# ENVIRONMENTAL HETEROGENEITY AND SPECIES COMPOSITION IN DIFFERENT COMMUNITIES OF MESIC DECIDUOUS OAK FORESTS IN CENTRAL - SOUTHERN ITALY

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ABSTRACT - Three independent sources of evidences, based on three different data treatments (floristic classification, ecological classification, diversity profiles) have been used to characterize the deciduous forests dominated by mesophytic *Quercus* sp.pl. of the low and middle altitudes in the Apennines (Central - Southern Italy). At present, these forests are scanty scattered remnants of an arboreal biome depleted from its most significant representants. Their coenological *status* is still highly controversial and floristic (phytosociological) classifications are under a steady state of revision. Here, a "functional" classification of these communities is proposed, in order to assess a physiognomical model for a validation, from the adaptive point of view, of the floristic classifications. The topic has been approached by the application of Ellenberg's Ecological Indicators. Canonical Correspondence Analysis (CCA) has been used to test the correspondence between the floristic matrix and the ecological one. Diversity analysis has pointed out aggregations shaped by the sharing of niches and aggregations in which competitive exclusion might have selected a lower amount of species in the canopy.

KEYWORDS - Deciduous oak forests, Ellenberg Indicators, Diversity, coenological model, Canonical Correspondence Analysis.

## INTRODUCTION

Deciduous forests dominated by mesophytic *Quercus* sp.pl. are scattered throughout C- and S-Italy where they grow at middle elevations usually outside the areas with true Mediterranean climatic conditions.

Along the Mediterranean coast, on sites where a flat topography provides a high, persisting, water table, the effects of drought are buffered and large areas are covered by these communities. Here, they compete with the broadleaved evergreen ones which are controlled by the Mediterranean macroclimate.

The floristic structure ranges from *Quercus cerris* dominated aggregations with thermophilic, both deciduous and evergreen associates (*Q. ilex*, *Q. pubescens* s.l,, *Ostrya carpinifolia*, *Carpinus orientalis*), to mixed ones in which more sub-continental oaks (*Q. frainetto*, *Q. petraea*, *Q. robur* and their hybrids) coexist, along with *Carpinus betulus*, *Castanea* and sometimes *Fagus*.

These communities are largely dominated by an Euro-Siberian flora (Zohary, 1973; Pignatti, 1998). They exhibit high Balkano-Apenninic floristic affinities, both in the canopy and understorey (Horvat *et al.*, 1974, Mayer, 1984), where sub-mediterranean as well as temperate species grow. Their coenological *status* is still highly controversial (Lucchese & Pignatti, 1990; Pignatti E. & Pignatti S., 1990; Pignatti, 1998) and floristic (phytosociological) classifications are under a steady-state of revision (Blasi *et al.*, 2004).

Most of the uncertainty deals with the zonal *versus* extrazonal *status* of these communities, with their successional *status* and with their parametrization (climatogenic *versus* edaphogenic) over larger territories. Indeed, the present-day forests in the Apennines are scattered, scanty remnants of an arboreal biome depleted from its most significant representants. A long history of human disturbance affected these regions, nearly annihilating stands on planar-inland sites, where climatogenic forests, mainly controlled by macroclimate, formerly grew. As a consequence, the scientific attention has been focused on communities with only presumptive zonal characters, often mis-classifying as merely ecotonal, significant remnants of previous climatogenic forests with a "standard" floristic composition.

Moreover, local geographical differences in floristic structure are probably too much emphasized, while affinities at a continental scale are often neglected, with a consequent loss of information about phytogeographically and phytohistorically significant patterns.

## Aims

Here a "functional" classification of these forests is proposed, in order to assess a physiognomical / coenological model for the subcontinental oak forests in S- and C- Italian peninsula as background for a consistent validation, from the adaptive point of view, of floristic classifications. This is intended to detect and semplify redundancy in the current syntaxonomical framework of the deciduous, thermo-mesophilic oak dominated forest of the middle altitude in the Apennines.

This model is approached by an ecological classification obtained by the application of Ellenberg ecological indicators (Ellenberg *et al.*, 1992).

## Study area

The study area ranges between 41° 30' N and 42° 30' N (Figure 1, Table 1). Macro-climatic heterogeneity is buffered by local conditions of slope, aspect and water table. This provides favourable sites for large deciduous forests stands all along the costal plains of middle Thyrrenian districts. Apparently given a high water table also a Mediterranean type macro-climate does not provide constrains for any of the species of the temperate deciduous S-European forest belt.

