BRIEF REPORTS

Dendrochronological Assessment in Establishing of Felling Dates of Birch Stumps

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Abstract

Dendrochronology can be used for resolving disputes over the felling dates of a forest cut. In the case of controversy in establishing the cutting times of a forest cut, dendrochronology can provide independent evidence. A successful attempt was made to establish the felling dates of stumps of silver birch (*Betula pendula* Roth.) in southern Estonia using dendrochronology. Difficulties met were mainly due to excessive decay of the wood, which made the tree-rings in some instances undistinguishable. Despite these problems two different felling periods were revealed to an accuracy of ca. half a year. Marks of different cutting machines on stumps supported the datings obtained. Our results show that dendrochronology can usefully be applied to birches when assessing past forest management practices.

Key words: *Betula pendula* Roth., felling date, stump samples, tree rings, expert assessment

Introduction

Various issues associated with felling dates of trees from a clear-cut area can arise in forest management practice. If the yield of timber from a clear-cut area is clearly smaller than could be expected from the stumps, an earlier partial felling can be assumed to have taken place from the same area. If the limits of felling areas are not very clearly establishable in the forest, over cutting outside the legal limits can occur. The felling company may contest the over cutting, claiming that it had been made by another company. As it is improbable that two companies have worked side-by-side in a forest plot at the same time, the key question becomes whether the felling dates are the same or different in the problematic areas. If suspicious forest exportation has been discovered, there may be a need to determine the origin of the timber from an alleged cut area. If the tree-stumps present in the cut area are old, then the origin of the fresh timber cannot be from that felling area. In all these and similar cases there is a need to determine the felling date of the stumps. The age of the stumps can be assessed by their appearance and coverage by mosses and fungi. Sometimes the footprints of different felling machines on stumps help to distinguish between different felling programmes. These external characteristics of stumps can give only an approximate or relative assessment of the age of the stumps.

However, the dendrochronological dating method can reveal exact felling dates of tree stumps with a precision of about half a year. The case in question is a claimed over cut or possible illegal cutting by another company. The clearcut area for which the felling dates of silver birch (*Betula pendula* Roth.) stumps were required in order to aid clarification is located in southern Estonia. As birch yields high quality timber (Sachsse 1989), it is essential to detect every possible abuse of this commercially valuable resource.

Materials and methods

Wood samples of triangular prismatic form were taken from the stump surfaces by chain saw. The wood samples comprise a waney edge (mostly with bark attached) and the pith of the tree trunk. Altogether 53 birch stumps were sampled. All stumps and samples were numbered and photographed (Figure 1). In order to facilitate the production of a local reference curve, 12 growing birches were cored by increment borer at breast height near the cut area in November 2006. In addition, 12 spruce stumps were sampled in the same

Figure 1. Birch stump No. 5 with sawn wood sample on it (on the moss cover at right). This birch has been cut after the vegetation period of 2001 (most probably in spring 2002), the sample has been cut and photographed 4.5 years later in November 2006. Note the fungus decay patches in the wood

cut area and again, in order to allow the production of a local reference curve, three growing spruces were cored.

The wood samples were investigated in a raw state, drying being avoided by preserving them in polythene in a fridge. A radial section on the surface of the stump samples was prepared by razor knife and razor blades, and then treated with white chalk to enhance the distinction of the individual tree rings. The widths of the tree rings were measured in 0.01 mm units by the measuring table Lintab in program TSAP (Rinntech 2006). Measurement was carried out starting from the waney edge towards the pith. Some stump samples were unmeasurable because of the advanced state of decay of the wood. Ring widths of cores from growing birches were also measured to the same degree of precision. The quality of the tree-ring series of growing birches was checked using program COFECHA (Grissino-Mayer 2001). The synchronised tree-ring series of the growing birches were averaged into a mean series in program Catras (Aniol 1983).

The well-established principle of cross-dating was taken for the basis of the determination of the felling date of the trees (Wimmer 2002). The principle assumes that where similar site conditions prevail the ring-width series of a certain tree species fluctuates according to the yearly fluctuations of climate factors. Therefore the ring-width series of growing birches and birch stumps should be similar when their growing periods coincide. If matched by similarity, the ring-width series of stumps must end before the ring-width series of growing birches, as they were cut some years earlier. Each individual tree-ring series from a stump was compared with the graph of the mean series of growing birches in program TSAP (Rinntech). Dating was attributed to stump series that showed convincing similarity with the reference curve through both visual and statistical means. The successfully dated tree-ring series of the birch stumps were averaged into a mean series by using program Catras. The mean tree-ring series of stumps was correlated with the reference series of growing birches in Catras and their graphs were also visually matched in program TSAP. Dendroclimatological analysis of the residual tree-ring chronology 1930-2006 (program ARSTAN Vers. 6.05P, DPL) of growing birches was carried out using program DendroClim2002 (Biondi and Waikul 2004). The comparison of the residual chronology was made with meteorological data from Viljandi (about 10 km from the sample site), with common period for all input variables (the chronology, monthly temperatures and precipitation amounts) being 1937-2003. The time window started with July of previous year and ended with September of the current year (15 months).

