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Taxonomy and ecology of *Castanea sativa* Mill. forests in Greece

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Abstract *Castanea sativa* Mill. is an important species of the Balkan Peninsula with high ecological and economic value. This article contributes to a phytosociological synsystematic approach of the *C. sativa* plant communities in Greece that covers the southern part of the Balkan Peninsula and describes the ecological parameters involved in their distribution and taxonomy. Phytosociological data have been collected from 14 mountainous areas across continental Greece, which are considered representative of the main forest types of *C. sativa* in the area. The 14 mountains demonstrate a variety of environmental conditions. Five communities (associations) and seven sub-communities (sub-associations) have been identified and described using TWINSPAN, Correspondence Analysis and the Braun-Blanquet classification scheme.

Castanea sativa (chestnut) forests of Greece can be distinguished as three broad groups, defined primarily by their geographical distribution. In northern and central Greece chestnut stands are characterized by their high floristic homogeneity, which is reflected in the identification of only one community per region. Chestnut forests in northern Greece, in particular, exhibit strong floristic similarities with those of the rest of the Balkans. In southern Greece, on the other hand, the southern distribution limit of chestnut in the Balkans, there is a greater floristic diversity between the sampled mountains which is reflected in the presence of three confirmed communities and two sub-associations.

Several factors have been identified as important in determining the structure and floristic composition of chestnut forests in Greece. Whilst climate and the grazing regime are influential, the degree of silvicultural management appears to be the most important factor determining the floristic composition of chestnut forests and their long-term sustainability.

Keywords *Castanetum sativae* · Correspondence analysis · Forest ecology · *Quercus frainetto* · TWINSPAN

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Introduction

Castanea sativa Miller (chestnut) is the only native species of the genus *Castanea* to parts of Europe, with most of its distribution in the southern part of the continent. It is a valuable resource for many Mediterranean mountainous areas, due to its edible fruits and the good quality timber and that makes it one of the most important forest species in the Mediterranean basin. *C. sativa* was traditionally an important

source of food for human populations, particularly in rural areas, and was already cultivated during Roman times (Zoller 1960). The Romans are held responsible for the great expansion of the species throughout the Mediterranean region, as well as in central Europe and countries such as Germany, France, Switzerland, Austria, Hungary etc. (Huntley and Birks 1983). In recent years, however, both socio-economic changes, including the abandonment of mountainous areas and the incidence of fungal diseases, have markedly reduced the importance of chestnut compared with the first decades of the 20th century (Cutini 2001). According to the fossil pollen maps of Huntley and Birks (1983), first post-glacial records of *C. sativa* were found in Spain and Greece 9,000 years ago. Fossil records from the Tertiary period revealed the presence of *C. sativa* in areas of Scandinavia, which suggests that the warmer climate of the period allowed the expansion of the species into northern Europe. *C. sativa* was also present in France, Italy, former Yugoslavia, Austria and Hungary during the same period. The long presence of *C. sativa* in Greece has been further confirmed by the findings of the fossilized flora in the lignin deposits of Megalopolis (Ganiatsas 1967).

Our knowledge of the biogeographic origin of the genus *Castanea* is rather limited, but it is thought to have originated from Asia, where during the Tertiary period, eastward migration gave rise to the American chestnut, *C. dentata* (Marsch.) Borkh., and westward migration resulted in the European chestnut, *C. sativa* (Zohary and Hopf 1988). During the latest ice age and the harsh climatic conditions, *C. sativa* was confined towards the southern parts of Europe, where it survived in glacial refugia in the Mediterranean peninsulas, like most other European tree species (Bennet et al. 1991; Hewitt 1996; Taberlet et al. 1998; Fineschi et al. 2000). These "islets" of *C. sativa* forests formed the sources for the distribution of the species in central Europe and elsewhere during the years followed the ice age (Dimoulas 1986). As already mentioned, the current distribution of *C. sativa* is largely anthropogenic, but it has adapted well in most areas where it was introduced and exhibits similar behaviour, in terms of reproduction and response to disturbance, to the native species (Horvat et al. 1974).

According to Horvat et al. (1974), the southern parts of the Balkan Peninsula form the largest distribution zone of chestnut, which stretches from the regions of Thessalia, Macedonia and Thrace, to the area of Former Yugoslav Republic of Macedonia (FYROM). *C. sativa* can be found even further north, up to the borders between Serbia, Bulgaria and Romania where, however, its distribution is declining. In the southern parts of Greece, chestnut forms stands in many areas within the vegetation zone of *Quercus frainetto*. The general trend is towards decreasing the abundance of *C. sativa* forests as we move from the coastal zone to the inner regions of the Balkans, reflecting the influence of Greek and Roman civilizations. According to the last inventory (Anonymous 1992), these forests cover 33,081 ha or 0.5% of the total forest area of Greece. They occur, mainly, on east-facing slopes of mountains in South Balkan Peninsula within the *Quercetalia pubescentis* zone (Castanetum) and especially in the *Quercion frainetto* alliance (Horvat et al. 1974).

Despite the ecological and economic importance of *C. sativa* forests in South Balkans, they have only quite recently been subject to phytosociological study, with the resulting taxonomies of chestnut plant communities published for some regions. Horvat et al. (1974) mentions early attempts to classify such forests in the Balkans by Oberdorfer, Rechinger and Grebenščikov and he provides the relevant records. Some early descriptions of chestnut plant communities were also provided by Grisebach (1841), Mattfeld (1925, 1927), Ganiatsas (1939, 1963), Regel (1943), Oberdorfer (1948), Rauh (1949), and Stojanov and Kitanov (1950). Horvat et al. (1974) described the ecology and theories on the origin and classification of *C. sativa* forests of the South Balkans, whilst Dafis (1966) and Karagiannakidou-Iatridou (1983) have also carried out site studies in northern Greece. Zoller et al. (1977) studied the forests of *C. sativa* in Mount Athos and Raus (1980) described them in the region of Thessaly in Greece (especially Mt. Pilio). Further, Gamisans and Hebrard (1979, 1980) studied the forest of Epirus, Northeast Macedonia and Thrace, Bergmeier (1988, 1990) the forest of Mt. Kato Olympus, Petermann (1999) the forests of Mt. Rhodope (Thrace-N. Greece), while Korakis and Athanasiadis (2003) studied the forests of Mt. Paiko (N. Greece).

Studies on the ecology of *C. sativa* forests have also been carried out in Southern Europe. Asciuto et al. (1988) described the ecology, distribution and

utilization of plantations and coppices in Sicily. Arrigoni and Marras (1990) outlined the status of *C. sativa* in Sardinia, whilst Gamisans (1999) described the plant communities of North-East Corsica. Rexhepi (1991, 1994) synthesized the results of 13 years of fieldwork (1976–1988) spent classifying the vegetation of Kosovo, including the chestnut forests of the region, whilst Matovic (1993) studied the ecological characteristics of chestnut habitats in Serbia. Cobos-Suarez (1989) presented an introduction in the taxonomy of *C. sativa* and its distribution in Spain, whilst Rubio and Gandullo (1994) and Rubio et al. (1999) studied the distribution and established optimum and marginal value parameters defining the physiographic, climatic and edaphic conditions of *C. sativa* in Spain. Kargioğlu (1988) and Özel (1999) classified the *C. sativa* forest of Kaz Dağları in the Iç Bati Anadolu forests (North Aegean Region, Turkey). Keller et al. (1999) classified *C. sativa* forests of the southern Swiss Alps, whilst Viciani and Gabellini (2000) and Lombardi and Viciani (2003) carried out a similar exercise for the Apennine Toscana (Central Italy). Arrigoni and Viciani (2001) described the physiognomical and phytosociological aspects of the Tuscan *C. sativa* woods from 226 original relevés. Arrigoni et al. (1996) identified sub-communities of *Oenantho pimpinelloidis—Castanetum sativae* Arrigoni and Marras 1990 and *Quercetosum pubescentis* Arrigoni et al. 1996 in Sardinia. *C. sativa* communities have also been described in the province of Avila (Spain) (Rivas-Martínez 1975), Southern France and Corsica (Olivier et al. 1995), on the southern slope of the Mt. Krstilovica, at Coska and Sobina (Serbia, Yugoslavia; Dinic et al. 1998) and in the area of Gos Hill in the northern Transdanubian Hills, at the border region between Zala and Vas counties, Hungary (Ovari 1998).

This article contributes a phytosociological syn-systematic approach to *C. sativa* plant communities in Greece, covering the Southern part of Balkan Peninsula, and describes the ecological parameters involved in their distribution and taxonomy. We attempted to study these communities within a large geographic region, covering a wide spectrum of ecological (climatic and geological) conditions and roughly representative of those in the rest of Mediterranean Europe, in order to assist foresters with their planning and management of these ecosystems. This study contributes to the relatively scarce phytosociological forest research in South-East Europe, by adding new data to the existing information with the aim of developing a more comprehensive phytosociological analysis.

Materials and methods

Study area

Phytosociological data were collected from 14 mountainous areas across Greece that were considered representative of the main forest types of *C. sativa* in the area. The 14 mountains encompass a variety of environmental conditions, since they are distributed from north to south and east to west of mainland Greece, covering almost the entire country. The mountain locations were: Pageon and Menikio in Northeast Greece; Holomon, Strempenikos and Paiko in North Greece; Pindos and Vermio in Northwest Greece; Kato Olympus, Ossa and Pilio in East-Central Greece; Telethrio in Southeast Greece; Arakinthos in South-West Greece; and Erimanthos and Helmos in Southern Greece (Fig. 1). A total of 116 phytosociological records (relevés) were taken, covering an altitudinal range between 250 m (Mt. Strempenikos) and 1,120 m (Mt. Erimanthos), with the majority of records between 600 and 900 m. Table 1 shows the geological and climatic conditions of the 14 study areas included in the current study.

