Section 1. Aims and Objectives#

1.1 Background to the Guide#

1.1.1 What is Dendrochronology?

Dendrochronology is applied in cultural-heritage research including archaeology to determine the exact calendar age of ancient wood. Such age determinations contribute significantly to assessments of the meaning of archaeological and architectural structures in terms of their chronological and cultural context. This method uses the fact that in climate zones with distinct growing seasons (i.e. outside the tropics and subtropics) trees respond to seasonal temperature differences with a growth stop in autumn, after which growth starts again in spring. This seasonal rhythm is laid down in annual growth rings. The width of each ring reflects the environmental conditions during the growing season, such as temperature, precipitation and soil conditions, as well as local impacts such as flooding, fire and forest clearing or thinning. The alteration of wide and narrow growth rings in ancient wood provides a key to the exact period during which this wood was formed. As an absolute dating method dendrochronology is restricted to the last 12,000 years (Holocene), although the availability of reference chronologies means that in some regions dates are only possible for more recent time periods. Obtaining absolute dates through dendrochronology results in tree-ring measurement series that, when combined, are useful for the reconstruction of former trade/exchange networks, the former landscape and its uses, wood technology and other topics. Therefore it is essential that measurement series are deposited in trusted repositories and made available for follow-up research.

1.1.2 Applications of Dendrochronology in Archaeology

For a great deal of human history, wood has been an important construction material. Remnants of ancient wood are preserved to this day in archaeological sites on land and under water, as well as in buildings and mobile heritage. Dendrochronology is applied to this wood with the following purposes:

a) Obtaining absolute calendar dates for archaeological sites/structure

When a piece of wood has been dated using dendrochronology, we know the exact calendar year during which each of its rings was formed. Absolute dates are obtained by comparing measurement series of undated wood patterns to absolutely dated reference chronologies of average annual tree growth.

There are several manners in which the growth patterns of archaeological wood are measured, ranging from destructive (using a cross section or thin core taken out of a timber) to non-destructive (measurements taken from the outside of an artefact). When a cross section is available, the surface is prepared in such a manner that the annual rings become visible, after which ring widths are measured directly from the sample or (on screen) from a photo using a 0.01 or 0.001mm resolution. During this process in most cases dendrochronological measuring tables are used which are linked to a computer. When measurements are taken from the original wood surface, either photos or a hand lens are used. In the latter case measurements are registered on paper and are entered into the computer afterwards.

When dating archaeological wood a wide variety of reference chronologies are needed, because: (i) tree growth reflects environmental conditions that vary regionally and even - in highly variable landscapes - across small distances; (ii) different tree species respond differently to environmental conditions; (iii) the timber may have been brought to the construction site from other regions.

Comparisons to reference chronologies are performed using a variety of commercial and open source software. Dendrochronological dates are based on statistical variables that express the agreement between time series, on replication of results (significant matches against a variety of chronologies), and on visual verification of statistical agreements (expert judgement).

The calendar year during which the outer ring of an archaeological timber was formed does not necessarily provide an absolute date for the archaeological structure in which this timber was used. Reasons for differences between a dendrochronological and construction date are: (i) the wood is incomplete, i.e. lacks the outer rings; (ii) the wood was stock piled before use (i.e. used some years after it was harvested); (iii) the wood was re-used (i.e. had a previous function); (iv) the wood represents a later repair. The first issue (i) is dealt with in dendrochronology by estimating a minimum number of missing outer rings and using this number to derive a *terminus post quem* date for the felling of the tree.