The soils are usually deep, with relatively high water capacity and are well drained, ranging from udic to xeric moistures regimes (Dowgiallo & Vannicelli, 1993).

FIGURE 1 - Location of the study sites highlighted by ID number (see TABLE 1).

METHODS

A matrix of 268 species / 195 phytosociological relevés has been produced from own phytosociological data (Braun-Blanquet cover values) and processed by Agglomerative Classification (Complete Link, Chord Distance; SYN-TAX 2000 Package, Podani, 1994). Ordination (Canonical Correspondence Analysis, CCA: see ter Braak, 1987) has been applied to each cluster using the floristic matrix and an ecological matrix based on Ellenberg's indicator values (Ellenberg, 1979; Ellenberg *et al.*, 1992). On the basis of the correlation degree of the CCA axes with Ellenberg's indicator values, a selection of the significant ecological factors for each cluster has been detected (TABLE 2).

Diversity patterns according to Whittaker (1972; 1975) have been investigated by plotting species ranks against *ln* species abundance. The curves have been obtained for each cluster of the classification to test the models of species distributions.

RESULTS AND DISCUSSION

*Classification and ecological characterization*

The classification produced 6 clusters (FIGURE 2): their floristic structure (TABLE 3) and ecological requirements (FIGURE 3) are reported as follows. *Quercus cerris* is ubiquitous in the canopy in all stands.

*Cluster 1A:Temperate mixed stands*

These stands show features of a temperate *Q. cerris* community characterized by a stock of high frequency species with intermediate T requirements (*Carpinus betulus*, *Corylus avellana*, *Acer* sp.pl., *Castanea sativa*).

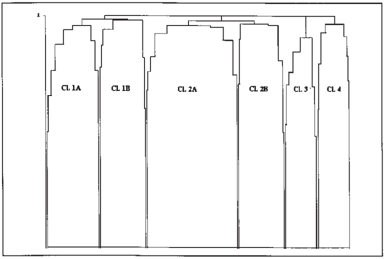


FIGURE 2 - Dendrogram from Cluster Analysis: six clusters of relevés are displayed.

The species composition of the core assemblage shows high affinity between these stands and the so called "forests with medio-European character (*C. betulus*, *Q. robur*) on moist sites" (*sensu* Horvat, 1974) recorded throughout SE-Europe. These forests achieve in the Balkan an extrazonal, edaphogenic character, growing on moister sites and, for this reason, they represent outposts of the zonal climatogenic communities of the mixed temperate forest of C - and CW - Europe (cfr. Walter, 1974; *p.p.* QTA, *sensu* Schmid, 1963).

*Cluster 1B*: *Intermediate, mixed Q. cerris stands*

This community is slightly more thermophilic than the former one; some species with higher T requirements (Oberdorfer, 1983), the submediterranean trees *Sorbus domestica*, *Mespilus germanica*, *Fraxinus ornus*, belong to the core assemblage of this community.

Among the high frequency associates and the discriminant, many fringe species are recorded in the canopy and understorey (*Rosa arvensis*, *Prunus spinosa*); furthermore, grasses and herbs of open spaces, often recorded in the study area at higher altitudes on steeper slopes, rocky outcrops and minor summits (see *Sesleria autumnalis*, *Onopordon illyricum*, *Melica uniflora*).

Along with this, also trees of deciduous forest stands, located near secondary summits with rocky outcrops on limestones (*Sorbus aria*, *Ostrya carpinifolia*) seems to stress the affinity of this cluster / community to silvofacies of the former one (1A), but on more dynamic sites.

*Cluster 2A*: *Quercus cerris mixed stqnds on mesotrophic subcoastal sites*

These stands display a high floristic heterogeneity. The core assemblage identifies a deciduous termophilic community; the presence of evergreen laurophyll woody species (*Q. ilex*, *Erica arborea*, *Rhamnus alaternus*, *Rosa sempervirens* etc.) points out proximity of some plots to the evergreen Mediterranean vegetation belt.

Selective cutting has affected these stands since immemorial time. The establishment of the dominant trees (*Q. cerris*, *Q. ilex*, *Carpinus betulus*, *Q. frainetto*) is likely to be an event related to periods of lower intensity of the human disturbance. Furthermore, the high water table of the plain forest near the shore allows the occurrence of mesophilous species (*Carpinus betulus*, *Ilex aquifolium* etc).

