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Full Length Research Paper

Effect of forest management on plant species diversity in *Castanea sativa* stands in Salamanca (Spain) and the Cévennes (France)

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For the last centuries, marked land use changes have taken place throughout the Mediterranean region. These changes have a great impact on plant diversity, variations of which can affect in return ecosystem functioning. This is particularly true for sweet chestnut (*Castanea sativa* Mill.) stands (groves or coppices) that have been more or less abandoned since the end of the last century. Thus, our objective was to analyse the consequences of various management types on plant species diversity, or to analyse if the land use changes may affect the diversity of plant species in chestnut areas of Southern Europe: in chestnut stands of the Honfría forest, located in the South of Salamanca province in Spain, and in the Cévennes in Southern France. Results indicate that plant species diversity is higher in groves than in coppice stands. Cultivated groves were generally characterized by small heliophilous therophytes, and abandoned groves by hemicryptophytes with anemochorous dispersal mode and chamaephytes. Coppice stands were characterized more particularly by phanerophytes with zoochorous dispersal mode. Thus, plant species diversity differs according to management types. The 17% of common species were found between the two Mediterranean areas studied. This difference can be explained by different ecological conditions (elevation, soil type), different management types (grove, coppice stand), and different stand characteristics (shoot density, diameter at breast height). The cultivated grove plots were very different from the other stands that constituted one sub-group. In the Honfría forest, the values of Jaccard index indicated that the cultivated grove had a plant species composition very different from the other stands. In the Cévennes, the lowest values of the Jaccard index were also found between the cultivated grove and the other stands. One solution could be to maintain a landscape mosaic constituted of diverse chestnut stands modified by human activities (chestnut groves, abandoned chestnut groves and chestnut coppice stands). This could allow the enhancement of the high regional plant diversity.

Key words: Functional trait, cultural abandonment, grove, coppice stand, *Castanea sativa*, Mediterranean area.

INTRODUCTION

By the end of the last century, chestnut stand management has been more or less abandoned because of rural exodus and tree diseases (Pitte, 1986; Romane et al., 1992; Etienne et al., 1998). Nevertheless, chestnut stands, groves and coppices cover large areas in the Mediterranean Basin and particularly in Portugal, Spain, France, Italy and Greece, and there are rich areas in plant species. Thus, it is urgent to analyse the effects of abandonment on plant species diversity in chestnut stands to develop management strategies which will allow conserving biodiversity and at the same time to optimize productivity and profitability. The characterization of community response to abandonment in terms of functional traits appears as a promising tool to achieve this goal (McIntyre et al., 1995; Hadar et al., 1999). The

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Table 1. Characteristics of the two mediterranean areas studied.

	Honfría Forest	Cévennes
Mediterranean area	Salamanca province, Spain	Southern France
Altitude (m)	900	650
Mean annual rainfall (mm yr^{-1})	1600	1300
Mean annual temperature (℃)	11	12
Mean duration of summer drought	4 months	3 months
Parent material	schist	schist
Soil	Huminc Cambisol	Dystric Cambisol

classification of species by their functional traits is a practice long exercised by ecologists (Raunkiaer, 1934; Körner, 1993; Gitay et al., 1996). The use of life traits in comprehension of plant species dynamics in relation with disturbance is clearly demonstrated by many authors (McIntyre et al., 1995; Díaz et al., 1999; Landsberg et al., 1999; McIntyre and Lavorel, 2001; Gondard et al., 2003a, 2003b). These authors hypothesize that there exists a pattern of response to perturbation (logging, grazing, cultural abandonment, etc.), linked to species biology, identical for plant species community which belongs to different environment and management (McIntyre et al., 1999). Thus, this approach allows to analyze ecosystem functionning and response to abandonment by focusing on vegetation description defined by functional traits and not only by species (Pillar, 1999). Functional traits fall into three biological categories: morphological traits, life history traits indicating plant behavior in the environment, and regeneration traits (Lavorel et al., 1997). Several empirical studies (Grime, 1997; Tilman et al., 1997) have demonstrated that ecosystem function is mainly a consequence of the prevailing strategies of constituent species, in interaction with the abiotic environment; some of the experimental effects that are referred to diversity are probably a consequence of the effect of abiotic conditions (Tilman et al., 1997; Schläpfer et al., 1999).

