VEGETATION CLASSIFICATION AND SURVEY

International Association for Vegetation Science (IAVS)

Vegetation Classification and Survey 1: 175–189
doi: 10.3897/VCS/2020/54942

RESEARCH PAPER

Phytosociological overview of the *Fagus* and *Corylus* forests in Albania

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Academic editor: Wolfgang Willner ♦ **Received** 2 June 2020 ♦ **Accepted** 30 November 2020 ♦ **Published** 30 December 2020

Abstract

Aim: The aim of this study is to analyze the mesophilous forests of Albania including *Fagus sylvatica* and submontane *Corylus avellana* forests. Mesophilous Albanian forests are poorly known and were not included in the recent syntaxonomic revisions at the European scale. **Study area:** Albania. **Methods:** We used a dataset of 284 published and unpublished relevés. They were classified using the Ward's minimum variance. NMDS ordination was conducted, with over-laying of climatic and geological variables, to analyze the ecological gradients along which these forests develop and segregate. Random Forest was used to define the potential distribution of the identified forest groups in Albania. **Results:** The study identified seven groups of forests in Albania: *Corylus avellana* forests, *Ostrya carpinifolia-Fagus sylvatica* forests, lower montane mesophytic *Fagus sylvatica* forests, middle montane mesophytic *Fagus sylvatica* forests, middle montane basiphytic *Fagus sylvatica* forests, upper montane basiphytic *Fagus sylvatica* forests, upper montane acidophytic *Fagus sylvatica* forests. These can be grouped into four main types: *Corylus avellana* and *Ostrya carpinifolia-Fagus sylvatica* forests, thermo-basiphytic *Fagus sylvatica* forest, meso-basiphytic *Fagus sylvatica* forest and acidophytic *Fagus sylvatica* forests. This scheme corresponds to the ecological classification recently proposed in a European revision for *Fagus sylvatica* forests **Conclusion:** Our study supports an ecological classification of mesophilous forests of Albania at the level of suballiance. Analysis is still preliminary at the level of association, but it shows a high diversity of forest types.

Taxonomic reference: Euro+Med PlantBase (http://ww2.bgbm.org/EuroPlusMed/) [accessed 25 Novemeber 2019].

Syntaxonomic references: Mucina et al. (2016) for alliances, orders and classes; Willner et al. (2017) for suballiances.

Keywords

Albania, *Corylus avellana*, *Fagetalia sylvaticae*, *Fagus sylvatica*, *Fraxino orni-Ostryion*, phytosociology, Random Forest

Introduction

Fagus sylvatica forests are among the most studied vegetation types in Europe (Braun-Blanquet 1932; Moor 1938; Soó 1964; Dierschke 2004). However, notwithstanding decades of research, the syntaxonomy of *Fagus sylvatica* forests is still problematic, particularly in Southern Europe. Locally, it is possible to encounter species which are endemic or with restricted range (Willner et al. 2009), which has led to the description of regional alliances such as *Aremonio-Fagion*, *Geranio striati-Fagion*, etc. (Gentile 1964; Marinček et al. 1992, Mucina et al. 2016), but the diagnostic species are usually rare and do not occur in the whole geographical range of the alliances, which are therefore not easily identifiable floristically. A recent broad-scale revision of *Fagus sylvatica* forests (Willner et al. 2017) supported a multidimensional classification that recognizes the traditional geographical alliances, but also classifies most of the variability of *Fagus sylvatica* forests at the level of suballiance. This classification groups *Fagus sylvatica* forests into three main informal groups: acidophytic, meso-basiphytic and thermo-basiphytic *Fagus sylvatica* forests, which in turn are divided into a number of geographical and floristically well-defined suballiances. This classification cuts across the geographical range of *Fagus sylvatica*, but the authors also proposed an alternative classification into six geographically defined alliances, e.g. *Aremonio-Fagion*, *Geranio striati-Fagion* and *Fagion moesiacae*. Even though Southern European forests have been extensively studied (Bergmeier and Dimopoulos 2001; Di Pietro 2009), they are still under-sampled with respect to Central Europe or the Dinarides. In Albania, very few vegetation relevés have been published (Mersinllari 1989; Kalajnxhiu et al. 2012; Mahmutaj 2015) and this country is a blank in the maps of Willner et al. (2017).