Not all wood can be dated by dendrochronology. Some species of tree are unsuitable for dendrochronology because they do not lay down reliable annual growth increments. Even species that do typically have annual growth increments may not be successfully dated if localised factors that affected the width of the rings (e.g. injuries; growth releases caused by the removal of competing trees) mask the regional signal used to discern matches between tree-ring patterns. Samples must also include sufficient rings to enable a secure match to be found with reference chronologies therefore short lived trees and branches are not suitable. Samples containing less than 60 rings as a rule are unsuitable for dendrochronological dating. Note, however, that some trees grow very slowly and therefore the size of the sample is not indicative of its usefulness for dendrochronology. Samples with small diameters can contain sufficient rings to date them successfully whereas very large samples sometimes contain very few rings. Also note that some tree species require lower ring numbers for dendrochronological dating than other species. In addition the number of rings that is needed depends on the severity of the environmental conditions that ruled the trees growth. The assessment of dendrochronological quality in terms of tree species and ring numbers is best left to a dendrochronologist experienced in the research of wood from the study area.

b) Establishing timber provenance and long-distance relations

The provenance of archaeological wood is determined based on the geographical provenance of the reference chronologies that provide the best dendrochronological matches. As the result of recent ICT developments in dendrochronology a data-network approach has become more common when assessing wood provenance. This application is useful when studying once mobile artefacts such as ships and barrels, to assess the scale and organisation level of large infrastructural works in open and deforested landscapes, and to reconstruct former trade and exchange networks. Oak is most commonly used in European provenance studies since oak timber was a valuable commodity in the past due to its structural and chemical properties and due to the existence of large international data collections of this species.

c) Assessing aspects of construction technology

Using dendrochronology it is possible to establish that separate timbers were derived from the same tree. Identifying trees in archaeological wood assemblages allows the reconstruction of aspects of, among others, former cooperage and ship-building technologies.

d) Reconstructing environmental history

Dendrochronology is possible because the annual variation in environmental conditions causes differences in the width of consecutive tree-ring widths. The type of environmental changes that trees respond to depends on a number of factors including the species and the position of the tree within its ecological range. For example, a species adapted to dry environments may be limited in some regions by excessive precipitation, while in another region the same species may be limited by winter temperatures. Statistical analysis of the ring widths can extract the environmental signals that limited growth, thus enabling the reconstruction of past temperature and precipitation and, in low-lying delta regions, of flooding due to climate and/or man-induced deforestation.

1.1.3 Current Issues or Concerns

a) The sustainability of dendrochronological data

Locally-managed dendrochronological collections are lost through the disposal of analogous collections, retirement of researchers and the closing down of research departments and commercial laboratories. This is why an international consortium of organisations has created the European heritage-based digital repository DCCD[1] (Jansma et al. 2012a; Jansma 2013). Dendrochronological collections are typically at much greater risk of disposal than other archaeological collections due to the inherent value of wood samples being much less obvious. Dendrochronological samples and their associated data and metadata should be sustainably curated to enable the re-evaluation of existing datasets and the generation of new datasets as techniques become available.

b) The reliability of dendrochronological data and results

Dendrochronology among others is offered commercially by (international) suppliers who may operate outside national systems of cultural-heritage quality regulations. This poses a risk to scientific accuracy, data sustainability and follow-up research. A common example of scientific inaccuracy is the presentation of calendar dates for tree-ring series that are too short to be dateable using dendrochronology. Even a long sequence of ring-widths does not guarantee a cross match will be possible. Less reputable laboratories may report the 'best' match for a sample as a calendar date, regardless of the significance of the fit. It is therefore essential that users of dendrochronological services insist upon the delivery of a comprehensive report along with the calendar date(s) for the submitted samples. Most importantly the report should include: the raw ring-width data; the reference chronologies (or a full description of the chronologies if they are not freely available) used as the basis for the dating; *t*-score and/or %PV (Gleichlaufigkeit) plus level of significance statistics for the cross-date; and graphs showing the visual similarity between tree-ring patterns and reference chronologies. Results produced by laboratories that are unwilling or unable to provide such supporting information should be treated with caution. As with any scientific analysis, dendrochronological determinations should be subject to review and critique by independent third parties where necessary.