We focused on plant species diversity occurring in understorey stratum which is a very important component in ecosystem functioning (Host and Pregitzer, 1991; Arsenault and Bradfield, 1995; Brakenhielm and Lui, 1998). Plant species diversity in the understorey is sensitive to changes of ecosystem conditions (Pregitzer and Barnes, 1982; Strong et al., 1991; Mitchell et al., 1997, 1998). Our hypotheses: species diversity differs according to management types, and it is possible to identify functional traits of plant species characteristic of one management type. The floristic differences between the stands under different management could be due to physiography, canopy density and other parameters as shoot density, basal area, soil type etc.

Our objectives were to analyse the consequences of various management types on plant species diversity, or to analyse if the land use changes may affect the diversity of plant species in chestnut areas of Southern Europe.

MATERIALS AND METHODS

Data collection

Our studies were carried out in two Mediterranean areas, in the Honfría forest, located in the South of Salamanca province in Spain, and in the Cévennes in Southern France (Table 1). The Honfría forest is representative of traditional chestnut (*Castanea sativa*) management practiced over many centuries in Spain, but also a model of possible sustainable management in the future (Santa Regina et al., 2005). In this forest, chestnut is considered as a paraclimax species (an introduced species and well adapted) and oak (*Quercus pyrenaica* Wild.) as a climax species. Thus, we selected five stands that are representative of this forest: a chestnut cultivated grove (for fruit), a chestnut abandoned grove, a chestnut coppice (for wood), a mixed chestnut-oak stand, and a pure oak stand. In the Cévennes, we identified a succession following agricultural abandonment from chestnut cultivated grove (for fruit) to chestnut old coppice stand (for wood). Thus, we selected five stages that form the following gradient: a cultivated grove, an abandoned grove, a young coppice (< 25 years old), a medium aged coppice stand (between 26 and 50 years old), and an old coppice stand (>51 years old). The stand characteristics of the stands selected are given in Table 2. In each stand selected, we designed five 10 x 10 m plots. The plots were contiguous because there was only little area available at the site with relatively homogeneous topographic conditions, and in order to respect 100 m² plot size minimum.

The diameter at breast height (DBH) of all trees, included in 1 ha area, at each experimental forest were measured and their distribution in diameter classes (5 - 10, 10-15, 15-20, 20-25 cm, and so on…) were calculated for the Spanish (chestnut cultivated grove (for fruit): 310 trees ha^{-1}, a chestnut abandoned grove: 380 trees ha^{-1}, a chestnut coppice (for wood): 1890 trees ha^{-1}, a mixed chestnut-oak stand: 2325 trees ha^{-1}, and a pure oak stand: 3210 trees ha^{-1}) and French sites (chestnut cultivated grove 410 trees ha^{-1}, chestnut abandoned grove: 420 trees ha^{-1}, chestnut old coppice stand:2600 trees ha^{-1}, chestnut medium coppice stand:2900 trees ha^{-1}, chestnut young coppice stand:3600 trees ha^{-1}) and this measure give us the measure of basal area. Tree age was estimated by the Pressler technique in various representative diameter classes (Génova, 2000). The tree height was measured in all trees in 1 ha chestnut forest area, where all the trees were counted.

In each plot, we recorded all plant species occurring in the understorey stratum. The plant cover of each species was estimated by point quadrat method (Gounot, 1969), using 100 points, i.e. one point every 10 cm, along a 10 m line traversing each plot. According to previous works (Gondard et al., 2003a, 2003b), 100 m² plots appeared to be suitable for reflecting this kind of vegetation

Table 2. Main characteristics of stands selected in the Cévennes in France, and in Honfría forest in Spain. Confidence intervals 95%. For each site, mean values in the same column followed by different letters are significantly different. Mann-Whitney test, 95%.