Mesophilous forests, including *Fagus sylvatica* and *Corylus avellana* forests, cover a large area in Albania: 171.000 ha, about 17% of the total forested area (Albanian Forest Cadastre of 2017, INSTAT 2019). The widespread cloud belt at an altitude of 1000–1800 m in most mountain ranges, due to the condensation of humidity coming from the sea (Markgraf 1927), can explain such a wide distribution.

The aim of this study is to analyze the Albanian mesophilous forests, and contribute to the syntaxonomic knowledge of these forests in Southern Europe, in particular at the higher ranks of the phytosociological system. This is particularly important from a conservation point of view, as there are many relicts of pristine or ancient *Fagus sylvatica* forests in Albania, that have been declared World Heritage sites recently (Knapp et al. 2014; Diku and Shuka 2018). A better knowledge of the ecological and floristic composition of these forests would greatly enhance their effective and appropriate management and conservation.

Methods

Study area

Despite its small area (28. 748 km^2), Albania is a diverse country with a quite distinct and rich flora and vegetation (Dring et al. 2002; Barina et al. 2018). The geological formations are very diverse. They include, ranging from Palaeozoic to Quaternary, mainly sedimentary, magmatic, metamorphic and ultrabasic rocks (Xhomo et al. 2002). Along the coast, Albania has a Mediterranean climate (Pumo et al. 1990), with humid winters and dry summers, whereas inland the climate becomes temperate (Rivas-Martinez et al. 2004).

Mesophilous *Fagus sylvatica* forests are most widespread on the western slopes of the mountain ranges (Figure 1) stretching all the way from Shkodër to Nemërçkë (Mersinllari 1989). They occur from the northernmost zone of the Albanian Alps (Vermosh, Lekbibaj, Valbonë, Fushëzezë, Theth), that are dominated by calcareous rocks, southwards along the central-eastern part of Albania (Arrën, Livadh-Kabash, Lurë, Dejë, Qafështamë, Bizë, Steblevë, Shebenik, Stravaj, Zavalinë, Polis, Valamarë, Tomorr), to the south-eastern areas (Moravë, Rovje, Gërmenj, and few very small stands at Nemërçka mountain). Generally, they occur at altitudes of 800–1800 m, between the deciduous oak belt and the alpine meadows. They are missing in southern Albania, where climate becomes too warm, with higher temperatures and longer summer aridity.

Within the *Fagus sylvatica* distribution area, as seen in the Vegetation Map of Europe (Bohn et al. 2000, 2004; Figure 1), the annual mean temperature is 8.9 °C (minimum: 7 °C, max: 14.7 °C), with the maximum temperature of the warmest month reaching on average 24.2 °C (minimum: 13.8 °C, max: 30.3 °C) and minimum temperature of the coldest month -4.1 °C (minimum: -10.1 °C, max: 1.5 °C) (CHELSA data; Karger et al. 2017). The mean annual precipitation is about 1046.6 mm. The average, minimum, maximum and standard deviation of all bioclimatic CHELSA variables are presented in Suppl. material 1. The geological substrata are the same for the whole of Albania, except for the absence of alluvial sediments (see Suppl. material 2 for the complete list).

Dataset

We used 284 relevés of mesophilous forests obtained from the "Vegetation database of Albania" (De Sanctis et al. 2017), stored in EVA (Chytrý et al. 2016). They have been collected by the authors between 2002 and 2016 within the framework of international projects (see Acknowledgments) or during personal field investigations. All the relevés were carried out according to the Braun-Blanquet approach (Braun-Blanquet 1964; Dengler et al. 2008). The plot sizes range from 30 to 500 m^2, with an average of 174 m^2 (further details about site and layer data of the relevés are presented in Suppl. material 3). Bryophytes have been collected and identified where they were abundant.

