Dendrochronological analysis of oak (*Quercus robur* L., Fagaceae) in the Serra da Carba (Galicia, NW Spain): an application of cluster analysis

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Abstract


Some oak trees growing at three different sites located in the Serra da Carba (Galicia, NW Spain) were sampled for dendrochronological purposes. The rings for each tree were measured in order to obtain individual chronologies, which were cross-dated and standardised following usual dendrochronological procedures. Individual tree-ring series were grouped according to their similarity using cluster analysis. As a result of this analysis, two different groups can be easily observed. The first one, a well-defined group composed by trees growing at the Río Boz site, appears to be much more homogeneous, as indicated by its shorter linking distances among individuals in comparison to both other sites. This latter feature seems to be a consequence of the disturbance regime at each site, with the Río Boz site being a less disturbed and more extensive woodland than the other two. The grouping of individuals into two groups should be interpreted as a result of geographical and climatological conditions in the area.

Key words: dendrochronology, tree-rings, *Quercus robur*, cluster analysis, Galicia.

Resumen


Se muestrearon varios árboles con fines dendrocronológicos en tres localidades situadas en la Serra da Carba (Galicia, NO de España). Para cada uno de los árboles, se midieron los anillos de crecimiento para obtener cronologías individuales, las cuales fueron sincronizadas y estandarizadas siguiendo los métodos habituales en dendrocronología. Estas series individuales se agruparon, atendiendo a su similitud, por medio de un análisis jerárquico. Como resultado de este análisis se aprecian dos grupos diferentes. El primero de ellos, mucho mejor definido, está formado por los árboles de la localidad de Río Boz y muestra una mayor homogeneidad, que se ve reflejada en las distancias entre individuos, mucho menores que en las otras dos localidades. Este hecho parece estar motivado por el grado de perturbación en cada localidad, ya que en el caso de Río Boz se trata de un bosque mucho más extenso y sometido a una menor perturbación. La agrupación de los individuos en dos grupos diferentes debería interpretarse como resultado de las condiciones geográficas y climatológicas en el área.

Palabras clave: dendrocronología, anillos de crecimiento, *Quercus robur*, análisis jerárquico, Galicia.
INTRODUCTION

Many tree species growing at temperate latitudes form annual growth rings. Tree-ring formation is sensitive to environmental variations, and individual trees growing under similar conditions show a synchronic response (Fritts, 1976); as a result, growth rings may provide information on regional- or local-scale climate variation over a given period, which causes that «almost every tree-ring series can be used to obtain climate information» (Schweingruber, 1987).

The standard dendrochronological approach to infer climate information (for a given site and time period) consists on constructing a tree-ring chronology by calculating the mean value of all individual tree-ring values for every year and then using this chronology to characterise the site. Frequently, the aim of the research is to analyse spatial variations of climate response by comparing chronologies along different ecological gradients, as it is the case of the study carried out by Fritts et al. (1965) in various sites in Northern Arizona. Multivariate analysis procedures are often used, as in the studies of Gutiérrez (1990), who ordinated chronologies of three tree species growing at different sites in Catalonia (Spain), or Fritts (1974) and Tessier (1989), who calculated and clustered response functions respectively in South-Western USA and the French Mediterranean Riviera.

However, most studies of this type have been focusing on site chronologies and there have been relatively few studies dealing with the variation of individual tree-ring series. Peters et al. (1981) recommended the use of principal component analysis to identify homogeneous groups from a single site referring to their climatic signal. Riemer (1994) reports that cluster analysis is an appropriate tool for classifying trees and sites, while Leuschner & Riemer (1989) used the same technique to investigate grouping patterns among individuals of Quercus robur L. for some Northern German sites.

In the present paper, cluster analysis was applied to individual tree-ring series of Quercus robur L. from three locations in the Serra da Carba (Galicia, northwest Spain). Our aims were, i) to characterise these sites as regards their bioclimatic and biogeographic conditions and ii) to establish a homogeneity-heterogeneity level at each site according to the results of these analyses.