Site	Stand	Tree age (years)	Tree height (m)	Diameter at breast height (cm)	Shoot density (shoot ha^{-1})	Basal area (m^2 ha^{-1})
Cévennes France	Cultivated grove	70	18.00 ± 1.0[a]	45.00 ± 7.1[a]	120 ± 45[a]	26 ± 18[a]
	Abandoned grove	75	17.40 ± 0.5[a]	44.60 ± 11.5[a]	440 ± 195[a]	45 ± 21[a]
	Young coppice	16	11.20 ± 0.8[b,c]	9.40 ± 1.5[b]	1 040 ± 611[b]	8 ± 4[b]
	Medium coppice	39	12.40 ± 0.9[c]	17.80 ± 7.8[c,d]	1 080 ± 396[b]	17 ± 14[c,d]
	Old coppice	56	16.40 ± 0.5[d]	24.00 ± 4.8[d]	840 ± 488 [b]	35 ± 13[d]
Honfría Forest Spain	*C. sativa* cultivated grove	90	11.30 ± 1.3 [b]	18.30 ± 2.1 [c]	295 ± 20 [a]	23.40 ± 5 [b]
	C. sativa abandoned grove	85	8.90 ± 0.8 [a]	20.40 ± 3.0 [c]	382 ± 30 [a]	18.50 ± 4 [a]
	C. sativa coppice stand	70	15.3 ± 1.3 [c]	12.90 ± 1.7 [b]	1 892 ± 100 [b]	28.40 ± 8 [c]
	Mixed *C. sativa-Q. pyrenaica* stand	60	10.7 ± 0.8 [b]	8.90 ± 1.2 [a]	3 208 ± 150 [c]	21.40 ± 5 [a]
	Q. pyrenaica pure stand	75	12.2 ± 1.0 [b]	11.60 ± 1.5 [b]	2 960 ± 125 [c]	26.50 ± 7 [c]

tation. Each plant species recorded was characterized by functional traits in order to investigate how species composition changed in response to management type (grove, abandoned grove, coppice stand). These functional traits refer to morphology (height plant, Raunkiaer's life form (Raunkiaer, 1934)), life history trait (light tolerance), and regeneration trait (dispersal mode). We obtained information about these life traits from botanical literature (Molinier and Müller, 1938; Pignatti, 1982; Rameau et al., 1989; Bonnier, 1990; De Bolos et al., 1993; Jauzein, 1995). The use of functional traits in comprehension of plant species dynamic in relation to perturbation is clearly demonstrated (McIntyre et al., 1999).

Data analysis

In order to obtain an overview of the data, we performed Correspondence Analysis (Greenacre, 1984) from a matrix composed by the 209 plant species observed in the 50 plots (25 in the Honfría forest, and 25 in the Cévennes in France), and hierarchical ascending classification to identify groups in factorial plane (Roux, 1985). The criteria to compare plots were species richness (number of taxa per 100 m² square) and species diversity (Pielou, 1975; Magurran, 1988). Among the many diversity indices available, we chose the Shannon-Weaver's index (H'), which was recommended by Pielou, (1975): $H' = -\sum_{i=1,n}(p_i \log_2(p_i))$, where p_i is the abundance ratio of species (i) in the square, and n is the species number in the square. Jaccard index was also calculated to obtain percentage of similarity of plant species composition between stands (Jaccard, 1908; Roux and Roux, 1967): $J_d = 100\ N_{ab} / (N_a + N_b - N_{ab})$ where N_a is the species number in (a) stand, N_b is the species number in (b) stand, and N_{ab} is the number of common species in (a) and (b) stands. The means were compared pair wise by the Mann-Whitney non-parametric test (Falissard, 1998).

In each Mediterranean area, to quantify the effects of management types on species functional traits we used CA and Canonical Correspondence Analysis (Ter Braak, 1987), and hierarchical ascending classification to identify groups in factorial plane (Roux, 1985). The first step was to perform a CA of the table composed by plant species observed on the entire point quadrat set (67 in Honfría forest in Spain, and 41 in the Cévennes in France) and management types. The second step was to process the CCA in order to determine the fraction of variance of the species-management types explained by the species-functional traits. Moreover, hierarchical ascending classification was used to identify groups in factorial planes (Roux, 1985).

RESULTS

Diversity indexes

Representation in the plane of the first two axes of plots after a correspondence analysis of the matrix composed by 50 plots (25 in the Honfría forest in Spain, and 25 in the Cévennes in France) and 209 plant species observed in the plots (Figure 1). Grouped were identified by a hierarchical ascendant classification. Subgroups are indicated in bold.

The first letter indicates the country, the second and the third letters indicate the type of stand and the number indicates the repetition (5 plots by type of stand). SCG = Spain *C. sativa* Cultivated Grove, SAG = *C. sativa* Spain Abandoned Grove, SCO = Spain *C. sativa* Coppice, SME = Spain Mixed *C. sativa*-*Q. pyrenaica*, SQU = Spain *Q. pyrenaica.* FCG = France Cultivated Grove, FAG = France Abandoned Grove, FYC = France Young Coppice, FMC = France Medium Coppice, FOC = France Old Coppice.