High N demanding species (*Urtica dioica*, *Mycelis muralis*, *Daphne laureola*, *Glechoma hederacea*, *Rumex* sp. pl., *Euphorbia amygdaloides*, *Rubus ulmifolius* etc.) seem to be mostly related to local accumulation of organic matter due to deadwood after the decline of coppicing in the late '60.

Discriminant species, such as *Ampelodesmos mauritanicus*, *Bromus madridensis*, *Hypochoeris radicata*, *Bromus hordeaceus*, are representants of dry, mostly annual grasslands of the most disturbed sites. They occur in the sample-plots located near the seashore (where a severe retrait of the shore- line is ongoing: Astura site), or on shallow soils in other inland locations.

*Cluster 2B*: *Thermophilic, mesotrophic, Quercus frainetto mixed stands*

The core assemblage identifies a *Q. frainetto-Q. cerris* mixed community of the subcoastal plains of Latium, with an amount of evergreen woody *taxa* in the dominated layers. In this case *Q. frainetto* is as frequent as *Q. cerris* in the canopy. According to Ellenberg's indicator values, the species is less thermophilic and requires higher amount of moisture than *Q. cerris*. The moister character of these stands is supported by the requirements of the discriminant species, which are partially hygrophilic (*Calamagrostis epigejos*, *Agrostis stolonifera*, *Phleum subulatum*), due to the circumstantial vicinity to ponds on fossil dunes and to subcoastal wet meadows (Pignatti *et al.*, 2001).

This community is quite similar to the one identified by cluster 2A. The dominance of *Q. frainetto* and the inclusion in this cluster (2B) of treelets with more eastern range bulk, emphasizes the affinities with the subcontinental *Q. frainetto* forest of the Balkan and some of their successional silvofacies (*Carpinus orientalis*).

*Cluster 3*: *Shady Quercus petraea mixed stands*

The structure of this community is largely shaped by the dominance of *Q. petraea* in the canopy; associates range from mesic deciduous trees (*Fagus sylvatica*, *Carpinus betulus*, *Ilex aquifolium*) to thermophilic and heliophilic trees and treelets (*Erica arborea*, *Quercus ilex*, *Q. suber*, *Arbutus unedo*). This Mediterranean stock is, like in other locations within the study area, a consequence of proximity to the coast and of the occurrence of shallow soils on acidic outcrops (kaolinite), favouring persistence of thermophilic *taxa* in submontane areas (Spada, 1977).

If compared to stands dominated by *Q. cerris*, with or without *Q. frainetto*, *Q. petraea* stresses the relatively more mesic character of this community. Its populations are restricted within the study area to submontane sites, where orographic precipitation and mist-rain occur. On the other hand, *Q. petraea* seems to be frequent in every old-growth oak forests in contiguous districts, suggesting the *status* of late successional species in the extant remnants of planar *Q. cerris* forests.

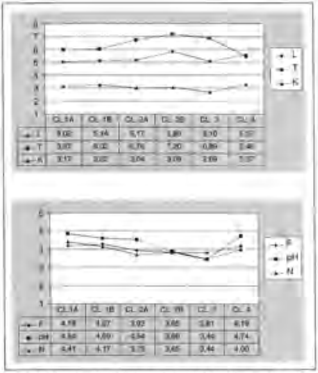


FIGURE 3 - Mean values of Ellenberg's indicators for Light (L), Temperature (T), Continentality (K), Soil Moisture (F), Soil Reaction (pH), Nitrogen (N) in the clusters.

*Cluster 4*: *Heliophilic, subcontinental Quercus cerris-Quercus pubescens mixed stands of the inner districts*

The core assemblage identifies a silvofacies of a *Q. cerris* - *Q. pubescens* mixed community of the inner districts of the Apenninic chain. This usually grow in catenal contiguity with the beech forest belt of higher elevations and the xerophilic *Q. pubescens* dominated permanent communities of topographically discontinuous sites (slopes, outcrops, shallow soils, S-aspects) at lower elevation (see among the high frequency canopy species *Acer obtusatum*). Discriminant species belong to a stock of megaphorbes of the upper elevations near the tree-line in S-Europe (*Colchicum lusitanicum*, *Aquilegia vulgaris*, *Narcissus poeticus*) and orophitic herbs of shallow soils and rocky outcrops (*Helianthemum nummularium*, *Sanguisorba minor*, *Sedum rupestre*) linked to topographycal discontinuities.

