



Original Article

Evaluating the robustness of three ring-width measurement methods for growth release reconstruction



Sybryn L. Maes^{a,*}, Astrid Vannoppen^b, Jan Altman^c, Jan Van den Bulcke^d, Guillaume Decocq^e, Tom De Mil^d, Leen Depauw^a, Dries Landuyt^a, Michael P. Perring^{a,f}, Joris Van Acker^d, Margot Vanhellemont^a, Kris Verheyen^a

^a Forest & Nature Lab, Ghent University, Geraardsbergsesteenweg 267, BE-9090 Melle-Gontrode, Belgium

^b University of Leuven, Division Forest, Nature and Landscape, Department of Earth and Environmental Sciences, Celestijnenlaan 200E, Box 2411, BE-3001 Leuven, Belgium

^c Institute of Botany of The Czech Academy of Sciences, Zámek 1, 25243 Příhonic, Czech Republic

^d UGCT-Woodlab-UGent, Ghent University, Laboratory of Wood Technology, Department of Forest and Water Management, Coupure Links 653, BE-9000 Gent, Belgium

^e Ecologie et Dynamique des Systèmes Anthropisés (EDYSAN, FRE 3498 CNRS—UPJV), Jules Verne University of Picardie, Rue des Louvels 1, 80037 Amiens Cédex, France

^f School of Biological Sciences, The University of Western Australia, 35 Stirling Highway, Crawley, WA 6009, Australia

ARTICLE INFO

Keywords:

Dendrochronology
Ring-width measurement
Growth release
Lintab
measuRing
XCT
Ring-porous
Diffuse-porous
Disturbance reconstruction
TRADER
Forest disturbance
Historical ecology
Methodological evaluation

ABSTRACT

Growth release analysis on tree rings can be used to validate forest disturbances from the known past or reconstruct those beyond the time line or resolution of documentary evidence. Differences in ring-width measurements may result in incorrect disturbance reconstruction. Yet, little is known about how growth release detection is influenced by the ring-width measurement method. Methodological comparisons mostly do not take into account the ultimate objective of the measurements nor their practicalities, such as time consumption or sample preparation. We assessed differences in ring-width measurements between three methods (Lintab, measuRing, and DHXCT), in a ring-porous (*Quercus robur*) and diffuse-porous (*Fagus sylvatica*) species, and evaluated whether detection of growth releases was consistent among methods. We also comprehensively compared the methods, including quantitative and qualitative criteria. Growth releases were consistent among methods despite small, but significant differences in ring-width values. The apparent robustness of the methods suggests that they may be substitutable in future growth release studies, although the highlighted drawbacks and necessary improvements may advocate combined approaches. Furthermore, we propose an evaluation framework for quantitative and qualitative methodological decision-making and advocate the need for similar methodological comparisons within other fields of dendrochronology.

1. Introduction

Ring-width (RW) series contain highly valuable and versatile information to monitor and understand a variety of natural (e.g. succession dynamics) and anthropogenic (e.g. forest management) processes (Speer, 2010). In dendroecology, growth release analyses allow the detection of historical forest disturbance events (e.g. Nowacki and Abrams, 1997; Altman et al., 2013). A growth release is an abrupt increase in radial growth in a tree which experienced improved light or nutrient conditions after mortality of a neighbouring tree (Oliver and Larson, 1990).

Obtaining reliable RW series is essential in growth release studies, since measurement or crossdating (CD) errors in RW series may give

rise to incorrect disturbance reconstruction (Cook and Kairiukstis, 1990; Stokes and Smiley, 1996; Speer, 2010). In literature, three types of RW measurement methods are often used. First, a measuring stage which combines a sliding table with a microscope and software package (e.g. Lintab + TSAP-Win) is considered the conventional method (Stokes and Smiley, 1996). Second, semi-automatic image analysis on scanned digital images has gained interest and popularity thanks to increased availability and improved performance of affordable Flatbed scanners and software for image analysis (Speer, 2010; Maxwell et al., 2011). Commercial (e.g. Coorecorder) or user-created image analysis programs (e.g. measuRing, Lara et al., 2015) allow manual or automatic detection of ring boundaries based on properties of scanned images such as colour or light intensity (Maxwell et al., 2011). Third, semi-

* Corresponding author.

E-mail address: Sybryn.Maes@UGent.be (S.L. Maes).

automatic image analysis on micro-focus X-ray computed tomography (XCT)-scanned images is a recent, innovative application for tree-ring analysis (Okochi et al., 2007; Grabner et al., 2009; Van den Bulcke et al., 2014; De Mil et al., 2016; Vannoppen et al., 2017).

Measurement methods have been compared in terms of accuracy of the resulting ring widths (Levanič, 2007; Maxwell et al., 2011; Nutto et al., 2012; Lara et al., 2015; Arenas-Castro et al., 2015). The majority of these comparative studies evaluated whether a more recent method measured RWs as accurately as a more conventional method (i.e. the “reference” for accuracy), and thus could substitute the latter.

However, the final objective of the measurements has mostly been ignored. Hence, to date, it remains for example unknown to what extent the employed method for RW measurement affects growth release results. Yet, it is highly relevant to investigate which methods are (more) robust for certain tree-ring analysis types, and thus might be more suited to use when performing that type of analysis. Firstly because an increasing number of available methods currently exist and are being used, without a thorough understanding of how the measurement method used influences the measurements and subsequent tree-ring analysis. Secondly because the resolution of measurements, for instance, might be a bigger issue in dendroclimatological studies (precise annual dating necessary for linking with climate events) than in growth release studies. That is, in growth release analyses, mean growth rates around a year of interest are *relatively* compared along the tree-ring series to identify growth increases above a critical level, so that the precise RW values might not be of key importance in the release detection process. Also, minor dating errors that can arise from using a lower resolution might be less of an issue in growth release analyses, since the timing and duration of a release is often allowed to differ with a number of years and still be considered “the same”. This accounts for the fact that growth responses of trees following the same disturbance can be delayed in time as well as differ between trees or even within cores of the same tree (e.g. Copenheaver et al., 2009; Šamonil et al., 2015; Müllerová et al., 2016).