This rrepresentation in the plane of the first two axes after a correspondence analysis of the matrix, about the species richness and the hierarchical ascending classification allowed us to identify two plot groups that correspond to the two Mediterranean areas studied the Honfría forest in Spain and the Cévennes in France (Figure 1). Thus, there exists a very strong Mediterranean area effect on separating vegetal species and their intrinsic structure. Indeed, we found only 17% of common species

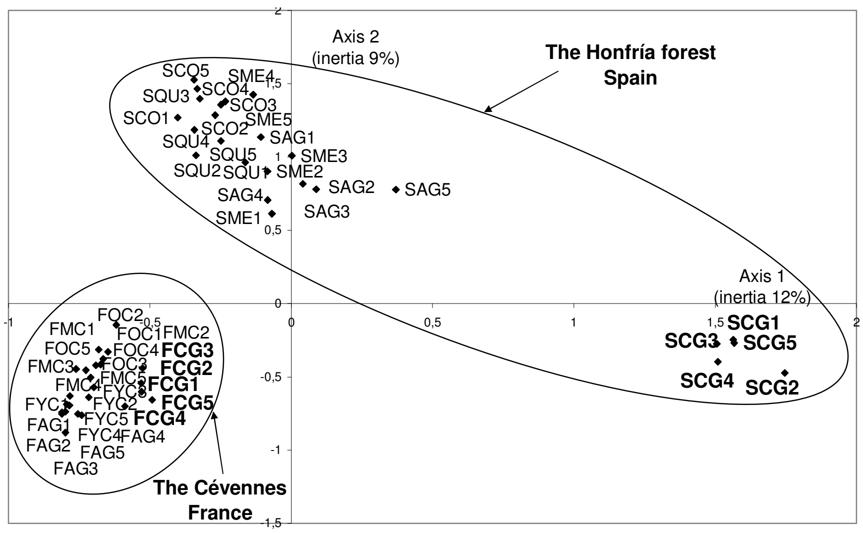

Figure 1. Representation in the plane of the first two axes of plots after a correspondence analysis of the matrix. Grouped were identified by a hierarchical ascendant classification. Subgroups are indicated in bold.

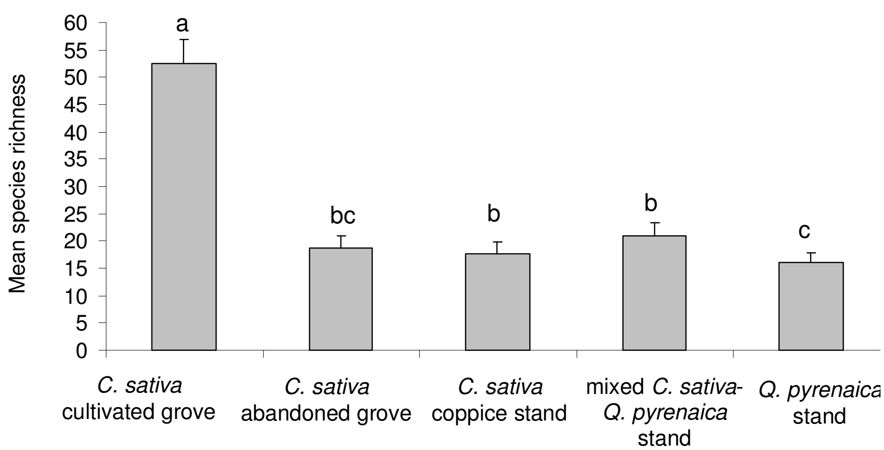

Figure 2. Mean species richness in the Honfría forest in Spain. Mean values with different letters are significantly different. Mann-Whitney test, 95%.

between the two Mediterranean areas (see Appendix). Moreover, in each group, the cultivated grove plots were very different from the other stands that constituted one sub-group. In the Honfría forest, the values of Jaccard index indicated that the cultivated grove had a plant species composition very different from the other stands (Figure 1). In the Cévennes, the lowest values of the Jaccard index were also found between the cultivated grove and the other stands.

