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Forest structure and understory diversity in *Quercus pyrenaica* communities with different human uses and disturbances

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Abstract

The aim is to compare the diversity of the understory in *Quercus pyrenaica* communities according to the type of human intervention (grazing, obtaining wood or firewood, forest fires). This interaction results in a modification of the characteristics of the arboreal layer and shrub cover. Four types of oak communities were selected, each with five replicates: communities with a high density of shrubby oak (oak shrublands), open woodlands (''dehesas''), mature oak woods with abundant woody biomass in the understory and mature oak woods with little woody biomass in the understory. In each study site, we quantified the size of the trees (height, trunk perimeter and crown diameter) and their density, woody cover in the understory and species richness as well as diversity using the Shannon index, on both a small scale (per m^2) and for the total of each community. A clear difference was observed between the dehesas and the oak shrublands, the two community types with higher human intervention (the dehesas, with sustainable use for grazing and the oak shrublands, the most degraded due to repeated fires), in the principal components analysis carried out with these variables. The other two community types, considered more mature forests, presented an intermediate location on the principal components analysis. However, there was no clear relationship between the different community types and the diversity values. No differences were observed in total species richness, except that the number of annuals being significantly higher in the dehesas. Nor was it possible to detect any differences using the Shannon index, except for the oak shrublands which, although with a great variability among them, had a lower mean diversity than the other community types. The distance between trees was positively correlated to diversity, measured using the Shannon index, and to annual species richness and negatively correlated to woody cover in the understory. The variability in the distance between trees (associated with clumped distributions) was positively correlated to spatial heterogeneity, measured as S_β. The size of the trees had very little correlation to species diversity. As a whole, the results obtained show the difficulty involved in making generalised conclusions on the effects of disturbances on plant diversity.

Keywords: *Quercus pyrenaica*; Human intervention; Land-use history; Oak trees; Density; Size; Diversity; Woody species; Perennial herbs; Annuals

1. Introduction

The loss of diversity associated with exploitation by humans has been one of the main subjects of discussion in the last few decades and especially since the Rio declaration (United Nations Conference on Environment and Development, Río de Janeiro, 1992). However, the controversy among ecologists dates from much earlier and has produced different hypotheses. The first linked human use of resources with an almost automatic loss of biological diversity, which would then tend to increase in the course of succession. However, alternative hypotheses soon arose, such as that of intermediate disturbance, which proposes that maximum diversity will be attained with an intermediate level of disturbance (Connell, 1978; Huston, 1979). Although the controversy is classic, it has acquired new significance because of its implications for sustainable management (Pineda et al., 2002; Howard and Lee, 2003; Sheil and Burslem, 2003; Ishida et al., 2005). Some forms of traditional grazing management, like the dehesa systems, seemed to be linked to high plant diversity (Pineda and Montalvo, 1995), whilst a loss of woody or herbaceous species occurs in other cases because of grazing by domestic livestock or wild herbivores (González-Hernández and Silva-Pando, 1996; Marañón et al., 1999; Webster et al., 2005). Other forms of forest management, such as clearcutting, logging or fire, have been shown to affect plant diversity (Calvo et al., 1999; Kraft et al., 2004; Onaindía et al., 2004; Wardell-Johnson et al., 2004; Ishida et al., 2005), although this effect

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is sometimes complex and more difficult to generalise than was originally thought.

Quercus pyrenaica oak forests are mainly distributed over the Iberian Peninsula, in a situation of transition between the typical Mediterranean sclerophyllous forests (dominated by *Quercus ilex*) and the clearly temperate deciduous forests (*Quercus petraea* or *Fagus sylvatica* forests). The current characteristics of these ecosystems are associated with their historic use for humans, by obtaining wood or firewood or for livestock use in dehesa systems, or with disturbances linked to these uses, like fire, which forms part of the traditional management of these areas by shepherds (Calvo et al., 1999; Luis-Calabuig et al., 2000). In the last few decades and linked to the decrease in the rural population, these traditional uses have been wholly or partially abandoned and this has brought about new changes, like the recovery of oak forests in old grazing or crop areas, or the proliferation of shrubby species in the understory as wood was no longer taken and livestock no longer passed through these forests.