The altitudinal zone corresponding to *C. sativa* forest distribution is characterized by a transition from mediterranean to continental climatic conditions, with long-lasting hot summers (mean temperature of July: 22–25°C), mild winters (mean temperature of January: from −2 to 3°C) and humid conditions throughout the year. Mean precipitation varies between 615 mm (North) and 1,200 mm (West), whilst snow lies for 1–2 months per year. The dry period lasts from 1.5 to 2.5 months. All the study sites belong to the sub-mediterranean vegetation zone of *Quercetalia pubescentis* that occurs in Greece at altitudes between 250 m and 1,000 m. Two sub-zones are distinguished: *Ostryo-Carpinion orientalis* at lower altitudes and *Quercion frainetto* (confertae) at higher altitudes. According to Horvat et al. (1974) and our own records, *C. sativa* forests occur primarily in the second subzone. Due to the frequent presence of *C. sativa* forest in the vegetation sub-zone of

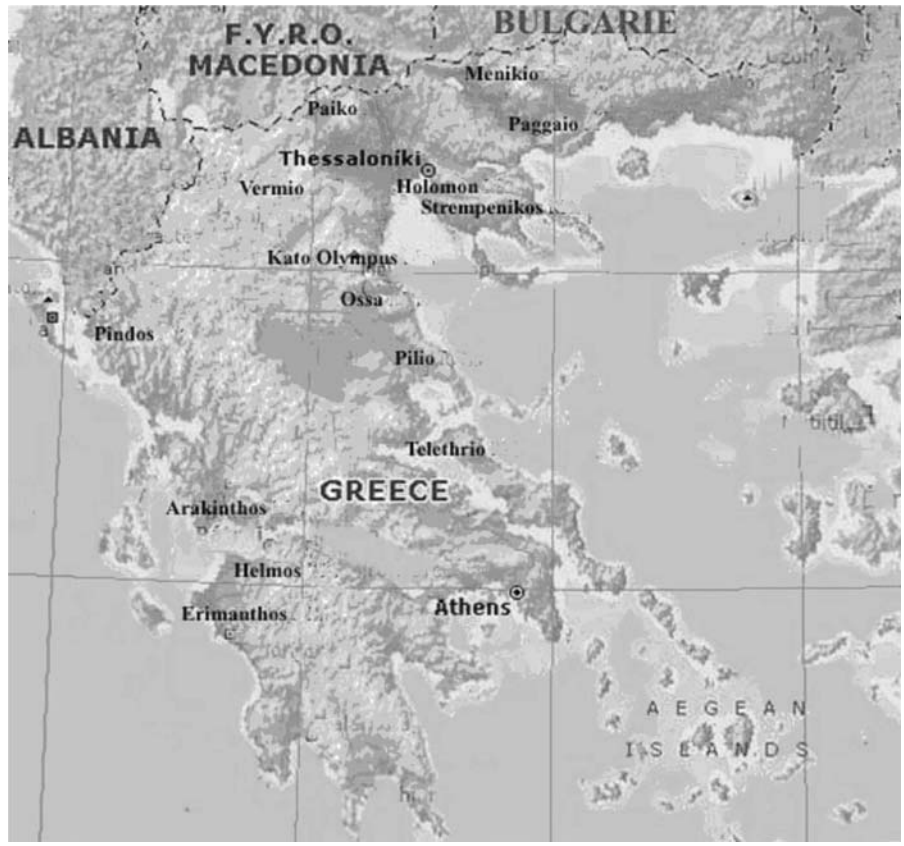

Fig. 1 Distribution of the studied mountains across Greece

Quercion frainetto, some taxonomists have identified a distinctive *Castanetum* growing zone adjacent to it (Dafis 1972; Athanasiadis 1986). At higher elevations *C. sativa* forests are still frequent, but *Fagus sylvatica* (beech) then dominates locally and constitutes the growing zone of *Fagetum moesiacae*. Although, *C. sativa* forms pure stands in some areas, the majority of these are mixed with *Quercus* sp. (especially *Q. frainetto*), *Fagus* sp., *Abies cephalonica* and *Pinus nigra* depending on the altitude and the geographic latitude.

Data collection and classification approach

The relevés were sampled during May and June, between 1996 and 2003, using the Braun-Blanquet (1964) approach (Mueller-Dombois and Ellenberg 1974). The plots were located at various altitudes, aspects, slope inclinations and relief. Plot size was set at 300 m^2 and efforts were made to achieve high ecological and physiognomical homogeneity within each plot (Dafis 1972; Athanasiadis 1986). The following parameters were recorded for each relevé: elevation, inclination, slope orientation, abundance for each layer (tree-, shrub- and grass-layer) and the geographic coordinates. Vascular plants were identified using "Flora Europaea" (Tutin et al. 1964–1980); Diapoulis (1939–1949); Kavvadas (1956–1964). The nomenclature of taxa follows "Flora Europaea" (Tutin et al. 1964–1980). Climatic data for all areas were also collected from local meteorological stations (Table 1).

The identification of vegetation units was done using the polythetic divisive method TWINSPAN (Hill 1979; Hill et al. 1975). The original Braun-Blanquet scale of abundance was first converted into an ordinal scale (Bergmeier and Dimopoulos 2001), with values ranging from 1 to 7 corresponding to the original seven classes of abundance. A data matrix was then created including all samples and species with the converted abundance values. The classification was done using the TWINSPAN for Windows 3 software. The pseudospecies cut levels used were 0.1,

Table 1 Location of study areas of *Castanea sativa* forests in Greece and main climatic parameter to adjacent meteorological stations

Site	Geographic coordinates	Altitude (m.)	Aspect (degree)	Slope (%)	Substrate	Meteorological station	Altitude (m)	Geographic position	Q^2	m (C)	Bioclimatic zone
Zagori (Pindos)	(20° 50′, 39° 50′)	750–900	100–200	10–30	Flysch	Krania	952	21° 15′–39° 53′	119	−19	Hard winter humid
Vermio	(22° 35′, 40° 34′)	600–1,000	100–300	10–50	Schist, Flysch,	Velvendos	500	22° 05′–40° 15′)	50,8	−1.7	Hard winter semi-arid
Paiko	(22° 00′, 41° 05′)	640–850	0–100	0–30	Gneisses, Schist	Goumenissa	1,140	22° 20′–40° 58′	137	−2, 3	Hard winter humid
Holomon	(23° 34′ , 40° 28′)	650–750	0–360	25–50	micaschistsgneiss	Polygyros	540	23° 26′–40° 23′	73	+0,2	Cold winter sub-humid
Stratonikon	(23° 45′, 40° 33′)	300–650	0–200	25–80	Biotite gneiss	Arnaia	565	23° 40′– 40° 39′	78, 6	−2, 2	Hard winter sub-humid
Paggaio	(24° 10′, 40° 40′)	650–900	0–300	15–60	Gneisses	Paggaio	1,310	23° 12′–40° 50′	85.8	−5.1	Hard winter sub-humid
Menikio	(23° 48′, 41° 10′)	550–900	100–350	20–50	Gneisses	Chysopigi	605	23° 34′–41° 10′-	69.7	−40.6	Hard winter sub-humid
Kato Olympus	22° 38′–39° 42′	400–800	0–300	10–30	Gneisses	Skoteina	740	22° 12′–40° 11′	85,2	−1, 5	Hard winter sub-humid
Ossa	(22° 40′, 39° 50′)	350–800	100–300	15–38	Schists, gneiss	Agia	650	22° 26′–39° 43′	69	1,2	Cold winter sub-humid
Telethrio	(23° 10′, 38° 50′)	900–1,000	200–360	20–35	Flysch	Chalkida	5	23° 36′–38° 28	59, 8	5, 1	Cold winter semi-arid
Pilio	(23° 10′, 39° 23′)	350–850	50–250	20–50	Gneisses	Skoteina	740	22° 12′–40° 11′	85, 2	−1,5	Hard winter sub-humid
Arakynthos	(21° 25′, 38° 30′)	400–700	50–200	15–40	Flysch	Mesolongi	650	21° 26′–38° 22′	101	+6, 6	Temperate winter
Helmos	(22° 15′, 38° 00′)	900–1,100	250–360	20–55	Flysch	Kalavrita	700	22° 06′–38° 02′	59.95	1.2	Cold winter semi-arid
Erimanthos	(22° 00′, 38°00′)	800–1,000	150–300	10–50	Flysch	Andritsena	760	22° 29′–37° 23′)	114	+2, 9	Cold winter sub-humid

3.1, 4.1, 5.1 and 6.1 ordinal scale units. Classification to the 5th hierarchical level was performed, with the minimum number of samples to justify further division set at 2. The maximum number of indicator pseudospecies was set at seven and all pseudospecies were available as indicator species. The initial classification resulted in a large number of groups, but as not all of these represented distinctive vegetation units, some groups were merged into higher division levels. This process was aided by the results of a Correspondence Analysis ordination (CA) (Hill 1973, 1974). As TWINSPAN is based on a single axis ordination for the differentiation of the groups, it provides relatively little information on the floristic relationships between the groups and the degree of floristic overlap between them (Gauch 1982). Ordination analysis using CA, on the other hand, uses all the information contained in the samples by species data matrix, allowing interpretation of a two-dimensional sample ordination diagram in order to determine the floristic consistency of the identified groups, as well as the floristic relationships between groups. It should be noted here that at no case groups were merged that were not part of the same group at the next higher division level, because this would compromise the objectivity of the method.

The samples and species in the original data matrix were manually re-arranged according to the final groups identified by TWINSPAN in order to represent distinctive vegetation units. Samples comprising a distinctive group were allocated to consecutive columns, whilst the indicator and highly preferential species of the group were in consecutive rows. This table was then used to identify differential species in each group and to delimit a vegetation unit represented by the group. Nomenclature of the plant communities was based on Horvat et al. (1974) and Raus (1980). The definition of "zones" and "subzones" follows Dafis (1975) and Athanasiadis (1986).

Results

The initial classification by TWINSPAN resulted in 25 groups, which were reduced to ten distinctive vegetation units after merging similar groups using the CA results (Fig. 2). The rearrangement of species and samples in the original species-samples data matrix allowed the identification of differential species for each of the ten groups and the denomination of the vegetation unit. Differential species at higher hierarchical levels were also identified. Table 2 shows the frequencies of the differential species for the corresponding vegetation units. According to these results, the classification of the *C. sativa* forests in the mountains of Greece is as follows:

Syntaxonomic–synsystematic synopsis

CLASSE: *Querco-Fagetea* Braun-Blanquet and Vlieger 1937 in Vlieger 1937

ORDER: *Quercetalia pubescentis* Braun-Blanquet 1932

ALLIANCE: *Quercion frainetto* Horvat 1958

ASSOCIATION: *Castanetum sativae macedonicum* Nikolovski 1951

SUB-ASSOCIATION: *Castanetum sativae macedonicum Juniperetosum oxycedrus*

SUB-ASSOCIATION: *Castanetum sativae macedonicum Rubetosum hirtus*

SUB-ASSOCIATION: *Castanetum sativae macedonicum Calaminthetosum gradiflora*

SUB-ASSOCIATION: *Castanetum sativae macedonicum Alliarietosum petiolata*

SUB-ASSOCIATION: *Castanetum sativae macedonicum Scutellarietosum columnae*

ASSOCIATION: *Castaneo-Quercetum submediterraneum*. Wraber (1954).