By analyses of species richness, in the Honfría forest, this species richness was the highest in the *C. sativa* cultivated grove with 53 ± 4 species, and the lowest in the *Q. pyrenaica* stand with 16 ± 2 species (Figure 2). Species richness in *C. sativa* abandoned grove, *C. sativa* coppice stand and mixed *C. sativa-Q. pyrenaica* stand was not significantly different with 19 ± 2 species, 18 ± 2 species, 21 ± 2 species respectively. In the case of the Cévennes, species richness was the highest in the *C. sativa* cultivated grove, and the lowest in the old *C. sativa* coppice stand, and both values were significantly different from the other stands (p<0.01) (Figure 3). Species richness decreased irregularly along the successional gradient following abandonment of the chestnut groves.

According to the Shannon index in the Honfría forest, species diversity was the highest in the *C. sativa* cultivated grove (3.3 ± 0.3) and the lowest in the *C. sativa* abandoned grove (1.7 ± 0.2), and the *C. sativa* coppice stand (1.4 ± 0.2) (Figure 4). The *Q. pyrenaica* stand (2.1 ± 0.2) had lower species diversity than *C. sativa* cultivated gro-

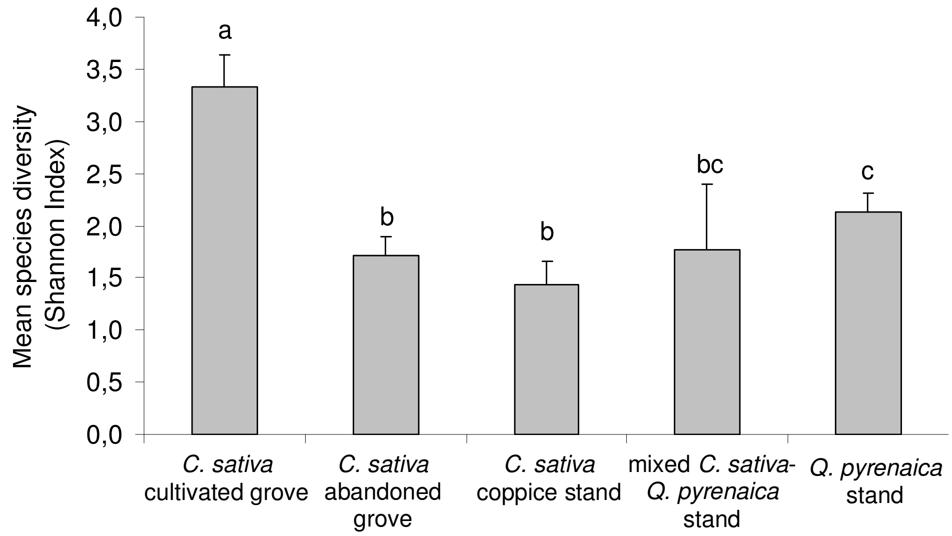

Figure 4. Mean species diversity in the Honfría forest in Spain. Mean values with different letters are significantly different. Mann-Whitney test, 95%.

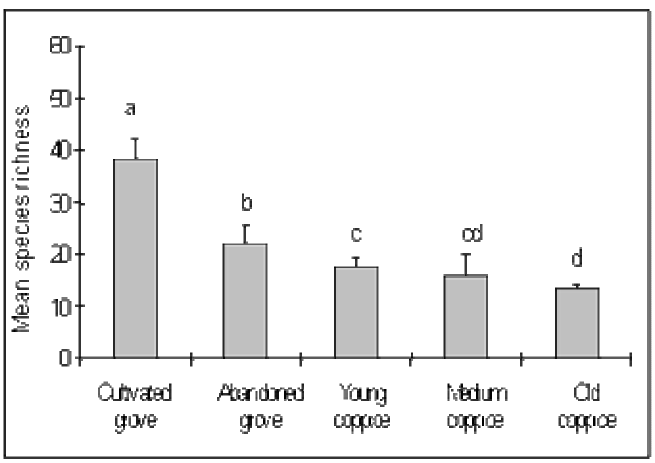

Figure 3. Mean species richness along the successional gradient in the Cévennes in France. Mean values with different letters are significantly different. Mann-Whitney test, 95%.

ve, and the same species diversity as mixed *C. sativa-Q. pyrenaica* stand (1.8 ± 0.6). The species richness of the *Q. pyrenaica* stand was low, compared to the other stands, but the species diversity in this *Q. pyrenaica* stand was comparable to the other stands. Thus, in *Q. pyrenaica* stand, there were no species dominating the others. In the Cévennes, species diversity was higher in cultivated groves than in the other stands (Figure 5).