As a whole these stands exhibit a structure which is likely to depend upon quite intense dinamic due to the decrees of selective coppicing.

DIVERSITY

The diversity profiles in clusters 1A, 1B, 2A display a log-normal distribution model ("a" coefficient of the equation line, ranging from 0.06 to 0.09; see FIGURE 4A). This suggests (Whittaker, 1972) that many species over a long time span have

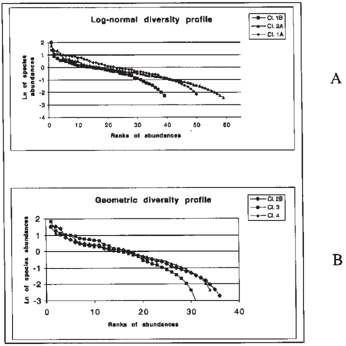


FIGURE 4 - Diversity profiles: two different distribution models (A: log-normal; B: geometric) of species abundances exhibited by the communities identified.

been able to share simultaneously the same niches (1A and 2A are the stands where the highest number woody species in the canopy is recorded), due to a larger water and nutrients availability in the soil, as shown by the importance of F, N and pH indicators (TABLE 2). This is consistent with the mechanisms enhancing site-coexistence among species in the canopy (Contoli, 1998; Whittaker, 1972; Ganis, 1991) "natural" disturbance (Conner & Slayter, 1977) to a higher degree of site heterogeneity which prevents outcompeting among the species of the canopy.

In the other clusters (2B, 3, 4: see FIGURE 4B) the profiles show trend-lines closer to the geometric distribution model ("a" coefficient ranging from 0.10 to 0.14), pointing out the increasing dominance of fewer species which exploit the resources and prevent niches overlapping ("b" coefficient of the line is > 1.6 vs. b < 1.6 in the log-normal model). This means that the local dominance of some species (*Q. frainetto*, *Q. petraea*, *Q. pubescens*) might depend upon the effect of limiting climatic factors in the stands or, alternatively, upon ongoing successional events. Here K, T and L (TABLE 2) are the most significant gradients, due to proximity to the coast where high termicity is buffered by a high water table (cl. 2B, *Q. frainetto*), to old-growth, dense stands with dominating *Q. petraea* (cl 3), or on disturbed stands (coppice) which favours the highly resprouting *Q. pubescens* (cl.4).

*Zonality versus extrazonality*

On the basis of the independent sources of evidences (floristic, ecological and diversity-based: see summary TABLE 4) the *Q. cerris-Q. frainetto* forests (cl.2 A) seem to be zonal in the study area in planar and colline locations where average macroclimatic conditions rule and the intermediate degree of disturbance relies upon an overall lower human impact (decrease in frequence of coppicing). This community shows some affinities with *Lathyro digitati-Quercetum cerridis* in Pignatti E. & Pignatti S. (1990), later named *Echinopo-Quercetum frainetto*, a *syntaxon* considered to be a synonim of the former (see Pignatti, 1998). A borderline case is represented by cluster 1 with arboreal species of Medio-Europaean character in the canopy. Its communities are apparently extrazonal in the study area, but they have been affected more than any other local forest community by the agrarian fragmentation and survived in some scattered, uncoppiced isolates. The same *status* suggests cluster 3 which encompasses stands dominated by *Q. petraea*. These are likely to represent a zonal community which has been nearly totally replaced by cultivated fields since time immemorial.

Extrazonal character exhibits cluster 2B which encompasses stands where *Q. cerris* and *Q. frainetto* dominate (see also the diversity profile in FIGURE 4B) both over evergreen Mediterrannean woody associates and deciduous thermophilic treelets of the submediterranean geoelement. They reveal a intense dynamic induced by frequent shifts of environmental conditions across a long time-span (the Holocene) within its local range due to vicinity to the coast, the high water table of sublitoral locations favouring the persistence and dominance of a less termophilic species (*Q. frainetto*) within a true Mediterranean area.

The stands dominated by *Q. pubescens* (cl. 4) exhibit accidental character in the study area, where it clearly replaces more mesic canopies due to a long history of human disturbance by coppicing and the condition of the soils on topographically heterogeneous sites.