Results

The last annual ring of the growing birches had grown in 2006, since the trees were cored after the vegetation period of 2006, in November. The comparison of tree-ring curves of birch stumps and growing birches demonstrated that nine stumps produced their last tree ring in 2003 and sixteen stumps produced their last tree ring in 2001. The average tree-ring series of the dated stumps from both 2001 and 2003 in a synchronous position with the reference curve (78 rings, 1929-2006) is shown in figures (Figures 2 and 3, periods shown according to the length of the stumps' curves). In a few birch stumps the last tree ring under the bark had formed in 2002 (stumps No. 44, 60, and 62) and in 2004 (stump No. 61). The rest of the samples could not be successfully dated because the resultant tree-ring series were too short for reliable dating due to darkening or decay of the wood.

The mean tree-ring series of the spruce stumps matched well to the spruce reference curve (60 rings, 1947-2006) (Figure 4), supporting the dating results of birches. Some of the sampled spruces were cut in 2002 and some of them in 2004.

Dendroclimatological analysis of the residual chronology of growing birches with monthly temperatures and precipitation amounts during 1937-2003 showed that birch ring width was significantly correlated with precipitation of November prior to growth year ($r = -0.26$) and with precipitation of current June ($r = 0.25$). As revealed by the analysis of moving 52-year intervals, the relation was rather stable in time.

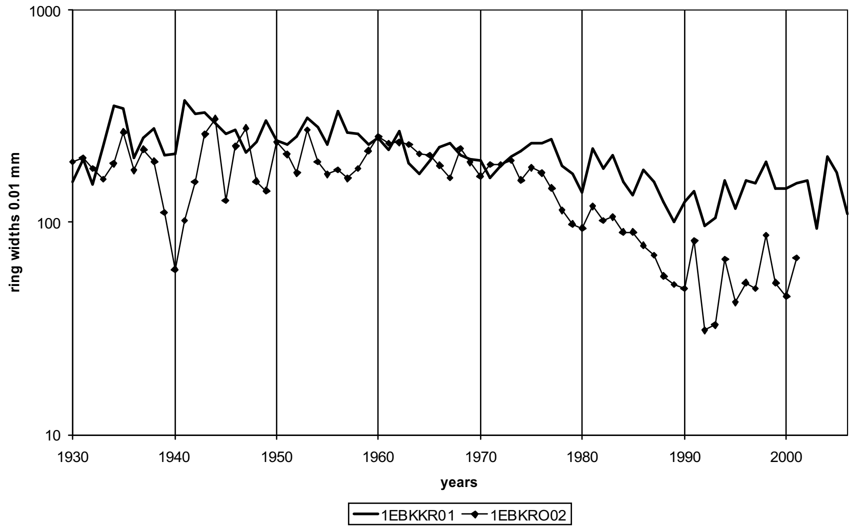

Figure 2. Mean ring-width series of birches, cut after the vegetation period of 2001 (graph line 1EBKRO02), in a synchronous position with mean ring-width series of 12 growing birches (1EBKKR01). t = 5.24, W = 72.4 at 99.0 significance level (overlap 50 years)

Figure 3. Mean ring-width series of birches, cut after the vegetation period of 2003 (graph line 1EBKRO03), in a synchronous position with mean ring-width series of 12 growing birches (1EBKKR01). t = 5.78, W = 79.3 at 99.9 significance level (overlap 59 years)

Figure 4. Mean ring-width series of spruces, cut after the vegetation period of 2003 (graph line 1ESKRO03), in a synchronous position with mean ring-width series of three growing spruces (1ESKKR01). The released growth of 2003 is apparently caused by sudden lack of light competition after cutting of neighbouring trees in the spring of 2002. The narrow tree ring of 2004 represents earlywood, as the spruces were cut in early summer 2004. t = 4.96, W = 69.7 at 95.0 significance level (overlap 34 years)

Discussion and conclusions

Tree-ring dating has been widely used in both archaeological and forestry studies for several decades. There are comprehensive handbooks on the topic (Fritts 1976, Schweingruber 1983, 1996, Cook and Kairiukstis 1990, English Heritage 1998 *etc.*). The distinct tree rings of conifers and of ring-porous trees like oak offer good material for dendrochronological studies. In Estonia there have been dendrochronological investigations of pine (Läänelaid and Eckstein 2003, Pärn 2004), spruce (Läänelaid *et al*. 2006), oak (Läänelaid *et al.* 2001, Läänelaid and Nurkse 2006) and even lime (Läänelaid and Sander 2004). Tree rings of lime were also investigated in Lithuania (Stravinskienė and Dičiūnaitė 1999). Birch, however, is a diffuse-porous tree like lime and its tree rings are relatively difficult to distinguish, in comparison to ring-porous tree species. T. Levanič and O. Eggertsson mention that various biotic and abiotic factors cause faint tree-ring boundaries in *Betula pubescens* Ehrh. in Iceland (2008). Therefore the investigation of birch tree rings from stumps and growing trees presented a technical challenge. There was limited experience of the analysis of birch tree rings in Estonia.