Study area and tree sites

The study area (Fig. 1) is located in the Serra da Carba, which belongs to the Northern Galician Sierras, a mountain range that separates the northern coast of Galicia and the depression known as Terra Chá that lies inland. Altitude ranges from about 500 m to just over 1000 m. Mean annual temperature ranges from 7.5 to 11°, and mean annual precipitation between 1300 and 1800 mm (Martínez Cortizas et al., 1997). Rainfall shows a seasonality pattern that is less pronounced than in other areas of northwestern Spain (Martínez Cortizas & Castillo Rodríguez, 1996). Potential vegetation throughout most of the area is oakwood belonging to the series Blechno spicant-Quercetum roboris sigmetum (Rivas-Martínez, 1987), though the landscape is currently dominated by seral scrub communities, and only small patches of scattered seminatural woodland remain.

Three sites were studied, all located in the River Eume catchment (Fig. 1, Table I). All three sites have seminatural deciduous woodland dominated by oak (Quercus robur L.), but with other tree species including Betula alba L., Ilex aquifolium L. and Corylus avellana L. also present. Ground cover is mainly composed by species such as Vaccinium myrtillus L., Blechnum spicant (L.) Roth, Lonicera periclymenum L., Hyacinthoides non-scripta (L.) Choudar ex Rothm., Deschampsia flexuosa (L.) Trin. and Melampyrum pratense L. Mosses are abundant, and various Erica species occur at the most disturbed sites. The presence of stumps or dead trees was not enough to establish differences among disturbance regimes.
The Río Boó site has the largest woodland area and the oldest trees. The other two sites have smaller woodland areas and are more disturbed.

Disturbance degree is understood in terms of human influence, such as logging, grazing or other activities. It was assessed by the examination of floristic composition within each site, which seemed to have a good relationship to the proportion of common signal contained in tree-ring series (GARCÍA GONZÁLEZ et al., 1998). The identification of forest disturbances in the growth patterns is not possible in this case because a greater number of trees should be sampled for this purpose.

**MATERIALS AND METHODS**

At each site, 10-15 representative trees were selected in the forest interior, all apparently healthy and dominant or codominant in the canopy. Two 5-mm diameter cores were taken from each tree at breast height, with the aid of an increment borer. The cores were then air-dried, mounted on wooden supports, and their surface was cut and sanded for an easy identification and measuring of the rings (STOKES & SMILEY, 1968). Tree-rings were measured to the nearest 0.01 mm using an Olympus W-CUE image analyser (version 2.06), resulting in an individual tree-ring series for each core. All measured series were plotted and compared in a light table for cross-dating, which was verified using the program COFECHA (HOLMES, 1983). Some anatomical features within the earlywood vessels were used to correct the match positions of the most difficult samples, and no sample was discarded because of lack of agreement. The mean value for each tree was calculated by averaging the tree-ring series of all its cores. Age trend was removed from the resulting series for each tree by a two-step standization, fitting a negative exponential function first, followed by a 32-year cubic smoothing spline with a 50% cut of frequency. Tree-ring indices were finally obtained as residuals of an autorregressive modeling to allow the removal of previous-year growth. These two last steps were performed using the program ARSTAN (HOLMES et al., 1986).

A cluster analysis was applied to group the individuals based on similarity as regards interannual variability in the tree-ring indices. The time span 1935-1994 (60 years) was considered in the analysis. Only series covering this period (12 at Río Boó, 8 at Prado do Inferno and 7 at Castelo de Goía) were used. The selected distance measure was (1-r) where r is the Pearson’s correlation coefficient between two series. The grouping method was an unweighted pair-group average (UPGMA), which computes the distance between two groups as the mean distance between each pair of individuals belonging to different groups; this is the method recommended by SNEATH & SOKAL (1973), unless there are specific reasons for using another one.
Table II. Statistics of the series before and after detrending

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<tr>
<td></td>
<td>Before</td>
<td>After</td>
<td>Before</td>
<td>After</td>
</tr>
<tr>
<td>Mean value</td>
<td>1.47</td>
<td>1.00</td>
<td>2.50</td>
<td>1.00</td>
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<tr>
<td>Standard deviation</td>
<td>0.69</td>
<td>0.28</td>
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<tr>
<td>Mean sensitivity</td>
<td>0.27</td>
<td>0.31</td>
<td>0.27</td>
<td>0.29</td>
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<tr>
<td>1st order autocorrelation</td>
<td>0.68</td>
<td>0.00</td>
<td>0.73</td>
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RESULTS AND DISCUSSION

All individual tree-ring series were characterised by some statistics before and after the standardization procedure (Table II). They include mean, standard deviation, mean sensitivity and the first order autocorrelation coefficient.