## CONCLUSIONS

The functional classification points out that the aggregations with highest diversity in the canopy, exhibit the most explicit mesic, temperate character and attain zonal *status* in the area. Moreover, the functional classification emphasizes the importance of the edaphic factors (F, N, pH) in their local differentiation (see summary TABLE). According to these results, the zonal forest vegetation fits into the model of communities (see Brackle & Walter, 2002; Rodwell *et al.*, 2002) scattered on even-levelled, slightly raised areas, deep soils, neither permeable (as sand is) nor too wet because or accumulation of water (Testi *et al.*, 2004). These forest occur only as relics due to the agrarian deforestation which has affected, in the study area, most of the sites with similar geomorphological characteristics.

On this basis, the following communities identified, 1B, 2A and 3, might well represent better than other ones, local expressions of climatogenic less disturbed communities.

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## Riassunto

L'utilizzo di tre differenti strategie d'indagine (classificazione floristica, classificazione ecologica, analisi della diversità) basate su metodi di elaborazione dei dati tra loro indipendenti, ha permesso una caratterizzazione delle foreste decidue mesiche, dominate da Quercus sp.pl., nei settori centro-meridionali della catena appenninica. Attualmente queste foreste sono rappresentate da comunità che costituiscono i resti di un bioma forestale privato dei suoi più significativi rappresentanti. Il loro status cenologico e sintassonomico sono ancora controversi e soggetti a continue revisioni.

In questo studio viene proposta una classificazione di tipo "funzionale", allo scopo di ottenere un modello cenologico che possa validare, da un punto di vista adattativo, la classificazione floristica, mediante l'utilizzo degli indicatori ecologici di Ellenberg. È stata applicata l'Analisi Canonica delle Corrispondenze (CCA) per analizzare le relazioni tra matrice floristica e matrice ecologica. L'analisi della diversità ha evidenziato come nelle comunità identificate emergano differenti modelli di occupazione della nicchia.

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TABLE 1 - Sites, altitude, environmental characteristics and communities identified in the study area.

| ID | Sites: | Altitude (m. a.s.l.) | Environmental characteristics: | Communities identified for each site |
|---|---|---|---|---|
| 1 | Allumiere | 609 | middle elevation hypsophilic mixed temperate old-growth forest on trachitic, alunitic outcrops. | 1A, 1B |
| 2 | Anagni | 430 | planar inland mixed oak forest on limestone (high forest and old coppices). | 1B |
| 3 | Astura | 10 | subcoastal plain forest on Plio-Pleistocenic alluvial sediments (relatively undisturbed) . | 2A |
| 4 | Ausoni | 500-700 | middle elevation mixed oak forest on limestone. | 1A , 4 |
| 5 | Canale Monterano | 100 | middle elevation mixed temperate old-coppices in gorges and deep valleys on ignimbrites. | 1A, 2A |
| 6 | Castel Porziano | 15 | subcoastal plain forest on Late-Quaternary levelled fossil dunes (relatively undisturbed). | 2B |
| 7 | Colli Albani | 500-600 | middle to high elevation hypsophilic mixed temperate forest on ignimbrites and leucitites. | 1A , 2A |
| 8 | Circeo | 3 | subcoastal plain forest on Late-Quaternary fossil dunes (relatively undisturbed). | 2A |
| 9 | Foglino | 37 | subcoastal plain forest on Late-Quaternary levelled fossil dunes (relatively undisturbed). | 2A |
| 10 | Gattaceca | 300 | piedmont, low to middle elevation mixed oak forest on limestone (old coppices). | 1B , 2A, 2B |
| 11 | Malboschetto | 509 | middle to high elevation pure inland *Q. cerris* high forest on sandstones. | 1B |
| 12 | Tolfa | 500 | middle elevation colline hypsophilic mixed temperate forest on trachites. | 2A , 3 |
| 13 | Trecchina | 499 | low elevation colline pure inland *Q. cerris* high forest on limestone. | 1B |
| 14 | Trisulti | 800 | middle to high elevation colline pure inland Q. cerris high forest on limestone. | 1B |
| 15 | Trivigno | 698 | middle elevation colline pure inland *Q. cerris* forest on dolomites outcrops. | 1B |

TABLE 2 - Correlations between Ordination axes and Ellenberg's indicator values.