ASSOCIATION: *Castanea sativa–Bellis sylvestris* comm.

ASSOCIATION: *Querco–Castanetum sativae*

ASSOCIATION: *Castanea sativa–Trifolium physodes* comm.

SUB-ASSOCIATION: *Castanea sativa–Trifolium physodes* with *Filago pyramidata*

SUB-ASSOCIATION: *Castanea sativa–Trifolium physodes* with *Pinus nigra*

ASSOCIATION: Castanetum sativae macedonicum Nikolovski 1951.

SITES: Pindos, Vermio, Paiko, Holomon, Strempenikos, Pageon, Menikio.

TWINSPAN CLUSTER: *0

ALTITUDE: 280 m. (Strempenikos), 1,020 m. (Vermio). Mean: 580 m.

ASPECT: North, North-east, East.

SLOPE: 0–70%. Mean 17,5%.

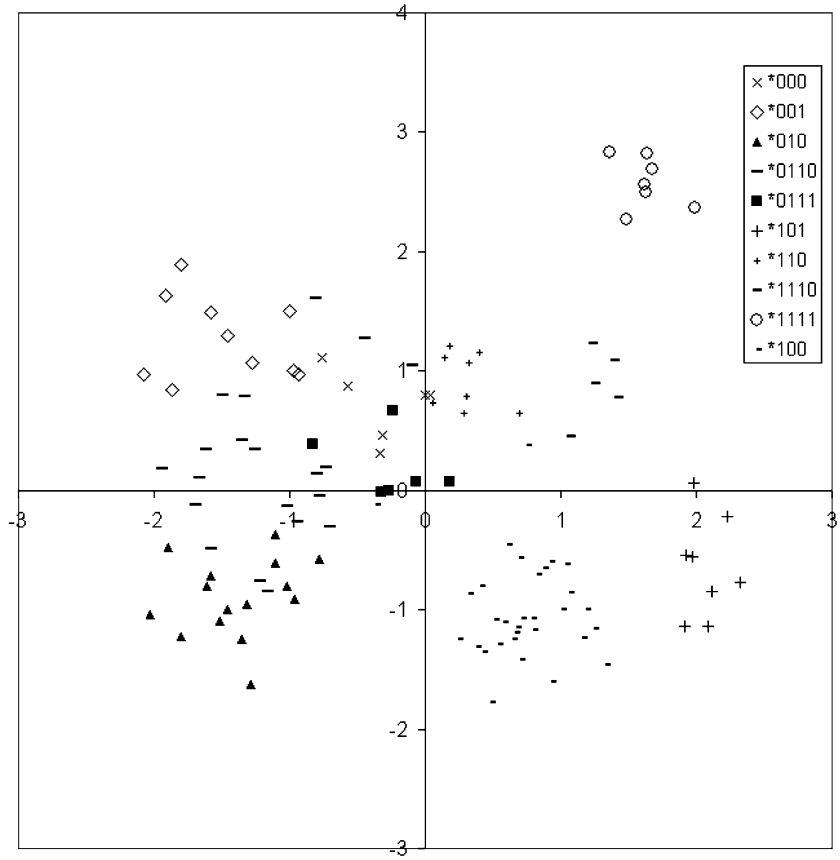

Fig. 2 CA samples ordination diagram for axis 1 and 2. The different symbols indicate the ten final groups resulted from the post-classification processing of the TWINSPAN classification scheme. The codes in the legend are the ones assigned by TWINSPAN (*000 = Pindos, *001 = Vermio, *010 = Strempenikos and Holomon, *0110 = Meniko and Pageon, *0111 = Paiko (with two relevéves of Telethrio), *101 = Telethrio, *110 = Arakinthos, *1110 = Helmos, *1111 = Erimanthos, *100 = Kato Olympus, Ossa, Pilio)

TREES COVER: 60–70%. Mean 80%.
SHRUB COVER: 5–50%. Mean 25%.
HERB COVER: 10–50. Mean 20%.
SUBSTRATE: Flysch, Schist, Gneisses (Biotite gneiss, Schist-Gneiss).
Differential species: *Euphorbia amygdaloides*, *Sorbus torminalis*, *Polygonatum odoratum*, *Viola hirta*, *Calystegia silvatica*, *Poa bulbosa*, *Silene coronaria*, *Hieracium murorum*, *Scutellaria altissima*, *Trifolium ochroleucon*, *Corylus avellana*, *Filago arvensis*.

The *C. sativa* forests on the mountains of northern Greece were classified under this association. Although modern phytosociology avoids the denomination of plant communities based on their geographical distribution, in the current study we adopted the nomenclature introduced by Nikolovski (Horvat et al. 1974), in order to emphasize the close affinities between the *C. sativa* forests of central Balkans and those of northern Greece. The same association has also been described by Rudski (1936), Tomašević (1959), Em (1960), Grebenščikov (1950) and Smith and Smith (2003).

This plant community has been found in all locations in the mountains of northern Greece, close to the borders with FYROM, and is possibly the most widely distributed plant community of *C. sativa* in the entire Balkan Peninsula. The soils on sites where the association occurs are moderately deep and highly productive, and are considered to be the most valuable forest soils in Greece. Climatic data from nearby meteorological stations indicate that *C. sativa* forests belong mainly to the sub-humid zone, characterized by hard winters (Table 1). The percentage cover in the upper canopy layer of these stands is a function of the local environmental conditions but it rarely falls below 70%. The understorey, on the other hand, is rather sparse and seldom exceeds 40% cover. According to the classification, the following five sub-associations have been identified, reflecting variations in the floristic composition of the association:

Table 2 Synoptic table of the C. sativa forests showing the frequencies of species in each of the identified associations and sub-associations. Species frequencies at higher hierarchical levels of the classification scheme are also shown

TWINSPAN CLUSTER	0					100	101	110	111	
	000	001	010	0110	0111				1110	1111
Number of relevés	6	10	15	19	7	31	8	8	5	7
Differential species of classe: Querco-Fagetea Braun-Blanquet and Vlieger 1937										
Brachypodium sylvaticum	V	IV	IV	IV	V	IV	IV	V	V	V
Dactylis glomerata	II	III	V	III	V	IV	IV	IV	V	V
Veronica chamaedrys	V	IV	IV	III	IV	IV	IV	IV	V	
Hedera helix	IV	III	IV	IV		III				
Aremonia agrimonoides	II	IV	V	III	II	III	I		III	IV
Rubus canescens			V	III		III				
Viola reichenbachiana				II	II	III				
Rosa arvensis				II	II	II				
Lapsana communis			I	III		I			II	
Ilex aquifolium		I		I		II				
Crataegus monogyna	I		I	II		IV	V	V	V	V
Epipactis helleborine		III		II		I				
Prunus mahaleb		III			III			II		
Mycelis muralis		I	I	III		III				
Campanula trachelium		III	IV	II	III	I				
Poa nemoralis		IV	IV	III	IV	I				
Fagus sylvatica		III	II			I				
Origanum vulgare			II		I	III				
Poa bulbosa		II	II	I	III	II	I		V	
Primula acaulis		III		II	V					
Primula veris		III		I	I					
Arbutus andrachne						III				
Milium vernale						II	II			
Digitalis viridiflora		I	II	I						
Geum urbanum	I	I	I	I						
Fagus moesiaca				II						
Ranunculus paludosus						I	V			
Euphorbia oblongata						I				
Clematis flammula						II				
Dorycnium pentaphyllum						I			I	V
Geum reptans						III	II			
Prunus spinosa			I	II		I		I		
Melica uniflora	IV	IV	V	III	II					
Piptatherum coerulescens	II					II				
Lilium martagon			II			I				
Differential species of classe: Quercetalia pubescentis Braun-Blanquet 1932										
Luzula forsteri	V	I	IV	IV	V	V	II	V	V	IV
Clinopodium vulgare	V	III	IV	III	V	V	III	III	III	II
Carpinus orientalis	I	V	I	III	IV	I		III	IV	V

Table 2 continued

TWINSPAN CLUSTER	0					100	101	110	111	
	000	001	010	0110	0111				1110	1111
Number of relevés	6	10	15	19	7	31	8	8	5	7
Cephalanthera longifolium		III			I	III				I
Ruscus aculeatus		III	IV	III	V	II		V		V
Silene vulgaris			III	I		III				
Anthemis tinctoria		I	III	II	II	III				
Selinum silaifolium					II	II				
Sorbus domestica	I		III		II	III				
Hypericum perforatum		III		I	I	I				
Fraxinus ornus			V	IV						
Festuca heterophylla	II	III	II	III	I					
Cornus mas	IV	V	I	III						
Verbascum nigrum			IV		V					
Vicia tenuifolia		V			V					
Asplenium adiantum-nigrum			II	I						
Orchis provincialis						III				
Dorycnium graecum						III				
Juglans regia					V	II				
Stellaria media						I			III	
Astragalus glycyphyllos			I	I	III					
Cardamine bulbifera			I	I	I					
Carex flacca			I	I	I					
Aristolochia rotunda			I	I	III					
Silene italica				II	III					
Differential species of alliance: Quercion frainetto Horvat 1958										
Castanea sativa	V	V	V	V	V	V	V	V	V	V
Pteridium aquilinum	V	IV	V	V	V	V	V	V	V	V
Quercus frainetto	V	IV	III	I	II	II		V		IV
Lathyrus laxiflorus			III	II	IV	V	III	III	IV	V
Leontodon cichoriaceus		III		I	IV	II				IV
Lathyrus niger	II	II	III	III	IV	III				
Cyclamen hederifolium	II		II	I		V	III	II		V
Melittis melissophyllum		III	I		I	III		IV	V	V
Campanula spatulata	II	III		II	V	V	IV	IV	V	III
Crepis fraasii		II				III	II	I	V	III
Sorbus torminalis	I	IV	III	II		II		I	I	II
Trifolium pignantii	IV	I	I		II					
Doronicum orientale			II	III	I					
Helleborus cyclophyllus	III		IV	I						
Potentilla micrantha			III		II					
Physospermum cornubiense		III	IV							
Differential species of association: Castenetum sativae macedonicum Nikolovski 1951										
Corylus avellana	V	V	II	II	II					
Trifolium ochroleucon	V	I	II	III	II	III				

