Journal of Archaeological Science 57 (2015) 180–196

Contents lists available at ScienceDirect

Journal of Archaeological Science

journal homepage: http://www.elsevier.com/locate/jas

Review

Tree-rings, forest history and cultural heritage: current state and future prospects of dendroarchaeology in the Iberian Peninsula

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ARTICLE INFO

Article history:
Received 5 February 2014
Received in revised form
5 February 2015
Accepted 8 February 2015
Available online 17 February 2015

Keywords:
Dendrochronology
Archaeology
Shipbuilding
Art history
Ancient wood
Timber trade
Spain
Portugal

ABSTRACT

We review the current state of dendroarchaeology in the Iberian Peninsula and discuss its potential, outlining the particular relevance and complexity of this territory and its material heritage for dendroarchaeological studies. Whereas dendrochronology is used throughout the rest of Europe to answer questions about cultural heritage, the application of dendroarchaeology in the Iberian Peninsula has been remarkably underrepresented in comparison to dendroecology and dendroclimatology. Existing tree-ring chronologies in this territory have a widespread geographical coverage, but are often too short to allow dendroarchaeological studies, resulting in inadequate assessments of material heritage made of wood in and originating from the Iberian Peninsula. However, different studies have demonstrated that dendroarchaeology has a great potential in the area. This review illustrates the rich variety of Iberian material heritage from different periods and cultures covering over 8000 years that could profit from dendrochronological research. Future research possibilities in relation to the available Iberian heritage in Spain, Portugal and worldwide are proposed.

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1. Introduction

Dendrochronology deals with the annual growth variations in the wood, which are mainly caused by the climatic and ecological conditions prevailing at the site where trees grow (Fritts, 1976), but can also be partly man-induced (Beeckman, 2005; Bleicher, 2014 and references therein; Schweingruber, 1996). Therefore, tree-ring patterns are series of annual records of the natural and historical environment of trees.

Several works overview the broad applications of this science within archaeology, art-history and architectural history, i.e. disciplines dealing with cultural heritage (e.g. Billamboz, 2014; Bridge, 2012; Čufar, 2007; Eckstein and Wrobel, 2007; Haneca et al., 2009). The direct application of *dendroarchaeology* is the establishment of the date and provenance of wood employed in historical and prehistorical objects and structures. Once the tree rings in the wood are anchored in time, the geographical provenance of the wood can be identified with different degrees of spatial resolution (Bridge, 2012), and information about the fabrication period of e.g. a panel painting, a ship, or a building can be inferred. Beyond construction dates, information about tree selection, type of forests, transport and trade of timber, tools, and ways to process the wood can be retrieved for well-defined temporal frames (e.g. Billamboz,

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http://dx.doi.org/10.1016/j.jas.2015.02.011
0305-4403/Published by Elsevier Ltd.

2003; Tegel, 2012). Additionally, in the lack of absolute dendrochronological dates, the relative crossdating of tree-ring series from numerous timbers of the same structure allows identifying construction phases, as well as defining the occupation timeline of ancient settlements, or inferring information about the organisation of wood supply (Billamboz, 2008; Bleicher, 2014). In summary, dendroarchaeology opens a window to the interactions between humans and their natural environment in specific periods of time.

Dendrochronological dating and provenancing requires reference or master chronologies for the specific tree species being researched, covering the time-span of interest and the area where the wood originated. In the last decades, European dendrochronologists have compiled numerous absolutely dated tree-ring chronologies from living trees, historic buildings, archaeological sites (both terrestrial and maritime), pieces of art and furniture, and palaeo-vegetation remains that represent local and/or region-specific tree growth of broadleaved and conifer species (e.g. Baillie, 1982; Becker and Delorme, 1978; Hollstein, 1980; Jansma, 1995; Jansma et al., 2004; Kuniholm, 1996; Leuschner and Delorme, 1988; Sass-Klaassen and Hanraets, 2006; Spurk et al., 1998; Wazny, 1990). The tree-ring data network currently available for central, south-eastern and northern Europe allows researchers not only to date timbers of different species and periods and accurately determine their provenance (e.g. Domínguez-Delmás et al., 2014; Fraiture, 2009; Sass-Klaassen et al., 2008), but also to address broader questions, such as European-scale timber trade (e.g. Crone and Mills, 2012; Wazny, 2005) or the influence of climate change on past societies (e.g. Büntgen et al., 2011). The recent development of a tree-ring repository for dendro-historical/-archaeological data in Europe (Digital Collaboratory for Cultural Dendrochronology, DCCD; Jansma et al., 2012; Jansma, 2013) further stimulates those lines of broad-scale interdisciplinary research.

In the Iberian Peninsula, the application of dendroarchaeology has been remarkably underrepresented in comparison to disciplines dealing with ecological and climatological questions, in spite of the abundance of historical wood from different periods. Sources of historical timber can be found all over the Iberian territory in archaeological sites from terrestrial and maritime contexts, in roof structures, ceilings, doors and windows from buildings, and in furniture, paintings and sculptures in public and private art collections in different countries. Additionally, wood from Iberian forests used to build ships survives in wrecks worldwide. This material could be used to develop long-span tree-ring chronologies for the Iberian territory, which in turn would allow assessing the date and geographical provenance of more cultural heritage.