The measured tree ring series of the birch stumps seldom reached the pith because the wood was darkened to black at the upper surface of the stumps and was too decayed inside the stumps to distinguish the rings in it. Although the stumps were not very old, in most samples darkening and decay were the main problems in the accurate measurement of the tree rings. It is known that tree rings can appear indistinct even in fresh-cut disc sections of a similar species, downy birch (Nieuwenhuis and Barrett 2002). However, these problems can be addressed and reduced by a variety of approaches. Pilcher (1990) lists several surface enhancement methods for tree rings, concluding that many researchers use chalk for this purpose. Schweingruber (1993) recommends that indistinct tree rings of birches can be made recognizable by colouring a transversal section with a brown stain and rubbing over it with white chalk. In our case the transversal surface of the stump cuts was sufficiently dark that the surface was treated with white chalk only. The chalk-treated surface revealed ring borders in most cases.

Various other methods of ring boundary enhancement have previously been investigated. Deflorio *et al*. (2005) have carried out an experiment to try to improve the detection of tree rings in silver birch. They incubated wood of birch for 4, 8 and 12 weeks with rot fungi *Fomitopsis pinicola* and *Laetiporus sulphureus* and found that the exposure of annual ring borders in degraded samples was apparently superior to that achieved by conventional treatment methods (sanding and staining). The authors admit that the results varied depending on the method applied and the duration of degradation. In our case, the exposure of stump wood to weather and fungi had greatly exceeded 12 weeks. Therefore the degree of degradation of the wood was often too high for tree rings to be accurately discerned. Lussier *et al* (2004) discuss a method for enhancing the distinctiveness of tree rings of diffuse-porous hardwoods like birch. The authors recommend the planing of fresh samples and the use of an ultraviolet light source in conjunction with a fluorescent dye. Blais (1995) describes an improved method for analysing annual rings by the use of a dye (uranin) in conjunction with an exciter filter. Birch rings have been treated with soya sauce for better visualization (DeCock and DeWildt 1983). Unfortunately these methods were not available for the analysis presented here but the application of chalk dust proved to be adequate.

The average number of measured tree rings in the birch stump samples was 38 (ranging from 12 to 76). The average number of tree rings in the dated spruce samples was 43. The average age of the sampled growing birches nearby was 68 years. We can assume from the samples retrieved that the felled birches were of a similar age. There is no doubt that dating potential is enhanced by the production of a longer tree-ring sequence for comparison with the reference curve. Generally a series overlap of at least 30 years is required for dating that is considered statistically reliable (Aniol 1983), although it is sometimes possible to date shorter ring sequences when they have clear external evidence of likely contemporaneity which allows assumptions to be utilised during the dating process (*i.e.* assuming that the series are likely to originate either from the cut of 2001 or 2003). The matched tree-ring series derived from the stumps were averaged together and these mean curves revealed statistically robust and visual similarity with the reference curve of growing birches. The similarity indices calculated in Catras, Student's t-value and Gleichläufigkeit W were sufficiently strong to confirm the dating. For the mean curve of birches cut close to the vegetation period of 2003, the Student's $t = 5.78$, and the $W = 79.3$ at the level of significance of 99.9 (Figure 2). For the mean curve of birches cut close to the vegetation period of 2001, the Student's $t = 5.24$ and the $W = 72.4$ at 99.0 significance level (Figure 3). The latter indices were calculated for the latest 50-year section of the series only, because of potential measurement errors in the earlier part of the stump curve. The decayed birch wood was often so homogeneously dark that the boundaries of the annual rings could not be precisely determined. It is clear from observations made that wood of birch stumps decays very rapidly within a few years. The appearance of the stumps varied: some of them were covered with moss, some not. On some stumps there were fruiting bodies of fungi. It seemed that the extent of moss cover on the stumps was more dependent on the degree of shade in the particular stump location than on the felling year. The measuring difficulties encountered suggest that reliable dating of birch stumps is possible for only a few years after felling has occurred.