Table 2 continued

TWINSPAN CLUSTER	0					100	101	110	111	
	000	001	010	0110	0111				1110	1111
Number of relevés	6	10	15	19	7	31	8	8	5	7
Polygonatum odoratum		IV	IV	III		I				
Viola hirta		III	III	I	V					
Calystegia silvatica		I	III	II	II					
Filago arvensis	V	V			V					
Silene coronaria			III		II					
Hieracium murorum				II	IV					
Scutellaria altissima			I	I	I	III				
Euphorbia amygdaloides				IV		II				I
Differential species of sub-association: Castanetum sativae macedonicum *Juniperetosum oxycedrus*										
Juniperus oxycedrus	V			II	II	I			II	IV
Helianthemum nummularium	V									
Acer pseudoplatanus	V									
Hypericum barbatum	V									
Anthoxanthum odoratum	II		I							
Prunella vulgaris	IV		I	I	I	II				
Quercus cerris	IV					I				
Thymus longicaulis	IV									
Eryngium campestre	IV									
Colutea arborescens	II									
Teucrium chamaedrys	II									
Differential species of sub-association: Castanetum sativae macedonicum *Rubetosum hirtus*										
Rubus hirtus		V			III					
Rosa canina		V		I	II			III		
Neottia nidus-avis		IV							I	
Cornus sanguinea		III			I					
Torilis arvensis		II				I				
Epilobium montanum		II		I	II					
Hieracium sp.		III								
Clematis vitalba		III		I	II	III				
Vicia parviflora		II		I						
Euonymus latifolius		II								
Acer campestre		II								
Asarum europaeum		II								
Calamintha nepeta		II								
Cirsium ligulare		II								
Corylus colurna		II								
Ruscus hypoglossum		II								
Vulpia ciliata		II								
Differential species of sub-association: Castanetum sativae macedonicum *Calaminthetosum gradiflora*										
Calamintha grandiflora			V							
Galium laconicum			V		II					
Genista tinctoria			IV		I	III				

Table 2 continued

TWINSPAN CLUSTER	0					100	101	110	111	
	000	001	010	0110	0111				1110	1111
Number of relevés	6	10	15	19	7	31	8	8	5	7
Hypericum montbretii			IV			II				
Lysimachia vulgaris			III							
Scrophularia nodosa			III							
Vicia hirsuta			III							
Lathyrus venetus			III	I	I	III				
Chamaecytisus hirsutus			III							
Achillea grandifolia		I	III							
Convolvulus arvensis			II							
Galium odoratum			II							
Galium asparagifolium			II							
Differential species of sub-association: Castanetum sativae macedonicum *Alliarietosum petiolata*										
Alliaria petiolata				V						
Fragaria vesca			I	IV						
Rubia peregrina				II		II				
Daphne laureola		II	I	II						
Lathyrus vernus				III						
Ajuga reptans				I						
Piptatherum miliaceum				II				II		
Differential species of sub-association: Castanetum sativae macedonicum *Campanuletosum spatulata*										
Scutellaria columnae		I		I	IV					
Hieracium pavichii				I	IV					
Trifolium campestre	I			I	III					
Campanula persicifolia			I		II					
Cardamine graeca				II	I					
Viola odorata					II		I			
Carex distans		I		I	III					
Dorycnium hirsutum			I		II					
Hypericum spruneri					II					
Lotus corniculatus					II					
Minuartia verna					II					
Muscari commutatum					II					
Trifolium heldreichian					II					
Differential species of Association: Castaneo-Quercetum submediterraneum										
Quercus pubescens				II		IV				
Vicia grandiflora						V	I			
Asplenium onopteris						V	I			
Poa trivialis		I			I	IV	I			
Viola alba		II				IV	II			
Cirsium morinaefolium	I					III				
Erica arborea			I			III				
Sanicula europaea		I	I			I				
Ranunculus bulbosum						II				

Table 2 continued

TWINSPAN CLUSTER	0					100	101	110	111	
	000	001	010	0110	0111				1110	1111
Number of relevés	6	10	15	19	7	31	8	8	5	7
Hieracium bracteolatum			I			III				
Geranium robertianum		I				III				
Asparagus acutifolius						III				
Lithospermum purpureocaeruleum						III				
Lolium multiflorum						I				
Melissa officinalis			I			II				
Polystichum setiferum						II				
Sedum cepaea			I			I				
Festuca drymeja						III				
Trifolium arvense		I				II				
Cardamine graeca						II				
Galium heldreichii						II				
Poa nemoralis						II				
Sanguisorba minor						II				
Differential species of Association: *Castanea sativa–Bellis sylvestris comm.*										
Bellis sylvestris						I	V			
Hordeum bulbosum							V			
Cerastium comatum							V			
Moenchia graeca							V			
Trifolium grandiflorum						I	II			
Trifolium repens						I	II			
Cruciata laevipes							III			
Leontodon tuberosus							III			
Viola sieheana							II			
Hordeum murinum							III			
Bromus rubens					I		I			
Calystegia silvatica							II			
Genista acanthoclada							II			
Hypericum perforatum							II			
Prunus cerasus							II			
Prunus domestica							II			
Pyrus communis							II			
Smilax aspera							II			
Trifolium angustifolium							II			
Umbilicus rupestris							II			
Differential species of Association: Querco–Castanetum sativae										
Quercus ilex						III		I		
Cytisus villosus	I							V		
Cyclamen repandum	I	I						IV		
Rubus species								III		
Galium aparine		I		II		II		IV		
Ostrya carpinifolia								III		

Table 2 continued

TWINSPAN CLUSTER	0					100	101	110	111	
	000	001	010	0110	0111				1110	1111
Number of relevés	6	10	15	19	7	31	8	8	5	7
Differential species of association: *Castanea sativa–Trifolium physodes comm.*										
Trifolium physodes									IV	V
Symphytum bulbosum							I		I	II
Quercus coccifera				III					V	V
Ranunculus sprunerianum		I							V	V
Stipa bromoides					I				II	
Cistus creticus	II					I			II	V
Abies cephalonica									I	I
Cistus creticus	II					I			II	V
Abies cephalonica									I	I
Differential species of sub-association: *Castanea sativa–Trifolium physodes* with *Filago pyramidata*										
Filago pyramidata	II	IV			I	II			V	
Galium rotundifolium						I			II	
Limodorum abortivum									II	
Phlomis samia									II	
Differential species of sub-association: *Castanea sativa –Trifolium physodes* with *Pinus nigra*										
Pinus nigra										V
Digitalis laevigata						I				V
Cynosurus echinatus							II			V
Hippocrepis emerus										V

Species with a single appearance have been omitted. Differential species for each vegetation unit are shown in rectangles. Frequency symbols are: I= species recorded in 1–20% of all relevés of each plant unit, II = 21–40%, III = 41–60%, IV = 61–80%, V = 81–100%.

Other plants with a single appearance: *Acer platanoides* (Vermio), *Acer tataricum* (Vermio), *Agrimonia eupatoria* (Ossa), *Aira elegantissima* (Ossa), *Alliaria petiolata* (Paggaio), *Anthoxanthum gracile* (Evia), *Arum italicum* (Evia), *Brachypodium pinnatum* (Holomon), *Buxus sempervirens* (Holomon), *Campanula rapunculoides* (Vermio), *Campanula trachelium* (Pilio), *Carex hallerianar* (Pilio), *Carex sylvatica* (Vermio), *Cephalanthera rubra* +(Vermio), *Cerastium brachypetalum* (Paggaio), *Cistus salviifolius* (Ossa), *Cotinus coggygria* (Ossa), *Daphne laureola* (Pilio), *Euphorbia dulcis* (Vermio), *Festuca jeanpertii* (*Helmos*), *Filago cretensis* (Vermio), *Gagea species* (Evia), *Genista carinalis* (Paiko), *Geum montanum* (Pindos), *Laurus nobilis* (Ossa), *Leontodon hispidus* (Paiko), *Lolium multiflorum* (Ossa), *Lonicera implexa* (Ossa), *Lonicera xylosteum* (Vermio), *Luzula campestris* (Paiko), *Luzula sylvatica* (Paiko, *Medicago lupulina* (Evia), *Muscari comosum* (Paiko, *Oenanthe pimpinelloides* (Holomon, *Phlomis fruticosa* (Evia), *Potentilla reptans* (Evia), *Prunella grandiflora* (*Vermio*), *Prunella laciniata* (Evia), *Psoralea bituminosa*, (Paiko), *Pyrus spinosa* (Evia), *Quercus petraea* (Vermio), *Ranunculus bulbosus* (Strempenikos), *Ranunculus thracicus* (Vermio), *Rosa gallica* (Pindos), *Salix caprea* (Vermio), *Saxifraga bulbifera* (Paiko, *Sedum cepaea* (Paggaio), *Solidago virgaurea* (Vermio), *Sonchus oleraceus* (Ossa), *Spartium junceum* (Ossa), *Stachys germanicar* (Evia), *Thymus sibthorpii* (Holomon), *Tilia platyphyllos* (Vermio), *Trifolium alpestrer* (Paiko), *Trifolium medium* (Holomon), *Urtica dioica* (Holomon), *Verbascum aphentulium* (Ossa), *Vulpia ciliater* (Ossa).

SUB-ASSOCIATION: Castanetum sativae macedonicum Juniperetosum oxycedrus
SITE: Pindos.
TWINSPAN CLUSTER: *000
ALTITUDE: 820 m., 910 m. Mean: 870 m.
ASPECT: East, South-east.
SLOPE: 10–20%. Mean 15%.
TREE COVER: 40–60%. Mean 50%.
SHRUB COVER: 5–50%. Mean 25%.
HERB COVER: 30–40. Mean 35%.
SUBSTRATE: Flysch.
Differential species: *Juniperus oxycedrus*, *Helianthemum nummularium*, *Acer pseudoplatanus*, *Hypericum barbatum*, *Anthoxanthum odoratum*, *Prunella vulgaris*, *Quercus cerris*, *Thymus longicaulis*, *Eryngium campestre*.

On northern Pindos ridge, where grazing by domestic animals is severe, the *Castanetum sativae macedonicum Juniperetosum oxycedrus* sub-association was identified. This sub-association is confined to small patches and with a relatively sparse canopy, characterized by the high abundance of non-edible or spiny species, such as *Juniperus oxycedrus*, *Anthoxanthum odoratum* and *Eryngium campestre*. The region is located in the hard winter, humid bioclimatic zone. Soils have a slightly acidic to neutral reaction and are shallow and relatively poor in nutrients. The relatively sparse canopy cover and the poor soil conditions are reflected in the ground flora species, which are shade intolerant and have low requirements for nutrients. The lack of systematic management of the *C. sativa* stands in the region results in their encroachment by *Quercus frainetto* and *Q. cerris*, which are both relatively abundant in this sub-association compared with other sub-associations. The dynamics of *Q. frainetto* in the area suggests that if the abandonment of *C. sativa* forest management continues, the latter could possibly be supplanted by *Q. frainetto* in the near future.