Plant functional traits and management types

Representation in the plane of the first two axes of functional traits after a canonical correspondence analysis from a matrix (Figure 6) composed of the 67 plant species observed on the line point quadrat of the 25 plots in the Honfría forest in Spain and a matrix composed by the same plant species and their functional traits. Groups were identified by a hierarchical ascending classification. For the Honfría forest, we distinguished three groups in the plane of the two axes of the CCA. Group 1 composed of *C. sativa* cultivated groves was characterized by small heliophilous therophytes (*Anthe-mis pratensis*, *Trifolium angustifolium*, etc.) (Figure 6). The *C. sativa* coppice stands, group 2, were characterized by shade tolerant phanerophytes with zoochorous dispersal mode and geophytes (*Aristolochia pallida*, *Prunus avium*, etc.). The *C. sativa* abandoned groves, mixed *C. sativa-Q. pyrenaica* coppice stands and *Q. pyrenaica* coppice stands, group 3, were composed essentially by hemicryptophytes and chamaephytes with anemochorous or barochorous dispersal mode (*Anthoxantum odoratum*, *Genista hispanica*, etc.). In the case of the Cévennes, the *C. sativa* cultivated groves (group 1) were characterized by therophytes with anemochorous dispersal mode and geophytes (*Pteridium aquilinum*, *Teucrium scorodonia*, etc.) (Figure 7). The *C. sativa* abandoned groves and the young coppice stands (group 2) were characterized by heliophilous hemicrypto-phytes and chamaephytes (*Erica cinerea, Hieracium murorum*, etc.). The *C. sativa* medium and old coppice stands (group 3) were composed more particularly by phanerophytes with zoochorous dispersal mode (*Hedera helix*, etc.).

DISCUSSION

The main trend emerging from species richness data indicated that species richness was higher in the chestnut

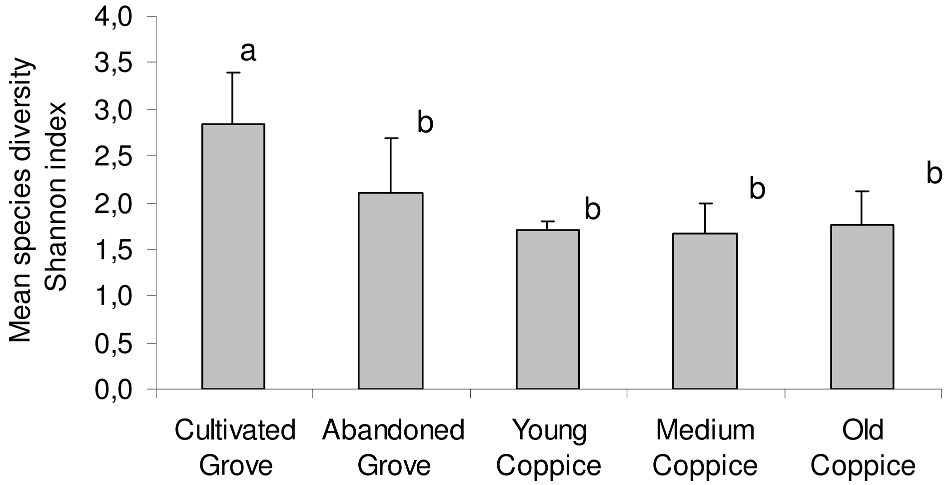

Figure 5. Mean species diversity along the successional gradient in the Cévennes in France. Mean values with different letters are significantly different. Mann-Whitney test, 95%.