Comparative studies, besides generally ignoring the final measurement objective, usually do not consider more practical aspects of the measurement methods, such as time or cost efficiency, required sample preparation steps, or the user-friendliness of a method, either (Maxwell et al., 2011; Lara et al., 2015; Arenas-Castro et al., 2015). However, besides resolution, these practical aspects may influence the results as well, and may be well-worth considering when choosing a method, since there are often important trade-offs involved. For instance, if a large number of cores has to be measured, greater financial investments to use a specific method with a higher time efficiency may be justified. On the other hand, when cost price is a cut-off criterion, scientists may opt for the method that involves the lowest financial investment, both in terms of hardware and software as well as salaries. Nevertheless, resolution/accuracy remains a key characteristic to consider, and one should not accept a lower accuracy in a method, if this leads to unreliable measurements and thus compromises inferences drawn from any estimates.

This study aims to address these knowledge gaps by (i) evaluating the robustness of three RW measurement methods with a specific objective in mind, i.e. growth release analyses, and (ii) taking into account all relevant criteria of the methods involved during this evaluation. Furthermore, anatomical differences in ring visibility are accounted for by performing this assessment for a ring-porous (*Quercus robur* L.) as well as a diffuse-porous (*Fagus sylvatica* L.) hardwood species. An important note concerning our first study objective should be made. Our evaluation of robustness should not be confused with comparative studies that assess the accuracy of RW measurements with a newer method compared to a reference method. Contrastingly, we want to evaluate whether expected differences in RW measurements, measured with three methods as commonly implemented, actually lead to different results of the ultimate growth release analysis. Therefore, we first evaluate how large or important these differences are, and next,

whether these differences result in different release detection.

2. Material and methods

2.1. Study area

Increment cores were collected from *Quercus robur* trees in Skåne (S Sweden) and *Fagus sylvatica* in Lyons-la-forêt (N France). The trees were sampled in 20 × 20 m² forest plots from the European PASTFORWARD project (ERC Consolidator Grant; Grant Agreement Number 614839): 9 plots in Skåne (55.81°N, 13.58°E, 79 masl), and 10 plots in Lyons-la-forêt (49.44°N, 1.48°E, 149 masl). The climate of the Swedish study site is temperate/subhumid (mean annual precipitation 550 mm, mean annual temperature 7.6 °C), the French site has a temperate climate (MAP 580 mm, MAT 10.0 °C, WorldClim, 2016).

2.2. Increment cores

We cored dominant trees to extract the longest possible tree-ring series. In each plot, we sampled two trees (max 14.1 m apart); while only one dominant tree was present in two plots in Lyons-la-forêt. Two trees per plot is a sufficient sample size for reconstructing (past) local disturbance events based on growth release analyses and historical plot records (for the ERC-project PASTFORWARD). From each tree, two perpendicular cores were taken at breast height to enable crossdating (CD) per tree and to increase the reliability of the detected releases, following Woodall (2008) and Buchanan and Hart (2011). In total, we collected 72 cores (18 trees of each species, 2 cores per tree), which was considered sufficient for an in-depth methodological evaluation (cf. Maxwell et al., 2011; Nutto et al., 2012; Lara et al., 2015; Arenas-Castro et al., 2015).

2.3. Sample processing

The samples were stored in paper straws. Before the X-ray Computed Tomography (XCT) scanning, the samples were dried for 24 h at 103 °C to ensure correct density estimates and then mounted in custom-made cardboard holders which can contain 33 intact cores of variable length (De Mil et al., 2016). The cores were scanned in batch at 110 μm resolution using NanoWood XCT facility, developed by Woodlab in collaboration with XRE (www.xre.be) (Dierick et al., 2014; Van den Bulcke et al., 2014; De Mil et al., 2016). After reconstruction with the Octopus Reconstruction software licensed by InsideMatters (www.insidematters.eu), core image extraction, tilt and tangential alignment of the 3D volumes was done (De Mil et al., 2016). To make the rings visible on the Lintab and the Flatbed scans, all cores were unwrapped and planed with a Core Microtome (Gärtner and Nievergelt, 2010). For *F. sylvatica*, additional sanding with two grades of sandpaper (320 and 400 grit) was needed to facilitate ring boundary demarcation. All cores were scanned with an Epson Perfection Photo (Flatbed) scanner and the 2D core images were cropped from the scanned images using the open-source software package ImageJ (Schindelin et al., 2015). The Lintab and Flatbed measurements were performed at equilibrium moisture content (i.e. air-dry) since this is custom procedure when using these methods. Table S2 provides a workflow including all steps for the three methods.

2.4. Ring-width measurements

Ring widths were measured with three different methods: (i) a Lintab measuring stage with TSAP-Win software (*the “Lintab” method*), (ii) Flatbed-scanned image analysis with *measuRing* in R (*“Flatbed”*) and (iii) XCT-scanned image analysis with the software program *DHXCT* in Matlab (*“XCT”*). These methods differ in (i) resolution, (ii) ring demarcation procedure, and (iii) fibre structure correction. First, the resolution was determined for each method as a compromise between

Download English Version:

<https://daneshyari.com/en/article/6541337>

Download Persian Version:

<https://daneshyari.com/article/6541337>

[Daneshyari.com](https://daneshyari.com)