SUB-ASSOCIATION: Castanetum sativae macedonicum Rubetosum hirtus
SITE: Vermio.
TWINSPAN CLUSTER: *001
ALTIDUTE: 630 m., 1020 m. Mean: 820 m.
ASPECT: North, North-east, East.
SLOPE: 10–30%. Mean 20%.
TREE COVER: 40–90%. Mean 77%.
SHRUB COVER: 10–50%. Mean 30%.
HERB COVER: 10–20. Mean 10%.
SUBSTRATE: Flysch.
Differential species: *Rubus hirtus*, *Rosa canina*, *Clematis vitalba*, *Neottia nidus-avis*, *Cornus sanguinea*, *Melittis melissophyllum*, *Epilobium montanum*, *Filago pyramidata*, *Hieracium* sp., *Vicia parviflora*, *Euonymus latifolius*.

This sub-association has similarities with the *Rubo hirti—Castanetum sativae* association that was identified and described in Toscana (Italy) by Arrigoni and Viciani (2001). The region has hard winters and is located in the semi-arid bioclimatic zone. The sub-association is characterized by the high frequency of hygrophilous species with relatively low requirements for soil nutrients. Such species include the semi-climbing, hygro-eutrophic and shade-tolerant species *Rubus hirtus, Clematis vitalba* and *Rosa canina*, the woody species *Carpinus orientalis, Sorbus torminalis, Prunus mahaleb*, as well as the underbrush species *Melittis melissophyllum, Epilobium montanum, Vicia parviflora, Euonymus latifolius, Neottia nidus-avis*. All of the above species prefer acidic or neutral and well-drained soils. They also grow in heavy clay soil, in open conditions or light shade.

SUB-ASSOCIATION: Castanetum sativae macedonicum Calaminthetosum gradiflora
SITES: Holomon, Strempenikos.
TWINSPAN CLUSTER: *010
ALTITUDE: 260 m., 630 m. Mean: 400 m.
ASPECT: North-east.
SLOPE: 10–70%. Mean 35%.
TREE COVER: 70–100%. Mean 90%.
SHRUB COVER: 10–50%. Mean 25%.
HERB COVER: 10–40. Mean 15%.
SUBSTRATE: biotite gneiss.
Differential species: *Calamintha grandiflora*, *Galium laconicum*, *Genista tinctoria*, *Hypericum montbretii*, *Lysimachia vulgaris*, *Scrophularia nodosa*, *Vicia hirsuta*, *Lathyrus venetus*, *Chamaecytisus hirsutus*, *Achillea grandifolia*.

This sub-association was identified in the two neighbouring mountains of the Chalkidiki peninsula (Holomon and Strempenikos). In this area, *C. sativa* forests occur at altitudes between 280 and 600 m and locally can even be found at sea level, the lowest altitudinal distribution of *C. sativa* in Greece. This is due to the cool maritime currents of north Aegean Sea, which, locally, lower the temperatures of the summer months allowing broadleaved deciduous forests to occur at low altitudes. Holomon is located in the cold winter, sub-humid bioclimatic zone and Strempenikos in the hard winter, sub-humid bioclimatic zone. The sub-association is particularly rich in accompanying species which vary in their preferences relating to both air temperature and soil water. The most characteristic are the thermophilous and xerophilous species *Origanum vulgare*, *Galium laconicum* and *Genista tinctoria*, the thermophilous and moderately hygrophilous species *Physospermum cornubiense*, *Potentilla micrantha*, *Cyclamen hederifolium* and *Helleborus cyclophyllus*, as well as *Asplenium adiantum-nigrum*, *Astragalus glycyphyllos*, *Cardamine bulbifera*, *Carex flacca*, *Sorbus domestica* and *Chamaecytisus hirsutus*, which are

also hygrophilous but grow under cooler conditions. Finally, species present in the sub-association and with broad preferences regarding air temperature and soil water include *Hypericum montbretii*, *Lysimachia vulgaris*, *Scrophularia nodosa*, *Vicia hirsuta* and *Achillea grandifolia*.

SUB-ASSOCIATION: Castanetum sativae macedonicum Alliarietosum petiolata
SITES: Menikio, Pageon.
TWINSPAN CLUSTER: *0110
ALTITUDE: 590 m., 900 m. Mean: 700 m.
ASPECT: North-east, South-west, South, West.
SLOPE: 10–50%. Mean 25%.
TREE COVER: 60–90%. Mean 80%.
SHRUB COVER: 10–25%. Mean 12,5%.
HERB COVER: 10–20%. Mean 15%.
SUBSTRATE: Schist-Gneiss.
Differential species: *Alliaria petiolata*, *Fragaria vesca*, *Rubia peregrina*, *Lathyrus vernus*, *Ajuga reptans*, *Piptatherum miliaceum*.

This sub-association was found in the neighbouring mountains of Pageon and Menikio, both located in the north-eastern part of Greece and the hard winter, sub-humid bioclimatic zone. One of the main characteristics of the sub-association is the presence of the acidophilus species *Fragaria vesca* and the xerophilous species *Euphorbia amygdaloides*, which are both indicative of the soil and climatic conditions prevailing in the area. Other species present are *Hieracium murorum, Galium aparine, Campanula spatulata* and *Silene italica*. Slope orientation seems to be of limited importance in this area since the sub-association is not restricted to north and east slopes, but can also be found on south and west-facing slopes where, however, it is restricted to less steep slopes (<30%) and nutrient-rich soils.

SUB-ASSOCIATION: Castanetum sativae macedonicum Scutellarietosum columnae
SITES: Paiko, Telethrio.
TWINSPAN CLUSTER: *0111
ALTITUDE: 640 m., 1000 m. Mean: 765 m.
ASPECT: North, North-east, East.
SLOPE: 0–30%. Mean 17%.
TREE COVER: 60–90%. Mean 78%.
SHRUB COVER: 10–30%. Mean 20%.
HERB COVER: 30–70. Mean 55%.
SUBSTRATE: Flysch.
Differential species: *Scutellaria columnae*, *Hieracium pavichii*, *Trifolium campestre*, *Campanula persicifolia*, *Cardamine graeca*, *Carex distans*, *Dorycnium hirsutum*.

This sub-association has many similarities to the sub-association *Castanetum sativae macedonicum Rubetosum hirtus* found at Mt. Vermio. The most important difference is that this sub-association has a very dense grassy ground flora. It occurs mainly on Mt. Paiko in N. Greece, although two relevés from Mt. Telethrio located in south-central Greece were also classified within the same sub-association, despite the big bioclimatic differences between the two mountains. The sub-association is characterized by the high frequency of meso-hygrophilous species (all the differential species) and species of the *Quercetalia pubescentis* order that have relatively low requirements for soil nutrients including *Brachypodium sylvaticum*, *Luzula forsteri*, *Veronica chamaedrys*, *Melica uniflora*, *Poa nemoralis*, *Clinopodium vulgare*, *Aremonia agrimonoides*, *Cephalanthera longifolium*, *Vicia tenuifolia*, *Dactylis glomerata*. There are also some woody species such as *Fagus sylvatica*, *Cornus mas*, *Carpinus orientalis*, whilst *Quercus frainetto* is also found in the two releves at Mt. Telethrio. All the above species prefer well-drained soils and can grow in heavy clay, acid and neutral soils too.

ASSOCIATION: Castaneo-Quercetum submediterraneum. Wraber (1954).
SITES: Pilio, Kato Olympus, Ossa.
TWINSPAN CLUSTER: *100
ALTITUDE: 200 m., 870 m. Mean: 520 m.
ASPECT: North, North-east, East, South-west, West, North-west.
SLOPE: 10–45%. Mean 30%.
TREE COVER: 70–90%. Mean 85%.
SHRUB COVER: 20–50%. Mean 30%.
HERB COVER: 10–50%. Mean 30%.
SUBSTRATE: Schist.
Differential species: *Vicia grandiflora*, *Asplenium onopteris*, *Poa trivialis*, *Viola alba*, *Erica arborea*, *Trifolium ochroleucon*, *Ranunculus bulbosum*, *Hieracium bracteolatum*, *Scutellaria altissima*, *Geranium robertianum*, *Asparagus acutifolius*, *Lithospermum purpureocaeruleum*, *Lolium multiflorum*, *Melissa officinalis*, *Polystichum setiferum*,

Prunella vulgaris, *Sedum cepaea*, *Arum italicum*, *Clematis vitalba*, *Festuca drymeja*.

The *C. sativa* forests of central Greece are characterized by a high floristic homogeneity (Figure 2) and this is reflected in their classification under the single association of *Castaneo-Quercetum submediterraneum*. This plant community has also been described in Slovenia by Wraber (Horvat et al. 1974), in the supramediterranean and submediterranean zones (Mayer 1974; Horvat et al. 1974; Pignatti 1982; Ellenberg 1988). Characteristic accompanying species of the community include: *Quercus pubescens, Pteridium aquilinum, Hieracium* sp., *Veronica chamaedrys*, *Luzula forsteri*, *Rubus hirtus*, *Crataegus monogyna*, *Viola reichenbachiana*, *Cruciata*, sp., *Brachupodium sylvaticum*, *Hedera helix*, *Geum urbanum*, *Euphorbia amygdaloides*, *Sanicula europaea*, *Mycelis sp*., *Geranium robertianum*, *Polygonatum multiflorum*, *Cephalanthera longifolia*, *Clematis vitalba*, *Melittis melissophylum*, *Quercus cerris*, *Cephlanthera* sp., *Lathyrus niger*, *Sorbus domestica* etc. With various local variations in nomenclature (e.g. *Querco-Castanetum submediterraneum*, *Querco-Castanetum hercegovinicum*, *Castanetum quarnericum*) *Castanea sativa*-dominated acidophilous forests that belong to the *Ostryo-Carpinion orientalis* zone of the Balkan Peninsula are found, in particular, in the Slovenian coastal mountains, in Istria, in the islands of Krk and Cres in Bosnia-Herzegovina and in Montenegro, an area where the species is undoubtedly indigenous (Devillers-Terschuren and Devillers-Terschuren 2001).