| AX1 | L | T | K | F | pH | N |
|---|---|---|---|---|---|---|
| 1A | -0,37 | 0,64 | -0,45 | -0,60 | 0,06 | -0,35 |
| 1B | -0,29 | -0,80 | 0,81 | 0,29 | -0,66 | -0,59 |
| 2A | -0,82 | 0,58 | -0,66 | 0,30 | -0,11 | -0,74 |
| 2B | 0,65 | -0,07 | 0,25 | -0,31 | 0,22 | -0,45 |
| 3 | -0,59 | 0,70 | 0,75 | -0,39 | 0,01 | -0,26 |
| 4 | 0,79 | 0,50 | -0,11 | -0,37 | 0,61 | -0,69 |
| **AX2** | **L** | **T** | **K** | **F** | **pH** | **N** |
| 1A | -0,31 | -0,11 | -0,47 | 0,25 | -0,69 | 0,08 |
| 1B | -0,06 | 0,11 | -0,31 | -0,48 | -0,48 | -0,28 |
| 2A | 0,02 | 0,20 | -0,15 | -0,66 | -0,64 | 0,29 |
| 2B | -0,48 | 0,75 | -0,12 | -0,45 | 0,14 | -0,04 |
| 3 | 0,35 | 0,56 | -0,56 | -0,35 | 0,00 | -0,13 |
| 4 | 0,23 | -0,34 | -0,72 | -0,65 | -0,18 | 0,27 |

TABLE 3 - Table of the detected communities: species are ordered by frequency classes.

| Clusters | 1 A | 1 B | 2 A | 2 B | 3 | 4 |
|---|---|---|---|---|---|---|
| QUERCUS CERRIS | IV | V | V | IV | II | IV |
| FRAXINUS ORNUS | IV | IV | IV | I | IV | IV |
| HEDERA HELIX | IV | II | V | IV | I | II |
| CRATAEGUS MONOGYNA | IV | IV | III | | I | V |
| MELICA UNIFLORA | IV | III | III | | III | II |
| RUBUS ULMIFOLIUS | IV | II | IV | | IV | |
| QUERCUS ILEX | II | I | III | III | IV | I |
| CYCLAMEN REPANDUM | I | IV | II | I | IV | I |
| RUSCUS ACULEATUS | | IV | V | | IV | |
| OSTRYA CARPINIFOLIA | II | III | II | I | II | III |
| CYCLAMEN HEDERIFOLIUM | III | I | II | IV | | III |
| RUBIA PEREGRINA | | I | IV | IV | IV | |
| FAGUS SYLVATICA | II | II | I | | IV | III |
| TAMUS COMMUNIS | V | I | III | | I | II |
| FESTUCA HETEROPHYLLA | I | IV | II | | IV | |
| BRACHYPODIUM SYLVATICUM | III | III | II | | III | |
| LUZULA FORSTERI | III | III | II | | II | I |
| ANEMONE APENNINA | | III | I | I | III | III |
| ACER CAMPESTRE | IV | I | III | | I | II |
| ASPARAGUS ACUTIFOLIUS | I | I | III | IV | I | I |
| CARPINUS BETULUS | III | | II | | IV | II |
| DAPHNE LAUREOLA | III | II | II | | II | I |
| EUPHORBIA AMYGDALOIDES | III | II | II | | I | II |
| CORNUS MAS | II | II | II | I | I | II |
| ACER OBTUSATUM | II | II | I | | | V |
| POTENTILLA MICRANTHA | II | II | I | | II | III |
| CRUCIATA GLABRA | I | II | I | | III | III |
| CORYLUS AVELLANA | IV | I | I | | | IV |
| CLEMATIS VITALBA | II | I | II | I | I | III |
| QUERCUS PUBESCENS | II | I | II | I | | IV |
| EUONYMUS EUROPAEUS | IV | I | II | | I | I |
| LONICERA ETRUSCA | III | I | II | | III | |
| PTERIDIUM AQUILINUM | II | I | II | | III | I |
| QUERCUS FRAINETTO | II | I | II | IV | | |
| DACTYLIS GLOMERATA | II | I | I | | III | II |
| QUERCUS PETRAEA | II | I | | | V | I |
| PHILLYREA LATIFOLIA | I | I | II | IV | I | |
| CARPINUS ORIENTALIS | I | I | I | II | IV | |
| ALLIUM PENDULINUM | I | III | I | | III | |
| LATHYRUS VENETUS | III | II | I | | | II |
| PRUNUS SPINOSA L. | II | II | II | I | | I |
| AJUGA REPTANS L. | II | II | I | I | | II |