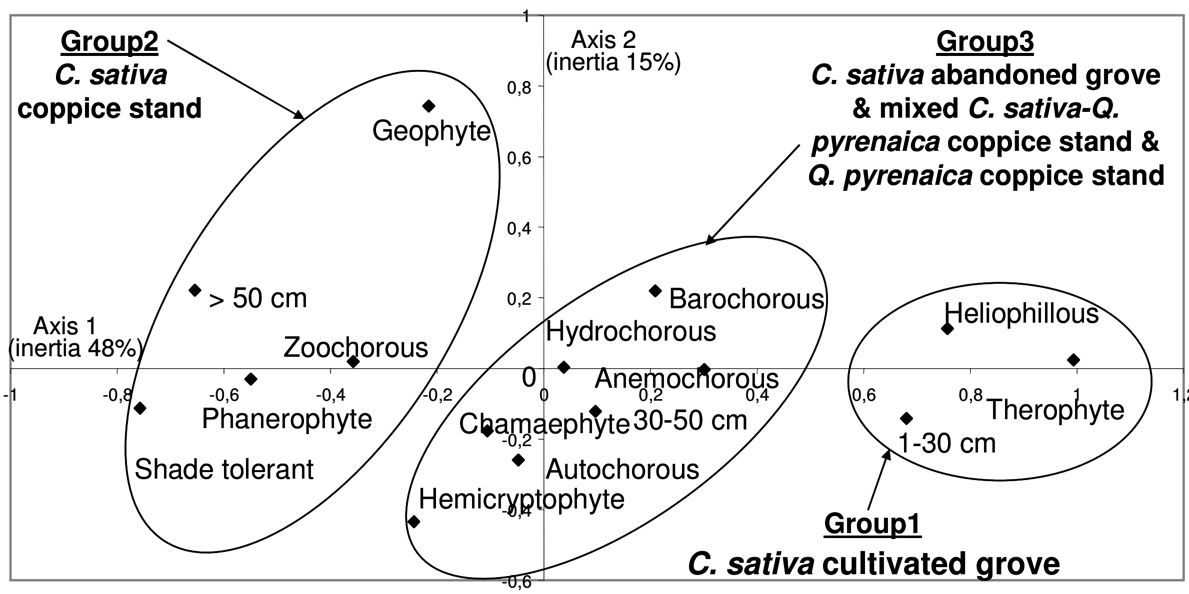

Figure 6. Representation in the plane of the first two axes of functional traits after a canonical correspondence analysis in the Honfría forest in Spain. Groups were identified by a hierarchical ascending classification.

cultivated chestnut groves than in coppice stands; both in the Honfría forest in Spain and in the Cévennes in France. Thus, a complete abandonment of a chestnut grove does not automatically induce the highest plant species diversity in the understorey (Houssard et al., 1980; Gondard et al., 2001). Moderate grazing, occasional ploughing, and pruning occurred in the well managed groves, and generated heterogeneity, both spatially and temporally, to produce a patchy habitat conducive to the maintenance of high levels of biodiversity (Shachak and Brand, 1991; Caswell and Cohen, 1991). Moreover, species richness in the cultivated grove of the Honfría forest (53 ± 4 species) was significantly higher than in the cultivated grove of the Cévennes (38 ± 4 species) ($p<0.01$). This difference may be explained by the strawberry culture under chestnut grove in the Honfría forest in Spain, some years ago. Growing awareness of the rapid loss of global biodiversity has stimulated the discussion on the functional relationship between species diversity and ecosystem processes (Schulze and Mooney, 1993). At local and regional scales, forest use changes are among the most immediate drivers of species diversity. Intensification of forest use is supposed to both change the composition and reduce the diversity of