The relative floristic stability of *C. sativa* forests in central Greece has also been pointed out by Raus (1980) for the Thessaly region and by Bergmeier (1984, 1988, 1990) for forests in Mt. Kato Olympus. We agree with Raus (1980), who classified the chestnut forests of Thessaly as Class *Querco-Fagetea*, Order *Quercetalia pubescentis* and Alliance *Quercion frainetto*, but we have further classified them to association level. Despite the floristic differences between the *C. sativa* forests of central and northern Greece there are many similarities in their distribution in terms of altitude, aspect and geology. The fungal pathogen *Cryphonectria (Endothia) parasitica* has affected the *C. sativa* forests of Mt. Pilio without, however, significantly affecting their structure and composition.

The characteristic species of *Castaneo–Quercetum submediterraneum* association are shade-tolerant and hygrophilous. Bioclimatic conditions vary from the hard winter, sub-humid type (Mts. Kato Olympos and Pilio) to cold winter, sub-humid (Mt. Ossa). At the lower southern altitudes the plant community has some similarities with the *Arbuto unedi-Castanetum* association that has been described by Arrigoni and Viciani (2001) in relation to thermophilous and subxeric aspects of the Tuscan Mts., where, depending on the altitude, some of the accompanying species are characteristic of Mediterranean maquis forests, such as *Erica arborea*, *Quercus ilex*, *Arbutus andrachne*, *Origanum vulgare* and *Asparagus acutifolius*. Due to the relatively low annual precipitation of eastern Greece the association is confined to sites with deep acidic and humid soils. On the mountains of Ossa and Pilio and on slopes facing the sea, the association can be found at relatively low altitudes due to the influence of cool maritime currents of the East Aegean Sea, which locally lower the summer temperatures.

ASSOCIATION: Castanea sativa–Bellis sylvestris comm.
SITES: Telethrio.
TWINSPAN CLUSTER: *101
ALTITUDE: 880 m., 1,090 m. Mean: 1,015 m.
ASPECT: North, South-east, North-west, South.
SLOPE: 20–40%. Mean 30%.
TREE COVER: 80–90%. Mean 85%.
SHRUB COVER: 20–40%. Mean 30%.
HERB COVER: 20–40%. Mean 35%.
SUBSTRATE: Flysch.
Differntial species: *Bellis sylvestris*, *Hordeum bulbosum*, *Cerastium comatum*, *Moenchia graeca*, *Trifolium grandiflorum, Trifolium repens, Cruciata laevipes, Leontodon tuberosus, Hordeum murinum.*

C. sativa forests on Mt Telethrio, which is located on the northern part of Euboea island (eastern central Greece), very close to the mainland, are quite distinct compared with other associations, including the *Castaneo-Quercetum submediterraneum* association present in the nearby mountains of central Greece. This was therefore provisionally classified as a new association, *C. sativa—Bellis sylvestris* comm., contingent on further research to show its cross-correlation with other identified communities. The region belongs to the semi-arid bioclimatic zone,

characterized by cold winters. In this area *C. sativa* forests are found between 880 and 1,090 m, relatively high altitudes compared with the associations mentioned earlier. Above the 900 m it occurs mainly on warmer, southern aspects with slopes between 20% and 35%. This distributional pattern results in a high number of accompanying hygrophilous and psychrophilic species, including *Crataegus monogyna*, *Ranunculus paludosus*, *Lathyrus laxiflorus*, *Cyclamen hederifolium* etc. The association is found in three isolated patches surrounded by *Fagus* sp. and *Quercus* sp. forests maintaining, however, their character and composition. The soils associated with this vegetation type are less acidic compared to the soild associated with the rest of the identified associations.

ASSOCIATION: Querco–Castanetum sativae (Horvat 1938)
SITES: Arakinthos.
TWINSPAN CLUSTER: *110
ALTITUDE: 390 m., 600 m. Mean: 500 m.
ASPECT: North, North-east, East.
SLOPE: 10–20%. Mean 15%.
TREE COVER: 80–90%. Mean 90%.
SHRUB COVER: 10–30%. Mean 25%.
HERB COVER: 30–40%. Mean 35%.
SUBSTRATE: Flysch.
Differential species: *Quercus frainetto*, *Quercus ilex*, *Cytisus villosus*, *Cyclamen repandum*, *Rosa canina*, *Galium aparine*, *Ostrya carpinifolia*.

C. sativa forests on Mt. Arakinthos, located on the southern part of Pindos ridge, are confined to relatively small patches. They have a high floristic diversity and most often occur in mixture with *Quercus frainetto*. The region of Mt. Arakinthos is located in western Greece, which has the highest rainfall in the country, in the temperate winter bioclimatic zone. Average winter temperatures here are higher than other regions of chestnut forest in Greece: the high humidity throughout the year creates ecological conditions similar to those observed in more northern, temperate climates. The same plant community has been described under different names, namely: *Castaneo-Quercetum croaticum*, *Querco-Carpinetum illyricum castanetosum*, *Querco-Castanetum illyricum*, occurring in western parts of central and northern Balkan Peninsula on extremely acid substrates and in warm, humid climates. These areas include the basins of the Drava and Sava in Slovenia, parts of Croatia, areas in north-west Bosnia-Herzegovina as well as the Mecsec hills of southern Hungary. The *Querco pubescenti-Castanetum sativae* association that was identified by Kargioğlu (1988) in Turkey also has similarities with this association. *Castanea sativa* forests in Mt. Arakinthos are relatively poor in other woody species and the few present are *Quercus frainetto*, *Carpinus orientalis*, *Rosa canina* and *Rubus* sp. The understorey is a combination of acidophilous, thermophilous species and species of the *Quercetalia pubescentis* zone including *Luzula forsteri*, *Clinopodium vulgare* and *Clinopodium vulgare*.

The degree of encroachment of chestnut forests by *Q. frainetto* in Mt. Arakinthos is probably the most advanced compared to the other study areas, and is an indication that the existence of chestnut forests depends largely on appropriate management and the continuation of the silvicultural activities prevalent in the area until the end of the 19th century. The relatively warmer conditions of southern Greece confine the presence of *C. sativa* forests in the area to north and north-east aspects and on sites with slopes not exceeding 20%.

ASSOCIATION: *Castanea sativa–Trifolium physodes comm.*
SITES: Helmos, Erimanhos
Twispan Cluster: *111
ALTITUDE: 830 m., 1,120 m. Mean: 1,000 m.
ASPECT: North. North-east, North-west.
SLOPE: 10–40%. Mean 30%
SHRUB COVER: 10–30%. Mean 20%
SUBSTRATE: Flysh
Differential speices: *Trifolium physodes*, *Quercus coccifera*, *Ranunculus sprunerianum*, *Cistus creticus*

Helmos and Erimanthos are two mountains in the southern part of Greece (Peloponnesus) in which the *C. sativa* forests share many characteristics of the previous association: they are relatively small and occur in isolated patches with high floristic diversity, often in mixture with *Q. frainetto* and *Pinus nigra* and sometimes with *Abies cephalonica*. The encroachment of these other species indicates that the *C. sativa* forests currently form a transition towards *Q. frainetto* or *A. cephalonica* forests. Although the geology of Peloponnesus is mainly limestone, *C. sativa* forests occur on patches of flysh

and conglomerate substratum. The presence at high altitudes of the phryganic species *Cistus creticus* and the thermophilous species *Quercus coccifera, Sorbus torminalis, Trifolium physodes, Ranunculus sprunerianum* and *Symphytum bulbosum* is an indication of the absence of long-lasting frosts in the area, where the mean temperature of the coldest month is above 1.2°C. *Juniperus oxycedrus* and *Quercus coccifera* are also quite common in the area, indicating the high-grazing pressure in those mountains.

The *Castanea sativa–Trifolium physodes* community varies between the two mountains of Helmos and Erimanthos, the floristic differences reflecting their different bioclimatic situations. Two distinctive sub-associations were identified: *Castanea sativa–Trifolium physodes* with *Filago pyramidata* and *Castanea sativa–Trifolium physodes* with *Pinus nigra*.

SUB-ASSOCIATION: Castanea sativa–Trifolium physodes with Filago pyramidata
SITE: Helmos.
TWISPAN CLUSTER: *1110
ALTITUDE: 830 m., 920 m. Mean: 880 m.
ASPECT: North, East, West.
SLOPE: 10–40%. Mean 30%
TREE COVER: 90%. Mean 90%
SHRUB COVER: 20–30%. Mean 25%.
HERB COVER: 30–40%. Mean 35%
SUBSTRATE: Flysch
Differential species: *Filago pyramidata*, *Galium rotundifolium.*

Helmos is an extensive mountainous mass in the northern part of Peloponnesus. The soils derive from the weathering of mainly limestone and Jurassic radiolarites, whilst in some small areas, where the *C. sativa* communities occur, there is a substratum of flyschs. *Filago pyramidata*, which characterizes the sub-association, is a broad-leaved cudweed that is common on arable and regularly disturbed land, indicating the previous land use. *Galium rotundifolium*, the second differential species, occurs in the clearings of dry sandy woodlands of *Abies cephalonica* or *Pinus nigra*.

SUB-ASSOCIATION: Castanea sativa–Trifolium physodes with Pinus nigra
SITE: Erimanthos.
TWISPAN CLUSTER:*1111
ALTITUDE: 1,000 m., 1,120 m. Mean: 1,070 m.
ASPECT: North, Northwest.
SLOPE: 25–40%. Mean 30%
TREE COVER: 70–90%. Mean 80%
SHRUB COVER: 10–30%. Mean 15%.
HERB COVER: 20–40%. Mean 30%
SUBSTRATE: Flysch
Differential species: *Pinus nigra*, *Digitalis laevigata*, *Cynosurus echinatus*, *Leontodon cichoriaceus*, *Hippocrepis emerus*, *Teline monspessulana*, *Achillea grandifolia*

Mt. Erimanthos forms the southern border of the distribution of *C. sativa* in continental Greece, beyond which higher temperatures restrict the distribution of the species. This explains why *C. sativa* forests in this region occur at higher altitudes than anywhere else in Greece. The differential species prefer light (sandy) or medium (loamy) acid or neutral soils and they usually grow in semi-shade (light woodland) or in the open. *C. sativa* forests are present on slate substrates of intense red or green colour.

Discussion

In the present study we encountered a number of difficulties in the taxonomic classification and denomination of *C. sativa* forests, which, to a great extent, is due to their transition between semi-natural forest ecosystems and artificially managed woodland formations. Many of the forests included here were established by humans in antiquity, but due to the lack of management over the last century they now appear to be reverting towards deciduous forest dominated by *Quercus frainetto* and *Fagus* spp., or alternatively coniferous *Abies cephalonica* and *Pinus nigra* forest formations (Horvat et al. 1974). Due to this instability, some ecologists have suggested that *C. sativa* ecosystems should not be classified below the level of the association (Raus 1980; Bergmeier 1990; Korakis and Athanasiadis 2003). Further, Horvat et al. (1974) have suggested that the plant communities of *C. sativa* do not include other characteristic species, apart from those of the acidic soils of sites where the communities occur. This unwillingness to classify chestnut forests below association level has resulted in the blanket classification of *Castanetum sativae* comm. which in reality shows profound floristic variation.