Annual ring width is lower for Río Boó, which can be related to a higher age, tree density and altitude of the sample site. Standard deviation is also lower because of the mean value, but coefficient of variation is similar in all sites.

Both mean sensitivity and autocorrelation coefficient are similar in the three sites. The former increases in the detrended series, and autocorrelation is removed by the autorregressive modeling. The value of mean sensitivity, which measures year-to-year variation in the rings, should be considered high and optimal for dendrochronological purposes.

A first attempt to assess the homogeneity level within each site was achieved by identifying pointer years along the studied period in the cluster analysis (1935-1994), as such years show a common response in a great proportion of individuals. A pointer year was considered when 75% or more of the tree-ring sequences show a same ascending or descending trend in comparison to the preceding year. The results of this analysis (Table III) indicate a higher common signal at the Río Boó site.

Table III. Number of pointer years at each site along the period 1935-1994

<table>
<thead>
<tr>
<th></th>
<th>Negative</th>
<th>Positive</th>
<th>Total</th>
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<tbody>
<tr>
<td>Río Boó</td>
<td>18</td>
<td>20</td>
<td>38</td>
</tr>
<tr>
<td>Castelo de Gofa</td>
<td>19</td>
<td>14</td>
<td>33</td>
</tr>
<tr>
<td>Prado do Inferno</td>
<td>16</td>
<td>14</td>
<td>30</td>
</tr>
</tbody>
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The results of cluster analysis performed on the 27 trees are shown in Fig. 2. The dendrogram reveals the existence of two clearly defined groups: the first one is made up of the trees from the Río Boó site, whereas the second group includes the trees from the Castelo de Gofa and Prado do Inferno sites; the analysis split off two trees from this latter site as well, since they have very low correlations with the other ones. The first group appears to be very homogeneous, according to the short linking distances between trees as it could be expected for growing at a less disturbed site. On the other hand, Castelo de Gofa and Prado do Inferno describe a much more heterogeneous group, with higher distances between trees. These two sites are smaller oakwood patches fairly affected by human activity. However, the trees growing at the Castelo de Gofa site show a higher trend to group together,
Fig. 2. Dendrogram showing the results of cluster analysis. BOO=Río Boó; GOI=Castelo de Goía; INF=Prado do Inferno.

Fig. 3. Schematic map of the study area showing the precise location of the three study sites. Rivers are shown as bold lines.
more clear than the trees from Prado do Inferno, which seem to be very spread.

The evident clustering into two groups (Rio Boó versus Castelo de Gófa + Prado do Inferno) is probably attributable to the location and biogeographical conditions of each site (Fig. 3). The Rio Boó woodland is located at a higher altitude (700 m a.s.l.) in the upper area of the Eume River watershed within a steep-walled valley area that allows the presence of protected sectors. Air masses from the sea are blocked in this sector due to a funnel effect which results in an increase in precipitation/water availability. In fact, Martínez Cortizas & Castillo Rodríguez (1996) found that rainfall distribution tends to be more homogeneous in the upper areas of the northern Galician mountains in comparison to low and medium altitudes to the west, where seasonality increases.

The two other sites (Prado do Inferno and Castelo de Gófa) are located at lower altitudes (500-600 m a.s.l.), within more open-walled valleys, thus are their climatic conditions more likely to change through time. There is however a certain gradation, as Prado do Inferno lies within a more open position at a lower altitude whereas Castelo de Gófa is somehow intermediate between Prado do Inferno and Rio Boó. The higher homogeneity shown within the sample at Castelo de Gófa may be related to this last feature. Nonetheless, forest disturbance regime may play an important role in explaining the differences among chronologies.

CONCLUSIONS

Cluster analysis reveals the existence of two groups: a well-defined group containing the trees sampled at Rio Boó, and a more diffuse group containing the trees from the other two sites.

Linking distances between trees allow to appreciate the homogeneity degree at each site. Rio Boó, a less disturbed and more extensive woodland, shows a higher homogeneity than both other sites, which are more affected by fragmentation and border effect.

The present results suggest that differences among tree sites and their homogeneity/heterogeneity degree is related to the climatic and geographical conditions in each site. Nevertheless, differences in the disturbance regime may also have had important effects.

ACKNOWLEDGEMENTS

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REFERENCES