To analyze the ecological features of these forests and model their potential distribution we selected a set of environmental variables we consider ecologically relevant for mesophilous forests. Bioclimatic variables were obtained from CHELSA (Karger et al. 2017): annual mean temperature (Bio1); temperature seasonality (Bio4); minimum temperature of coldest month (Bio6); temperature annual range (Bio7); annual precipitation (Bio12); precipitation of warmest quarter (Bio18). Geological substrata were obtained by grouping of the geological categories provided by the Geological Map of Albania (Xhomo et al. 2002) (see Suppl. material 2 for further details). The resulting types

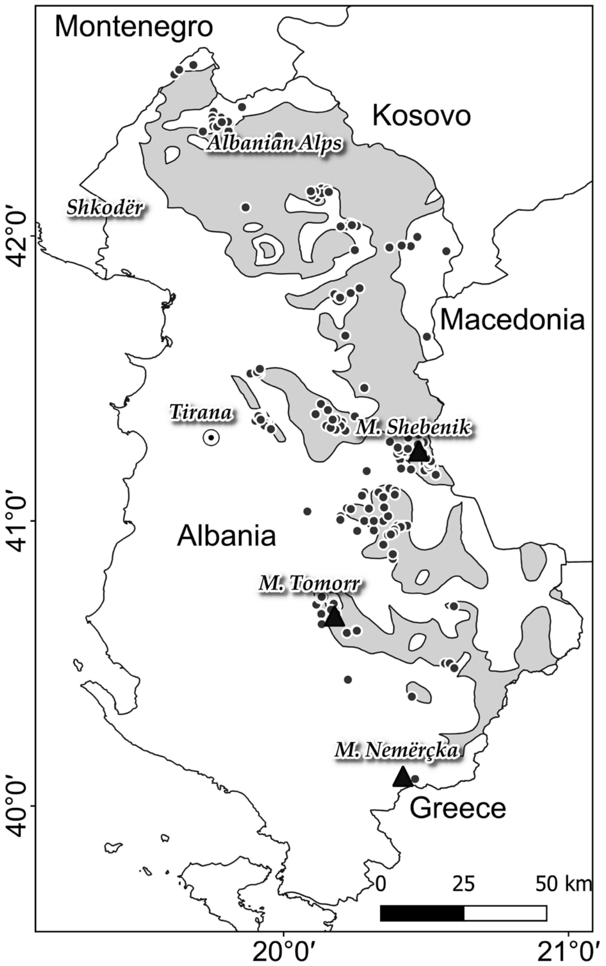

Figure 1. Study area. The black dots represent the relevés used in the analysis and the grey polygons represent the area of *Fagus sylvatica* forests according the Vegetation Map of Europe (Bohn et al. 2000, 2004).

were limestone, flysch, ophiolite and alluvion. Altitude was derived from the GTOPO30 digital elevation model (https://dds.cr.usgs.gov/ee-data/coveragemaps/shp/ee/gtopo30/; accessed 20 November 2019).

Data analysis

To identify the mesophilous forest types of Albania, we performed a hierarchical clustering using the *cluster* package (Maechler et al. 2019) of R software (http://www.R-project.org/). The Ward's minimum variance clustering (Murtagh and Legendre 2014) was used. It is a special case of the objective function approach originally presented by Ward (1963), with Euclidean distance as the similarity coefficient. The fidelity coefficient of Tichý and Chytrý (2006) was used to identify the diagnostic species of the resulting clusters (phi coefficient × 100). We performed a simultaneous calculation of Fisher's exact test in the JUICE software (Tichý 2002) to exclude species with non-significant fidelity. Group size was standardized to the average size of all groups present in the dataset (Tichý and Chytrý 2006) to avoid the phi coefficient being dependent on the size of the target group.

Ordination analysis was performed to analyze the ecological gradients underlying the distribution and floristic differentiation of the identified clusters. We adopted the Non-Metric Multidimensional Scaling (NMDS) analysis using the *vegan* package (Oksanen et al. 2016) of R. The NMDS procedure was applied with default options, which include use of the Bray-Curtis dissimilarity index and a maximum of 20 random starts in search of the stable solution. We used the Bray-Curtis dissimilarity, instead of the Euclidean distance, for ordination, because we were interested in the compositional dissimilarity between the sites, rather than in the raw differences in abundance of one species or another (Legendre and Legendre 1998; Bray and Curtis 1957). To identify the ecological variables involved in the identified NMDS gradients, we overlaid environmental vectors onto the ordination using the *envfit* function of the *vegan* package (Oksanen et al. 2016).

The interpretation of the forest types was supported by the construction of a map of their potential distribution. The map was obtained by modelling the spatial distribution of classified relevés and the environmental variables (Franklin 1995). Random Forests (RF) (Breiman 2001) was used as modeling method (see Suppl. material 4 for procedure and validation details) because of its widely recognized efficacy in similar vegetation studies (Brzeziecki et al. 1993; Maggini et al. 2006; Scarnati et al. 2009; Attorre et al. 2014).