In the following, we first outline the relevance and complexity of the Iberian territory and its material cultural heritage for dendroarchaeological studies, offering a glimpse into the different cultures and the forest history of the territory. Then, we present the current state of dendroarchaeology in the peninsula, and review the efforts undertaken so far to establish this discipline in the area. Finally, we propose research lines and strategies towards the future implementation of dendroarchaeology in the study of Iberian cultural heritage.

2. Geographical and bio-climatological peculiarities of the Iberian Peninsula

The Iberian Peninsula, located on the verge of the Atlantic Ocean and the Mediterranean Sea in the south-western corner of Europe (Fig. 1a), represents a key spot from a climatological, ecological and historical perspective. The peculiarities of its relief, with five main mountain ranges and a central plateau reaching an average altitude of 600 m a.s.l., strongly determine its biogeographical zonation (Blanco et al., 1997). Three of these mountain ranges spread along longitudinal gradients (the Cantabrian Mountains in the north, the Central Massif in the middle, and the Beticas in the south), whereas two of them follow a north-west south-east direction (the Pyrenees in the east and the Iberian Massif in the centre/east) (Fig. 1b). These mountains divide the peninsula into several watersheds, five of which gather the water of the main Iberian rivers: Douro, Tagus, Guadiana and Guadalquivir rivers flow from east to west and drain into the Atlantic Ocean, whereas the Ebro flows from north-west to south-east to the Mediterranean Sea (Fig. 1b).

This combination of relief and geographic location upon climate, coupled with the role of the Mediterranean as a refuge during the Ice Ages, confers on the Iberian Peninsula a remarkable diversity of plant species along altitudinal and latitudinal gradients (Galán et al., 2013). Average rainfall decreases from north to south and from west to east, reaching maximum values in mountain and coastal areas from the north-west where precipitation often reaches 3000 mm/year, and dropping down to 200 mm/year in the driest areas of the southeast and the Ebro basin (Fig. 1c). Average temperature increases from north to south and decreases from the coast to the inner regions of the peninsula, January and August being the months with the lowest and highest average temperatures respectively (Fig. 1d). The convergence of both Atlantic and Mediterranean climates creates two main biogeographical areas, commonly known as the Wet-(Atlantic) and the Dry-(Mediterranean) Iberia (Blanco et al., 1997).

Several tree species are endemic to Iberia (e.g. *Acer granatensis*) or Iberia and North Africa (e.g. *Abies pinsapo*, *Quercus faginea*, *Quercus canariensis* or *Tetraclinis articulata*). Many others have their south-western distribution limit in Spain and/or Portugal (e.g. *Pinus sylvestris*, *Abies alba*, *Quercus robur*, *Quercus petraea*, *Fagus sylvatica*, *Pinus uncinata*) (Ruiz de la Torre, 2006). Therefore, these species are of great scientific interest due to their susceptibility to climatic changes (Benito Garzón et al., 2008).

According to the Third Spanish National Forest Inventory (MAGRAMA, 2013) the total forested surface in Spain amounts to 18,265,394 ha (36.2% of the territory), from which 19.3% are open woodlands, 4.5% mixed forests, 35.7% conifer forests, 34.9% broadleaf forests and 5.7% plantations of fast-grown species (Table 1). Main native tree species are *Quercus* (both deciduous and semi-deciduous oaks, and also their evergreen relatives *Quercus suber* and *Quercus ilex*), *Pinus* (seven species are adapted to the ecological conditions of Iberia and the Spanish islands) and *F. sylvatica* (MAGRAMA, 2013). Other genera such as *Abies*, *Acer*, *Fraxinus*, *Juniperus*, *Sorbus* and *Betula* are also present in Iberia, but cover smaller areas. In Portugal, according to the 6th Portuguese National Forest Inventory (ICNF, 2013), the total forested surface amounts to 3,145,000 ha (34% of the territory), from which 43% are broadleaved forests, 31% conifer forests, and 26% forestry plantations of *Eucalyptus* (Table 1). The main species in the country is the planted *Eucalyptus*, mostly *E. globulus*, followed by the two native species *Q. suber* and *Pinus pinaster*. Other important species are *Pinus pinea*, *Castanea sativa*, *Q. ilex* and *Ceratonia siliqua*.

3. Iberian civilizations and forest history

The exploitation of timber resources and the clearing of woodlands in different parts of the world has been increasing from prehistory onwards proportionally with human population (Kaplan et al., 2009; Williams, 2006). The Iberian Peninsula is no exception. Its forest history is intrinsically linked to the different cultures that populated it since ancient times, as well as to their degree of development, their cultural exchanges and the socio-political events that took place in each period (Bauer, 1980). All these