Currently, many researchers using modern techniques have advanced the classification of *C. sativa* at the level of association and sub-association, providing significant information on the ecology and distribution of its communities. In Italy Gamisans (1977, 1999) and Bacchetta et al. (2004) described the association *Digitalo australi–Castanetum* Gamisans 1975 (1977) whilst Arrigoni and Viciani (2001) described and named five new associations with sub-associations, as follows: (1) *Teucrio scorodoniae–Castanetum sativae*, with the sub-associations *Seslerietosum argenteae, Aceretosum pseudoplatani* and *Quercetosum cerridis* (Viciani and Gabellini 2000, Lombardi and Viciani 2003), (2) *Rubo hirti-Castanetum*, (3) *Erico scopariae-Castanetum*, (4) *Arbuto unedi–Castanetum* and (5) *Symphyto tuberosi–Castanetum* with the sub-association *Frangulo alni – Quercetum cerridis castanetosum*. Di Martino (2001) identified the association *Melampyro italici–Castanetum sativae* (Hruska 1988) in the Parco Nazionale del Gran Sasso a mountain of Laga (Italy), whilst Olivier et al. (1995) have classified the plant communities of Southern France and Corsica as the *Aristolochio pallidae–Castanetum sativae* association. In Turkey Özel (1999) classified *C. sativa* forest as the *Osmundo regali–Castanetum sativae* or *Castanea sativa–Osmunda regalis* association, whilst Kargioğlu (1988) named it the Querco *pubescenti–Castanetum sativae* association. In Central Europe Ovari (1998) described the *Castanetum sativae* association in Transdanubian Hills (Hungary), and Keller et al. (1999) clasified the typical *C. sativa* forest of the southern Swiss Alps as *Cruciato glabrae–Quercetum castanetosum*. In the Balkan Peninsula Horvat et al. (1974) described many plant communities in which the constituents were mainly mixed forest of *C. sativa* and *Quercus* sp. Ubaldi et al. (1995) mentioned the *Asphodelo–Castanetum sativae* association, in Parco Nazionale delle Foreste Casentinesi, Mt. Falterona, Campigna (Romania); Rexhepi (1991, 1994) described the *Juglando-Castanetum sativae* association in Kosovo, and Dinic et al. (1998) the *Carpino orientalis–Querco–Castanetum sativae* association on southern slopes of Mt. Krstilovica (Serbia).

We believe that the methodological approach adopted in the current study combines contemporary techniques for vegetation data classification and data exploration with the traditional method of table rearrangement, allowing us to achieve a classification of *C. sativa* forests in Greece that reflects not only floristic differences, but also the ecological conditions responsible for the variation. The results suggest that the *C. sativa* forests of Greece can be divided into three broad groups defined primarily by their geographical distribution. The first group comprises the forests of northern Greece (Macedonia and Epirus), which form southern extensions of the *C. sativa* forests of the central Balkans. The second group comprises the forests of central Greece (Thessaly) and the third those of southern Greece (Sterea Hellas and Peloponnesus). The first two groups are characterized by the high degree of floristic homogeneity, reflected in the identification of only one association per group, with the more subtle floristic differences between the mountains of northern Greece sufficient to be represented at the sub-association level. The third group, on the other hand, being at the southern limit of *C. sativa* distribution (in continental Greece) is characterized by a high degree of heterogeneity between the sampled forests, reflected in the identification of three associations and two sub-associations in southern Greece.

According to Horvat et al. (1974), the most favourable altitudinal range for *C. sativa* in the Balkan Peninsula is between 600 and 900 m, corresponding to the growth zone of thermophilous deciduous oaks and the transition into the sub-Mediterranean growth zone, where xerophilous and sclerophyllous species dominate. In Greece, chestnut forests occur across a much wider altitudinal range, indicating that other factors such as soil acidity and microclimatic conditions might be more important in determining their distribution. *C. sativa* is a species known to avoid base-rich soils originating from limestone, and in the current study it exhibits rather broad soil preferences, occurring on soils derived from a wide range of soft rocks such as schist, flysch and gneisses that generally produce deep soils.

The optimum climatic conditions for the formation of *C. sativa* forests are determined by the lower local temperatures and higher rainfall due to physiographic and maritime influences. There is a clear tendency for these communities to occur more frequently on the relatively humid northern and eastern slopes (reflecting the relatively more favourable conditions in terms of soil water prevailing on those aspects), whilst avoiding southern and western slopes, especially at

lower altitudes. Further, the fact that chestnut forests are more frequent on less steep slopes is an additional indication of the highly influential role of cultivation and specific silvicultural activities on less steep slopes (<30%), where these activities are more feasible.

The management of chestnut forests and the degree of current human intervention determine to a great extent their floristic diversity. The general trend is towards increasing the number of species with increasing time since the cessation of intensive management, indicating the transitional stage of these forests from pure *C. sativa* stands to mixed deciduous formations. Grazing pressure by domestic animals was also found to have a significant impact on the floristic composition. In areas where grazing is a long-term disturbance factor, the abundance of non-palatable and spiny shrubs, such as *Juniperus oxycedrus*, or shrubs resistant to grazing such as *Quercus coccifera*, increases and the stands are characterized by relatively open canopies. Altitude and its subsequent effect on microclimatic conditions was also identified as a factor affecting the floristic composition.

The communities of *C. sativa* identified in the southern part of its distribution in Greece are characterized by their geographic isolation relative to each other and the fact that species antagonistic to *C. sativa* increase their abundance and may eventually lead to its complete suppression. On the mountains of Telethrio and Arakinthos, *C. sativa* is invaded by thermophilous oaks and mainly *Quercus frainetto*, whilst on the mountains of Helmos and Erimanthos the invaders are the conifers *Abies cephalonica* and *Pinus nigra*, respectively. The role of geographic isolation and fragmentation was also particularly obvious on Mt.Telethrio, where there are only three remaining isolated patches of *C. sativa* forest with pronounced floristic differences between them, which in some cases were more similar to other distant forests than to each other.

The depopulation of the Greek mountains, the decreasing economic interest and the abandonment of traditional silvicultural activities appear to be the main factors threatening the distribution and ecological uniqueness of *C. sativa* forests. In southern and western parts of Greece, these forests have relatively little economic importance due to their small extent. However, from an ecological point of view, they are very valuable formations because of their high floristic diversity, their rareness and their biogeographic isolation. It seems likely that the continuation of current trends in the use and management of *C. sativa* forests will result in a dramatic reduction in their distribution, especially in southern Greece, which is the most vulnerable region due to the marginal climatic conditions for the species.

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References

Anonymous (1992) Results of the First National Inventory of the Forests. Ministry of Agriculture/General Secretary of Forests and Natural Environment (ed.). Athens, 134 pp.

Arrigoni PV, Marras G (1990) Phytosociology and structure of *C. sativa* woods in central Sardinia. Webbia 44(2):217–231

Arrigoni PV, Di Tommaso PL, Camarda I, Satta V (1996) La vegetazione dell'azienda forestale "Uatzo" (Sardegna centrale). Parlatorea 1:61–72

Arrigoni PV, Viciani D (2001) Structural and phytosociological features of the Tuscan *C. sativa* woods. Parlatorea 5:55–99

Asciuto G, Crescimanno M, Raimondo A (1988) Il castagno in Sicilia. (The *C. sativa* in Sicily). (In Italian, Abstr: English, French, German). Cellulosa e Carta 39(2):4–11

Athanasiadis N (1986) Plant phytosociology (in Greek). Giahoudi-Giapouli, Thessaloniki, 110 pp.

Bacchetta G, Iiriti G, Pontecorvo C, Serra G, Vacca A (2004) Relationships between soils, climate and vegetation in Ostrya carpinifolia Scop. woods of Sardinia (Italy). EUROSOIL (2004). Freiburg, 4–12/9/04

Bennet KD, Tzedakis PC, Willesk KJ (1991) Quaternary refugia of the North Europeans trees. J Biogeogr 18:103–115

Bergmeier E (1984) Zur Vegetation in Thessalien (Griechenland) am Beispiel des gebietes "Kato Olympos" Diplomarbeit im Fach Biologie Justus Liebig Univercity Gieben

Bergmeier E (1988) Floristic notes on the Kato Olympos area (NE Thessaly, Greece). Willdenowia 17:37–58

Bergmeier E (1990) Wälder und Gebüsche des Niederen Olymp. (Karo Olympos), NO Thessalien). Ein Beitrag zur systematischen und orographischen Vegetationsglieburg Griechenlands. Phytocoenologia 18:161–342

Bergmeier E, Dimopoulos P (2001) *Fagus silvatica* forest vegetation in Greece: syntaxonomy and gradient analysis. J Veg Sci 12:109–126

Braun-Blanquet J (1964) Pflanzensoziologie-Grundzüge der Vegetionskunde. 3. Auflage, Wien

Cobos-Suarez P (1989) Phytopathology of *C. sativa* (*C. sativa* Miller.). Boletin de Sanidad Vegetal. Fuera de Serie 16:11–29

Cutini A (2001) New management options in *C. sativa* coppices: an evaluation on ecological bases. Forest Ecol Manag 141(3):165–174

Dafis S (1966) [Statmologikes kai dasoapodotikes ereynes se premnofyi dryothasi kai kastanota tis BA Chalkidikis] (in Greek). Thessaloniki, 120 pp.

Dafis S (1972) Forest phytosociology. (In Greek). Thessaloniki, 117 pp.

Dafis S (1975) Vegetationsgliederung Griechenlands. Veröff. Geobot. Instit. ETH. Stiftung Rübel, Zürich 55:23–36

Devillers-Terschuren P, Devillers-Terschuren J (2001) Convention on the conservation of European wildlife and natural habitats. Application and development of the Palaearctic habitat classification in the course of the setting up of the Emerald Project. Council of Europe–Croatia–Strasbourg, 5 February 2001 T-PVS/Emerald (2001) 10

Diapoulis C (1939–1949) [Flora of Greece] (in Greek). 1- 3, Athens

Di Martino V (2001) L'avifauna dei castagneti del parco nazionale del Gran Sasso e Monti della Laga: indicatori per la gestione. Università degli Studi di Camerino, RIASSUNTI, pp 19–21

Dimoulas I (1986) The chestnut. Edit. Agricultural Bank of Greece, Athens, 214 p.