The aim of this study is to determine whether the understory diversity in communities dominated by *Quercus pyrenaica* depends on the degree and type of human intervention. Given that in many cases there have been great variations in management and there is a lack of reliable quantitative data, we intend to relate the diversity of the low layer with the characteristics of the tree layer and the abundance of woody species, because both depend to a great extent on the way they are used and the superposition of impacts. Therefore, first we intend to carry out a comparative study of the density and dimensions of the oak trees in four types of oak forest communities: communities of shrubby oaks (oak shrublands, SL, result of secondary succession after abandoning grazing and halted by fire, or the progressive destruction of mature forests by felling and fires), dehesas (open woodland with few shrubs, DE, currently used as pasture), mature forests with practically no woody species in the understory (forests with open understory, FO, result of grazing or exploitation for firewood) and mature forests with abundant woody species in the understory (forests with shrubby understory, FS, where these uses have been abandoned). Secondly, we intend to compare diversity on a small scale (alpha diversity, per m^2), on a community scale (gamma diversity) and spatial or horizontal heterogeneity (beta diversity) in these communities and their relationship with the dimensions of the trees and their variability.

2. Materials and methods

Twenty *Quercus pyrenaica* study sites were selected, five of each type. To minimise the variability, geographically close study sites were selected (the total study area was 30 km × 25 km, situated in León province, NW of the Iberian Peninsula), with no slope or one of less than 10%, subhumid Mediterranean climate (mean annual temperature 10.9 °C, mean annual precipitation 927 mm, dry period in July and August, according to Ministerio de Agricultura, 1980) and humic cambisol type soil (Junta de Castilla y León, 1987). The differences between study sites were intended to be minimal, except in the type and degree of human intervention. However, it must be taken into account that human intervention depends to a great extent on the characteristics of each community, which determines the type and intensity of use. On the other hand, within those included in the same type, there were also differences between the different study sites, as it was impossible for the intensity of use or disturbances to be of equal magnitude in all of them. Thus, the distinction between communities of shrubby oak (SL) and dehesa (DE) is clear, but between oak forests with open understory (FO) and oak forests with shrubby understory (FS), the differences in some cases are more quantitative than qualitative.

The shrubby oak communities (SL) were identified physiognomically by a great density of small size specimens deriving from vegetative resprout as a response to disturbances, generally fires. The selected study sites had not been burned for at least the previous 3 years. Their altitude is between 920 and 1220 m (Table 1). The dehesa communities (DE) are the result of a traditional livestock management method in which the forest is cleared, leaving a low density of trees, which are pruned to favour crown development at the expense of height growth. In contrast to the typical privately owned dehesas of Salamanca and Extremadura (Rodriguez, 2001), in the study sites they are used as communal pasture by livestock (generally, sheep, but sometimes cows too), so it is difficult to establish the livestock load, which is usually highly variable. In the selected dehesa communities, the altitude was between 975 and 1020 m. The other two forested community types represent a lesser degree of human intervention, the difference between them being the higher or lower abundance of woody species in the understory. Because of this, the former are called forests with shrubby understory (FS) and the latter

Table 1
Location of the study sites

	Locality	Altitude (m)	N exp.	W exp.
SL1	Herreros de Rueda	932	42°38′	5°10′
SL2	Llamas de Rueda	975	42°38′	5°05′
SL3	Valdavida	921	42°36′	4°59′
SL4	Canalejas	973	42°39′	4°59′
SL5	Guardo	1218	42°47′	4°52′
DE1	Canalejas	1002	42°39′	4°58′
DE2	Corcos	975	42°39′	5°05′
DE3	Valdavida	1004	42°37′	4°57′
DE4	Castromudarra	1002	42°37′	5°05′
DE5	Castromudarra	1020	42°36′	5°06′
FS1	Cebanico	991	42°44′	5°03′
FS2	Cebanico	990	42°44′	5°03′
FS3	Modino	1110	42°47′	5°02′
FS4	Modino	1182	42°47′	5°02′
FS5	Santa Olaja	994	42°45′	5°03′
FO1	San Pedro Cansoles	1035	42°44′	4°55′
FO2	Guardo	1255	42°48′	4°53′
FO3	Guardo	1230	42°47′	4°52′
FO4	Prado Guzpeña	1244	42°47′	5°01′
FO5	La Espina	1305	42°49′	4°54′

The closest locality, altitude and geographical coordinates are given. (SL, oak shrublands; DE, open woodlands ''dehesas''; FS, forests with shrubby understory; FO, forests with open understory).