Dating difficulties might also be expected to arise from the fact that the stumps are often eccentric due to root buttressing close to the ground which may result in distortion of the ring series compared to the cores for the reference curve were bored from the more usual breast height. However in this instance the stumps were often rather higher (more than 0.5 m above the land surface in some cases) and not particularly eccentric, thus the effect of different sampling height to the results of dating was considered insignificant. A recent dendroclimatic investigation of birch (*Betula pubescens* Ehrh.) in Iceland has also successfully used samples from the heights of 1.30 m and 0.50 to 1.00 m (Levanič and Eggertsson 2008). To draw a parallel, there is an investigation on the effect of sampling height on radial growth response to climate in *Picea glauca* (Moench) Voss concluding that samples taken from stump height reflect climate as well as those from breast height (Chhin and Wang 2005).

Dendroclimatological analysis has revealed that only the precipitation of previous November and current June were significantly correlated with radial increment of birches, whereas the influence of monthly temperatures was insignificant. Thus it appears that a significant common climatic signal does exist to produce the similar fluctuations of ring widths of these birches. The spatial extension of the climatic sign in tree-ring widths of birches in Estonia was also investigated. The existence of a mean curve of 21 birches from a mixed forest with spruce from northeast Estonia (Kohtla mining area) at a distance of ca 135 km meant that it could be compared with this newly produced mean curve of tree-ring widths of birches from south Estonia (Figure 5). The compared curves do not show much statistical similarity to each other (t = 2.65, W = 59.2), although it is clear from the visual comparison that some of the increment fluctuations are synchronous in both curves as are the overall growth trends. The differences can be explained by origin in different forest types of these tree-ring curves: the south Estonian site is a birch forest with few spruces in it, while the northeast Estonian site is a mixed spruce-birch forest with signs of excessively moist soil in the past, thus demonstrating the importance of local reference material for investigations relating to cutting dates in specific areas of forest. The dating results of this investigation present evidence of two different felling years of the birches in the problematic clear-cut area. In addition it is clear that the birches were cut by two different means, as the footprints on the stumps show: by chain saw and by Harvester. The chain sawn stumps originate from the cut close to the vegetation period of 2003, while the Harvester stumps have been cut close to the vegetation period of 2001. The last tree ring of 2002 in some stumps indicates that these trees were evidently cut in summer 2002. Probably the felling period in spring 2002 extended to early summer, when birches had already

Figure 5. Mean ring width series of 12 growing birches (graph line 1EBKKR01) in synchronous position with mean ring width series of 21 birches from northeast Estonia (at distance ca 135 km, graph line 2EBB0002). In spite of the different forest sites many fluctuations of the curves coincide. t = 2.65, W = 59.2 at below 95.0 significance level (overlap 77 years)

started to form their annual ring. Regarding the birch stump with the last tree ring dated to 2004 (No. 61), there is confirmation from the legal felling company (I. Tust, person. commun., November, 2006) that their felling period in that cut area lasted until early summer 2004. Thus we measured the early earlywood band of the tree ring of 2004 in that birch stump.

On the base of his investigation we conclude that determination of felling date of silver birches using the measurement of tree-ring widths is possible. It enables the felling date to be determined to an accuracy of about half a year (either in the dormancy period or in the vegetation period of trees). In this case the existence of two felling events was proved at the same forest plot. The limitation of the method emerges in the case of a high degree of decay of the wood in older stumps. In such cases, sampling of stumps of tree species (primarily conifers) other than birches could be helpful for reliable dating. In any case the method of dendrochronological dating promises to become a powerful assessment tool in forest management. The method has not been applied widely yet apparently because the felling companies have not been aware of it.

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ОПРЕДЕЛЕНИЕ ВРЕМЕНИ РУБКИ БЕРЕЗЫ ПО ГОДИЧНЫМ КОЛЬЦАМ ПНЕЙ

А. Ляэнелайд

Резюме

В случае проблемы детерминации незаконных или законных рубок по времени их проведения может помочь дендрохронологический анализ. Года проведения разных рубок были установлены по сериям ширины годичных колец пней березы (*Betula pendula* Roth.) на вырубках в южной Эстонии. Основную трудность работы представляла гнилая древесина пней, где границы годичных колец иногда оказались почти неразличимыми. Для улучшения детерминации годичных колец при измерении, поперечный срез образцов был смочен водой и протерен меловым порошком. При сравнивании кривых радиального прироста пней с приростом растущих берез выяснилось время двух рубок (одна из них иллегальная) точностью до полгода. Датировки рубок были подтверждены по наличию отметок, оставленных разными механизмами на пнях. Результаты экспертизы показывают, что дендрохронологический метод может быть успешно использован в лесном хозяйстве для установления различных видов незаконных рубок.

Ключевые слова: *Betula pendula* Roth., время рубки, пни, годичные кольца, дендрохронологическая экспертиза