Dinic A, Misic V, Jovanovic V, Kalinic M (1998). Forest of sweet (*Castanea sativa* Mill.) in the surrounding of Vranje [Serbia, Yugoslavia], its significance and protection. Protec Nature 50:341–345

Ellenberg H (1988) Vegetation ecology of Central Europe, 4th edn. Cambridge University Press, Cambridge

Em H (1960) Edelkastanien—Waldgesellschaften im Belasica-Gebirge (V. R. Mazedonien). Acta museum Macedonica Scientific Nastural. Scopje: 89–103

Fineschi S, Taurchini D, Villani F, Vendramin G (2000) Chloroplast DNA polymorphism reveals little geographical structure in *C. sativa* Mill. (Fagaceae) throughout southern European countries. Mol Ecol 9:1495–1503

Gamisans J (1977) La végétation des montagnes corses. Deuxième partie. Phytocoenologia 4(1):35 –131

Gamisans J, Hebrard D (1979). A propos de la vegetation des forets d'Epire et de Macedoine Grecque occidentale. Documents Phytococio. Lille 4:289–341

Gamisans J, Hebrard D (1980) A propos de la vegetation des forets en Grece du nord-est (Macedoine orientale et Thrace occidentale). Documents Phytococio. Lille 5:243–289

Gamisans J (1999) La végétation de la Corse. Edisud, Aix-en-Provence

Ganiatsas K (1939) [Botanic investigation in Vermion Mt.] (in Greek). Scientific yearbook of Physic and mathematic departure of Aristotelian University of Thessaloniki, Thessaloniki

Ganiatsas K (1963) [Vegetation and flora of Athos Peninsula] (in Greek). Athoniki Politia, Thessaloniki, pp 509–678

Ganiatsas K (1967) [Phytogeography] (in Greek). Thessaloniki, 548 p.

Grebenščikov O (1950) O vegetaciji centralnog dela Stare planine. Zbornik radova SAN 2, Institut za ekologiju i biogeografiju 1:1–36

Grisebach A (1841) Reise durch Rumelien und nach Brussa im Jahre 1839. Göttingen

Gauch HG (1982) Multivariate analysis in community ecology. Cambridge University Press, New York

Hill MO (1973) Reciprocal Averaging: An eigenvector method of ordination. J Ecol 61:237–249

Hill MO (1974) Correspondence analysis: a neglected multivariate method. Appl Stat 23:340–354

Hill MO (1979) TWINSPAN-a Fortran program for arranging multivariate data in an ordered two way table by classification of the individuals and the attributes Cornell University, Department of Ecology and Systematics., Ithaca, New York

Hill MO, Bunce RGH, Shaw MW (1975) Indicator Species Analysis, a divisive polythetic method of classification, and its application to a survey of native pinewoods in Scotland. J Ecol 63:597–613

Hewitt GM (1996) Some genetic consequences of ice ages and their role in divergence and speciation. Biol J Linn Soc 58:247 276

Horvat I, Clavac V, Ellenberg H (1974) Vegetation Südosteuropas, Stuttgart, 660 pp.

Hruska K (1988) I castagneti dei Monti della Laga (Italia Centrale in Studi sulla flora e vegetazione d'Italia, Braun-Blanquetia 2:117–125

Huntley B, Birks HJB (1983) An atlas of past and present pollen maps for Europe: 0-13 000 Years Ago. Cambridge University Press, Cambridge

Karagiannakidou-Iatropoulou V (1983) [Standort Forschung in der Querco-Fagetea Zone des Chortiatis-Massivsenthalten] (in Greek). Thesis. Thessaloniki, 160 pp.

Kargioğlu M (1988) [Iç Bati Anadolu 'dan Iki Birlik (Querco cerridis-Coryletum avellanae ve Querco pubescenti-Castanetum sativae)]. XIV.Ulusal Biyoloji Kongresi (7-10 Eylül): 16–29

Kavvadas D (1956-1964) [Illustrated Botanical —Phytological Lexicon] I-IX (in Greek). Athens

Keller W, Wohlgemut T, Kuhn N, Schütz M, Wildi O (1999) Waldgesellschaften der Schweiz. auf floristische Grundlage. Mitt. Eidgenöss. Forsch. anst. Wald Schnee Landsch 73(2):91–357

Korakis G, Athanasiadis N (2003) The phytosociological units of *C. sativa* Mill. in Paiko Massif. Proceedings of the 11o conference Greek Forestry Association, pp 615–624

Lombardi L, Viciani D (2003) Analisi del paesaggio vegetale nel psic "Pascoli Montani e cespuglieti del pratomagno". Conservazione delle praterie montane dell' Appennino Toscano-Progetto N. LIFE00 NAT/IT/7239

Matovic M (1993) Ecological characteristics of the European *C. sativa* (*C. sativa* Mill.) on the habitats in Serbia (Yugoslavia). Zastita prirode (Yugoslavia), (1993–1994), 46–47: 77–85

Mattfeld J (1927) Aus Wald und Macchie in Griechenland. Mitt. Deutsch. Dedrol. Ges 38:106–151

Mayer H (1974) Wälder des Ostalpenraumes. Gustav Fischer, Stuttgart

Mueller-Dombois D, Ellenberg H (1974) Aims and methods of vegetation ecology. John Willey & Sons, New York

Oberdorfer E (1948) Gliederung und Umgrenzung der Mittelmeervegetation auf der Balkanhalbinsel. Ber Geobot Forschungsinst Rübel Zürich 1974:84–111

Olivier L, Galland JP, Nmaurin H, Roux P-P (eds) (1995) Livre Rouge de la Flore Menacé de France, I. Espéces Prioritaires. Museum National d'Histoire Naturelle, Conservatoire Botanique National de Porquerolles and Ministère de l'Environnement, Paris, 486

Özel N (1999) Kaz Dağları Orman Vejetasyonu Üzerine Fitososyolojik Ve Fitoekolojik Araştırmalar, Ege Ormancılık Araştırma Enstitüsü Müdürlüğü, Teknik Bülten Serisi No:11, İzmir. Phytosociologic and Phytoecologic Studies on Forest Vegetation in Kazdağları

Ovari M (1998) The vegetation of Gos Hill and neighbouring areas. Kanitzia, Research Report Series, Bio Tar 6:111–120

Petermann J (1999) Winterkahle Eichenwalder im Western der griechisen Rhodopen. Vegetation und Dynamik. Verlag Natur & Wissen schafft, Munster, 152 p

Pignatti S (1982) Flora d' Italian, vol. 3. Bologne, Edagricole

Rauh W (1949) Klimatologie und Vegetationsverhältnisse der Athos-Halbinsel und der ostägäischen Inseln Lemnos, Evstratios, Mytiline und Chios. Silzungsber. Heidelberger Akad. Wiss., Math. Naturwiss Kl: 511–615

Raus T (1980) Die Vegetation Ostthessaliens (Griechenland). In: III. Querco-Fagetea und azonale Gehölzgesellschaften. Bot Jahrb Syst 101:313–361

Regel C (1943). Phlanzengeographische Studien aus Griechenland und Westanatolien. Bot Jahrb Syst 73:1–98

Rexhepi F (1991) Fitocenoza Oraha I Pitomog Kestena (Juglando-Castanetum Sativae Rexhepi 1990) Na Kosovu. Zbornik Radova Sa Simpozijuma Nedeljko Košanin I Botaniĉke Nauke: 98–105

Rexhepi F (1994) The vegetation of Kosova [Vegjetacioni i Kosovës (hartografimi dhe hulumtimi fitocenologjik]. Universiteti i Prishtinës, Fakultetii i Shkencave të Naturës, Prishtinë

Rivas-Martínez S (1975) Mapa de vegetación de la provincia de Avila. Anal Inst Bot Cavanilles 32(2): 1493–1556

Rubio A, Gandullo JM (1994) Comparative ecological analysis of C. sativa (*C. sativa* Miller) forests in Extremadura and Astur-Cantabrian regions (Spain). Investigacion Agraria. Sistemas y Recursos Forestales (Espana), (Dic. 1994) 3(2):111–124

Rubio A, Elena R, Blanco A, Sanchez F, Gomez V, Sanchez O (1999) Autoecology of sweet-*C. sativa* stands in Catalonia (Spain). Investigacion Agraria. Sistemas y Recursos Forestales (Espana) 8(2):387–405

Rudski I (1936) O vegetaciji Planine Ošljaka.Glasnik Hrvatskog prirodoslovnog društva 41–48:118–146

Smith RD, Smith KA (ed) (2003) Country Study for Biodiversity of the Republic of Macedonia (First National Report). Ministry of Environment and Physical Planning Skopje, July, 2003. Skopje

Stojanov N, Kitanov B (1950) Rastitelnit. otnošenija na ostrov Tasos. Izv Bot Inst (Sofia) 1:214–357

Taberlet P, Fumagalli L, Wust-Saucy AG, Cosson JF (1998) Comparative phylogeography and postglacial colonization routes in Europe. Mol Ecol 7:453–464

Tomašević D (1959) Tipovi šuma i njihovi degradacioni oblici na Vodnu (II). God. Zbor. na Zemjodel. Šumar. Fak. na Univer. Skopje 12 Skopje

Tutin TG, Heywood VH, Burges NA, Valentine DH, Walters SM, Webb DA (eds) (1964–1980) Flora Europea. 1–5. Cambridge

Ubaldi D, Corticelli S, Rondini R (1995) Carta della vegetazione 1:25.000 del versante romagnolo del Parco Nazionale delle Foreste Casentinesi, M. Falterona, Campigna. Regione Emilia-Romagna

Viciani D, Gabellini A (2000) Contributo alla conoscenza della vegetazione del Pratomagno (Toscana orientale): le praterie di crinale ed il complesso forestale regionale del versantecasentinese. Webbia

Zohary D, Hopf M (1988) Domestication of plants in the old world. Clarendon Press, Oxford

Zoller H (1960) Pollenanalytische Untersuchungen zur Vegetationsgeschichte der insubrischen Schweiz. Denkschriften der Schweizerischen Naturforschenden Gesellschaft 83:157 pp.

Zoller H, Geissler P, Athanasiadis N (1977) Beiträge zur Kenntnis der Wälder, Moos und Flechtenassoziationen in den Gebirgen Nordgriechenlands. Basel Bauhinia 6(1):215–255