c) Digital formats of dendrochronological data

Dendrochronology has a long history of utilizing computers to assist with research. This has resulted in a large number of digital data formats each with their own strengths and weaknesses. The vast majority of these formats concentrate on the storage of tree-ring measurement series with little concern for metadata (see section 1.3 for a definition of data versus metadata in dendrochronology). Even the storage of ring-width data within many of these formats presents issues. For example many formats do not explicitly include measurement units and others do not allow for the recording of missing rings (i.e. years in which the conditions were so bad that the tree didn?t add a ring at all). The large number of data formats also present technical issues with the sharing of data, since many formats are only supported by the original software that they were designed to be used with. To address these and many other issues, an international consortium of dendrochronologists, computer scientists and users of dendrochronological data have created the Tree-Ring Data Standard (TRiDaS) [2] (Jansma et al. 2010).

d) The need for additional (meta)data

In many scientific fields the research questions determine which (combination of) variables are studied, which often leads to the necessity to collect new data according to a specific research plan. Dendrochronology differs in this respect because it always uses tree-ring width as a main variable. This is why for many applications of dendrochronology existing tree-ring measurement series can be used to answer (new) research questions (see section (case studies). The suitability of dendrochronological measurement series for new research depends on the available information about the series, such as the site or object that contained the wood, the dendrochronological dates and the tree species. This is why the inclusion of rich and associated (meta)data is essential when archiving dendrochronological measurement series The DCCD repository at present is the only tree-ring archive worldwide that allows for the standardised inclusion of such (meta)data.

1.2. Scope of the Guide#

This document serves as a good-practice guide for the collection and archiving of dendrochronological data in the context of archaeological and historical research. The guide is aimed at both those creating dendrochronological datasets, and those that commission dendrochronological analyses. This guide does not cover the methods involved in dendrochronological analyses, but focuses on how to describe and archive the data and metadata involved in these analyses. This guide is concerned with best practice for the curation of digital information but does not cover the equally important aspects of the curation of physical samples. However, physical samples are the primary source of information in dendrochronological analyses and should always be managed alongside the digital data wherever possible. This ensures that samples can be re-evaluated where necessary and also re-examined as new analytical techniques are developed.

It is also noted that as this guide is concerned with the management of digital dendrochronological data, it does not cover the issues associated with archiving data produced solely via the 'skeleton plotting' and associated methods of dendrochronology. Skeleton plotting is a technique developed by Douglass in the early 20th century and still commonly used, especially in the USA, whereby trees are crossdated using hand-drawn plots on graph paper. Skeleton plotting can be used to provide a dendrochronological date without the generation of any digital data, although it is common to measure samples even after skeleton plotting to enable the calculation of statistics and to facilitate further analyses.

1.3 Data and Metadata#

In many archaeological archives there is a clear difference between data and metadata (data about data). Making this distinction in dendrochronology, however, can be quite difficult. It is important to make a clear distinction firstly for the sake of clarity within this document (this is particularly necessary in section 3.3 for example) but also to assist in wider discussions surrounding data use and intellectual property.

All the information and knowledge generated by the dendrochronologist during the course of their analysis is regarded as data. The most important data are the measurement values for each ring (typically whole ring widths but it can also be a variety of other metrics). In addition the following data are essential since they are required for the interpretation of measurement series: sapwood counts; species; presence of bark, and calendar dates. Although these fields may be considered as describing the sample being analysed, they are derived during the analysis process itself and as such are regarded as data.

In contrast, metadata is typically provided by the archaeologist commissioning the analysis, or is collected by the dendrochronologist in the field at the time of sampling. Examples include: location; trench number; find number; artefact type, etc. The exceptions to this rule are associated documents such as publications, reports, photographs, etc., which are also considered metadata. Note though that these will typically also contain data.

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[1] Digital Collaboratory for Cultural Dendrochronology (DCCD) - http://dendro.dans.knaw.nl
[2] Tree Ring Data Standard (TRiDaS) Website - http://www.tridas.org/
