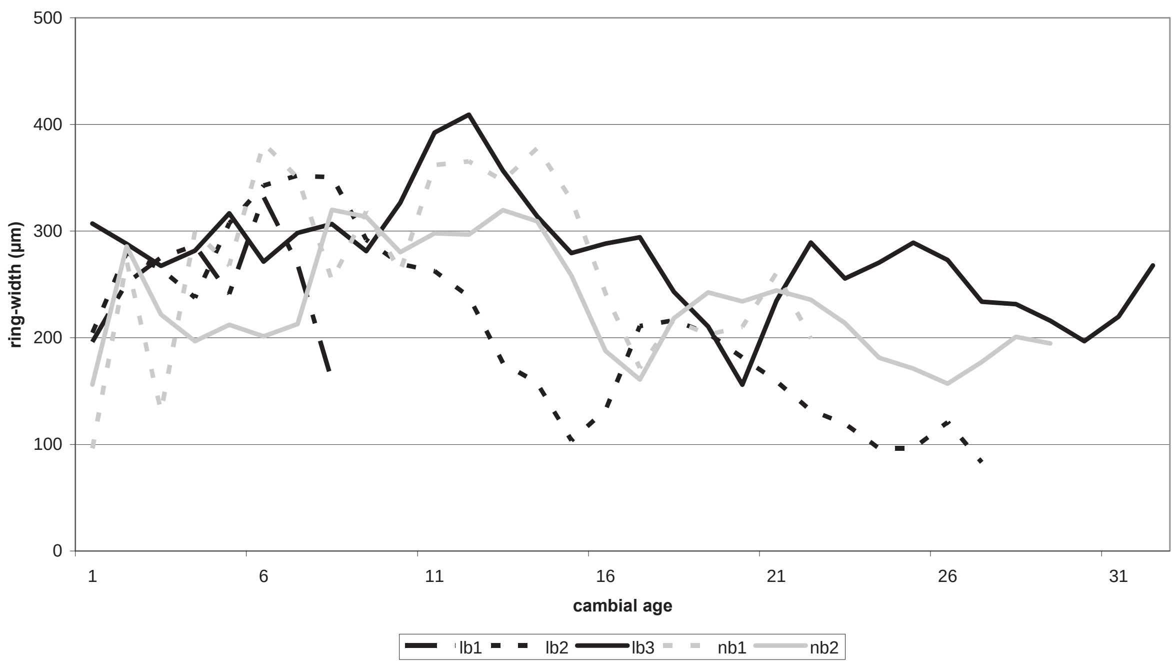

Figure 4: Average ring width patterns computed according to cambial age: 1 is the first-formed ring around the pith.

Is there a coppice fingerprint in earlywood- width patterns?

In comparison to ring width, EW-width patterns from all sites of both woodlands (Fig. 5) show less similarity in high-frequency when computed chronologically, both within as in between woodlands (Fig. 5). If the growth patterns are computed as cambial age (Fig. 6) a similar trend in EW width can be observed, independent of location during the first 10 years. After 10 years the similarity declines - the growth in the two Laarsenberg sites continues with the positive trend for another c. 5 years whereas growth in the two Noordberg sites stagnates. This consistency in EW-width trends over the first ten years could indicate a coppice-specific pattern. However, further research is needed to check whether seeded trees show a significantly different trend, taking into account amongst other things, social positions and soil types.

Consequences for the reconstruction of woodland management using wooden artefacts.