| | | | | | | |
|---|---|---|---|---|---|---|
| CRATAEGUS OXYACANTHA | I | I | II | III | I | |
| ERICA ARBOREA | I | I | II | | IV | |
| SMILAX ASPERA | I | | II | III | II | |
| FRAGARIA VESCA | II | III | I | | | I |
| MELITTIS MELISSOPHYLLUM | I | III | I | | | II |
| TEUCRIUM SICULUM | I | III | I | | II | |
| ILEX AQUIFOLIUM | I | II | I | | III | |
| MALUS SYLVESTRIS | II | I | I | I | I | I |
| ROSA CANINA | II | I | I | | | III |
| VIOLA ALBA ssp. DEHNHARDTII | II | I | I | I | II | |
| CYTISUS VILLOSUS | II | II | I | | I | |
| AREMONIA AGRIMONOIDES | I | II | I | | | II |
| HELLEBORUS FOETIDUS | I | II | I | | | II |
| LONICERA CAPRIFOLIUM | I | II | I | | | II |
| SILENE ITALICA | I | II | I | | I | I |
| STACHYS OFFICINALIS | I | II | I | I | I | |
| CASTANEA SATIVA | III | I | I | | | I |
| GEUM URBANUM | III | I | I | | | I |
| ASPLENIUM ONOPTERIS | II | I | II | | I | |
| LILIUM BULBIFERUM | II | I | I | | | II |
| SORBUS TORMINALIS | I | I | II | | II | |
| CORONILLA EMERUS | I | I | I | I | | II |
| CYTISUS SCOPARIUS | | I | I | I | III | |
| CAREX DISTACHYA | II | | I | III | | |
| ARBUTUS UNEDO | | | I | I | IV | |
| VINCA MINOR | I | III | I | | | |
| VIOLA REICHENBACHIANA | II | II | I | | | |
| ROSA ARVENSIS | I | II | II | | | |
| ALLIARIA PETIOLATA | II | I | I | | | I |
| ARUM ITALICUM | II | I | I | | | I |
| MERCURIALIS PERENNIS L. | II | I | I | | | I |
| POLYSTICHUM SETIFERUM | II | I | I | | | I |
| ACER PSEUDOPLATANUS | II | I | | | I | I |
| MESPILUS GERMANICA | I | I | II | | I | |
| SORBUS DOMESTICA | I | I | II | | I | |
| GALIUM APARINE | I | I | I | | | II |
| HOLCUS LANATUS | I | I | I | II | | |
| POPULUS TREMULA | I | I | I | | I | I |
| RANUNCULUS BULBOSUS | I | I | I | | I | I |
| DIGITALIS MICRANTHA | I | I | | | I | II |
| LIGUSTRUM VULGARE | | I | III | | | I |
| CAREX FLACCA | | I | I | I | II | |
| CISTUS SALVIFOLIUS | | I | I | II | I | |
| JUNIPERUS COMMUNIS | | I | | I | I | II |
| GERANIUM ROBERTIANUM | II | | I | I | | I |
| ACER MONSPESSULANUM | I | | I | | I | II |
| LATHYRUS VERNUS | | III | | | | I |
| VERONICA OFFICINALIS | | III | | | | I |
| HIERACIUM SYLVATICUM | | II | I | | | I |
| BUGLOSSOIDES PURPUROCAERULEA | II | I | I | | | |
| MYCELIS MURALIS | II | I | I | | | |
| POA SYLVICOLA | II | I | I | | | |
| RANUNCULUS LANUGINOSUS | II | I | I | | | |
| STELLARIA MEDIA | II | I | I | | | |
| VIOLA ALBA | II | I | I | | | |
| CARDAMINE BULBIFERA | II | I | | | | I |
| PULMONARIA SACCHARATA | II | I | | | | I |
| SANICULA EUROPAEA | II | I | | | | I |
| STELLARIA HOLOSTEA | II | I | | | | I |
| ROSA SEMPERVIRENS | I | I | II | | | |
| CORNUS SANGUINEA | I | I | I | | | I |
| CRUCIATA LAEVIPES | I | I | I | | | I |