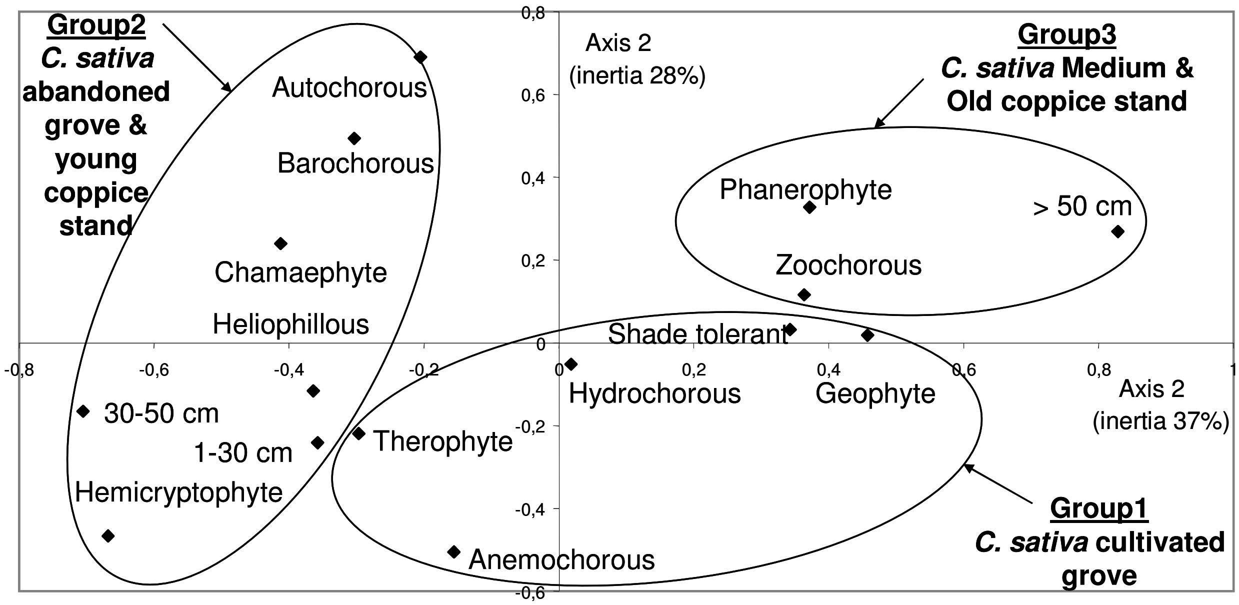

Figure 7. Representation in the plane of the first two axes of functional traits after a canonical correspondence analysis in the Cévennes in France. Groups were identified by a hierarchical ascending classification.

biological communities (Medail et al., 1998; Schläpfer et al., 1999). One of the possibilities to avoid the current loss of biodiversity could be to reduce the intensity of forest use, as well as to abandon cultivated forest.

About the plant species composition, the low values of Jaccard index indicated that few species were common to the two areas. This can be explained by the different ecological conditions between both areas (McIntyre et al., 1995; Landsberg et al., 1999; Gondard et al., 2003b), Salamanca province and the Cévennes differ by climate (especially duration of summer drought, practically without rainfall during the three summer months in Spain), elevation and by soil type (humic Cambisol soils in the Honfría forest, and dystric Cambisol soils in the Cévennes). In the analyses for each Mediterranean area, the low similarity in plant species composition between studied stands can be explained by the differences of management type (grove and coppice stand) and stand characteristics (shoot density, diameter at breast height, etc.). The differences concerning management type were observed in the two forest sites (Honfría forest in Spain and in the Cévennes in France), as well as in Extremadure (a region of Central Spain) in the study of Rubio et al. (1999); plant species composition in *C. sativa* cultivated groves were very different from the coppice stands, for the different light penetration across different trees density and different litter on the soil.

We assume that species diversity differs according to management types (groves and coppice stands). Indeed, groves have, in general, large trees with regular pruning, understorey cleaning, etc., and coppices have many shoots without cleaning but logging. It could be possible to identify functional trait of plant species characteristic of one management type.

The analysis of the species composition changes with respect to management type (CCA analyses) showed that generally small heliophilous therophytes characterized *C. sativa* cultivated groves. Indeed, in well managed groves, chestnut trees have large spacing and thus light, which is recognized as a factor linked positively with species richness (Barkham, 1992; Gilliam et al., 1995), is available in the understorey and favored annuals and short lived perennials (Grime, 1979; Grubb, 1986; McIntyre et al., 1995; Pettit et al., 1995). The effects of species (such as species richness) or functional diversity on ecosystem functioning are expected to increase with the magnitude of the differences among species or functional types (Tilman et al., 1997). Removal of plant functional types, representing permanent exclusion of plant species from the species pool, has important consequences for ecosystem processes and properties such as productivity, decomposer activity, nutrient uptake and ecosystem stability. Hemicryptophytes with anemochorous dispersal mode and chamaephytes characterized *C. sativa* abandoned groves, mixed *C. sativa* -*Q. pyrenaica* coppice stands, *Q. pyrenaica* coppice stands, and young *C. sativa* coppice stands. According to Julve, (1989), hemicryptophytes could colonize all types of environment. As in the old field succession studies performed in Mediterranean region by Houssard et al. (1980) and Debussche et al. (1996), we found that phanerophytes with zoochorous dispersal mode characterized more particularly coppice stands, where the management was lower.

Conclusion

Species diversity differs according to management types, and it is possible to identify functional trait of plant species characteristic of one management type. We found that the highest plant species diversity was observed in cultivated groves. Perturbations were necessary to maintain a quite high level of species diversity. In contrast, the abandonment of chestnut stands, for decades or even centuries, will turn into closed and homogeneous vegetation with decreasing plant diversity. One solution could be to maintain a landscape mosaic constituted of diverse chestnut stands modified by human activities (chestnut groves, abandoned chestnut groves and chestnut coppice stands). This could allow the enhancement of the high regional plant diversity.

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