This study on contemporary oak coppice from two woodlands in the Netherlands indicates that there is a lot of variation in ring-width patterns of coppice shoots, even when only dominant stems, growing under similar conditions were considered. Although we found that rings formed around the pith are generally wide, we could not identify a consistent pattern as hypothesized by e.g. Haneca et al. (2005 & 2006) that can be taken as a fingerprint for wood originating from coppice.
Therefore, it is unlikely that ring-width patterns of wooded artefacts can be used to gain information on woodland management. In addition the use of growth patterns is even more complicated when the position of wood within the stem is considered. Only in the ontogenetically young rings - the rings formed just after germination or resprouting - information is stored regarding the origin of the stem. In wooden artefacts it is generally impossible to detect whether the first rings around the pith are the youngest, ontogenetically. Consequently it is not known whether wide rings around the pith are the result of coppice management or that they reflect vigorous growth of a seeded tree some years after germination.
A comparison of EW-width patterns in the oaks from the different coppice sites showed a similar pattern of increasing EW width during the first c. 10 years that might be used as a fingerprint of coppice management but first further research is needed to show whether this pattern is restricted to the coppice origin of the wood, or can be detected in seeded oaks as well.

Figure 5: Average EW width patterns for the sites Laarsenberg (lb) and Noordberg (nb).

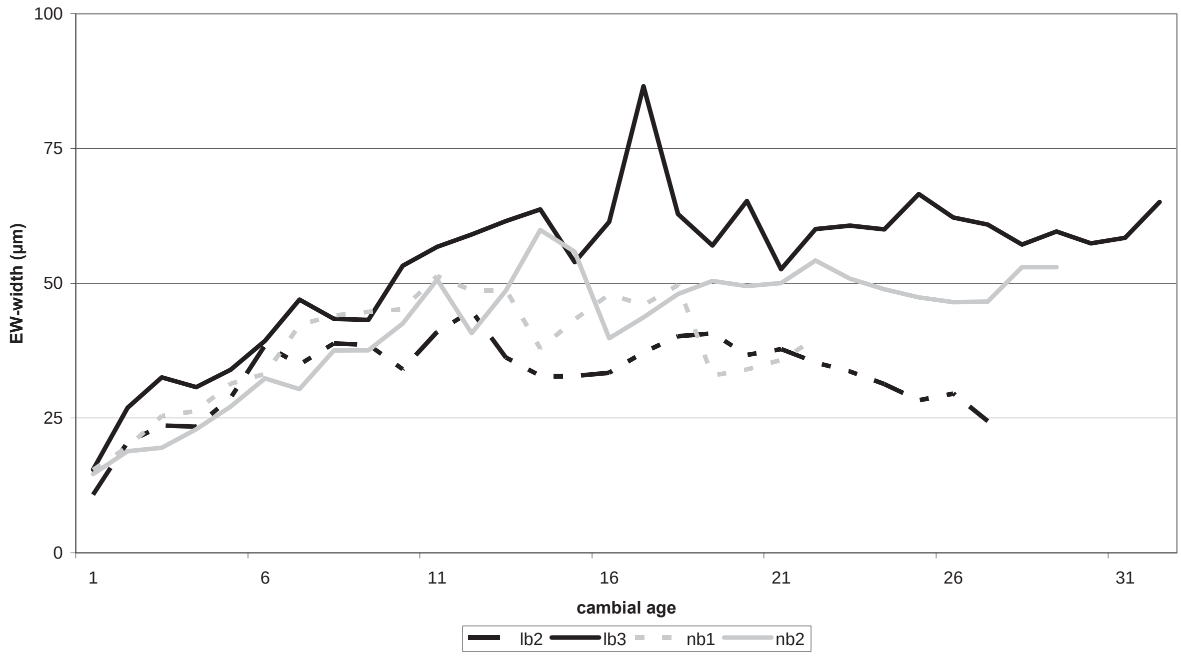

Figure 6: Average EW width patterns computed as cambial age.

Conclusion and future perspectives

This study on contemporary oak coppice from two woodlands in the Netherlands indicates that the pattern of wide ring around the pith can not be used as a fingerprint of coppice management - it has been found that variation in ring widths around the pith is considerable, even in stems growing under similar conditions. EW-width patterns of trees from different coppice sites have found to be more consistent. However, further research is required to indicate whether this consistency in EW width is characteristic for oaks from coppice sites or can be found in seeded oaks as well. Further research is underway encompassing measurements on height growth, EW width and vessel-size patterns in coppiced stems as well as seeded trees.

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