| | | | | | | |
|---|---|---|---|---|---|---|
| GERANIUM SANGUINEUM | I | I | I | | | I |
| PRUNELLA VULGARIS | I | I | I | | | I |
| PYRUS PYRASTER | I | I | I | | | I |
| RANUNCULUS NEMOROSUS | I | I | I | | | I |
| SYMPHYTUM TUBEROSUM | I | I | I | | | I |
| CHAEROPHYLLUM TEMULUM | I | I | | | | II |
| EPIPACTIS HELLEBORINE | I | I | | | | II |
| ANTHOXANTHUM ODORATUM | | I | I | II | | |
| PLATANTHERA BIFOLIA | | I | I | | | II |
| TEUCRIUM CHAMAEDRYS | | I | I | | I | I |
| CYTISUS SESSILIFOLIUS | | I | | | | III |
| SCUTELLARIA COLUMNAE | II | | I | | I | |
| THALICTRUM AQUILEGIFOLIUM | II | | I | | | I |
| CAREX HALLERANA | I | | I | | II | |
| DACTYLIS HISPANICA | I | | | II | | I |
| PISTACIA LENTISCUS | | | I | III | | |
| QUERCUS SUBER | | | I | II | I | |
| MYRTUS COMMUNIS | | | | III | | I |
| SESLERIA AUTUMNALIS | | III | | | | |
| OENANTHE PIMPINELLOIDES | I | I | I | | | |
| PRIMULA VULGARIS | I | I | I | | | |
| PRUNUS AVIUM | I | I | I | | | |
| ASTRAGALUS GLYCYPHYLLOS | I | I | | | | I |
| CALAMINTHA NEPETA | I | I | | I | | |
| CEPHALANTHERA LONGIFOLIA | I | I | | | | I |
| LUZULA PILOSA | I | I | | | | I |
| MYOSOTIS ARVENSIS | I | I | | | | I |
| PIPTATHERUM MILIACEUM | I | I | | | I | |
| SILENE VIRIDIFLORA | I | I | | | | I |
| VICIA SEPIUM | I | I | | | | I |
| ARISTOLOCHIA PALLIDA | | I | I | | | I |
| CETERACH OFFICINARUM | | I | I | | | I |
| HEPATICA NOBILIS | | I | I | | | I |
| POLYGONATUM MULTIFLORUM | | I | I | | | I |
| STYRAX OFFICINALIS | | I | I | I | | |
| VIOLA RIVINIANA | | I | I | | | I |
| AGRIMONIA EUPATORIA | | I | | I | | I |
| ORNITHOGALUM PYRENAICUM | II | | I | | | |
| SEDUM CEPAEA | II | | I | | | |
| LAMIUM MACULATUM | II | | | | I | |
| ASPLENIUM TRICHOMANES | I | | I | | | I |
| CAREX DEPAUPERATA | I | | I | | I | |
| CAREX SYLVATICA | I | | I | | I | |
| LATHYRUS PRATENSIS | I | | I | | | I |
| LEOPOLDIA COMOSA | I | | I | | | I |
| LOTUS CORNICULATUS | I | | I | | | I |
| SAMBUCUS NIGRA | I | | I | | | I |
| SILENE ALBA | I | | I | | I | |
| ULMUS MINOR | I | | I | I | | |
| URTICA DIOICA | I | | I | | | I |
| BRIZA MAXIMA | | | I | II | | |
| DAPHNE GNIDIUM | | | I | II | | |
| LAURUS NOBILIS | | | I | I | I | |
| OSYRIS ALBA | | | I | I | I | |
| QUERCUS ROBUR | I | | I | | | |
| RHAMNUS ALATERNUS | | | I | I | | |
| DIGITALIS FERRUGINEA | | II | | | | |
| PTILOSTEMON STRICTUS | | II | | | | |
| RUBUS HIRTUS | | II | | | | |

TABLE 4 - Summary table of data from floristic classification, diversity analysis and ecological characterization. For each cluster diversity distribution models, species number in the canopy and the most important ecological factors are reported.

| Floristic classification | Diversity profiles | Species richness in the canopy | Most important Ellenberg's, indicators |
|---|---|---|---|
| 1A | Lognormal | High | T, F, pH |
| 1B | Lognormal | High | T, F, pH |
| 2A | Lognormal | High | N, F |
| 2B | Geometric | Low | N, T, L |
| 3 | Geometric | Low | T, L, K |
| 4 | Geometric | Low | L, K, N |