Results

The dendrogram (Figure 2) splits the dataset into two main clusters. The first on the left includes groups A1 and A2 and represents the vegetation of lower altitudes (*Corylus avellana* and *Ostrya carpinifolia-Fagus sylvatica* forests). The second cluster was further split into a sub-cluster including the groups B and C, characterized by thermo-basiphytic *Fagus sylvatica* forests, and a second sub-cluster with groups D, E and F including the mesophytic *Fagus sylvatica* forests. Mesophytic *Fagus sylvatica* forests are finally divided into meso-basiphytic (D, E) and acidophytic (F) *Fagus sylvatica* forests.

The NMDS diagram (Figure 3) shows that the seven clusters have minimum overlap (stress 0.24). The first axis is correlated with a climatic gradient which includes all the climatic variables (precipitation of the driest quarter, mean annual temperature, mean temperature of the coldest month, temperature seasonality). The second axis separates the different lithologies, with acidic lithologies such as serpentines on the negative side and alluvions and limestones, with neutral to alkaline reaction, on the positive side.

The seven clusters are ordered mainly according the first axis, representing the different altitudinal belts. Although the second axis is strongly correlated with lithology, it is probably also in part correlated with summer drought since it separates clusters B and C, which show some influence of the Mediterranean climate (see Figure

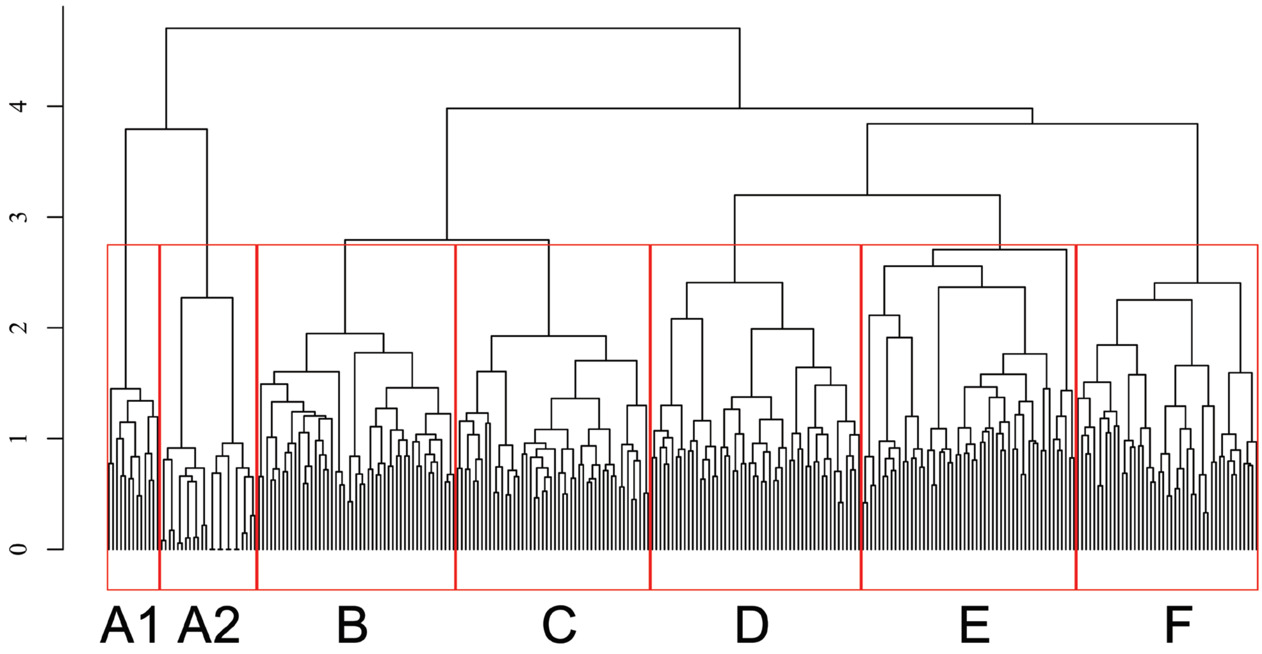

Figure 2. Dendrogram of relevés resulting from Ward's minimum variance clustering, with Euclidean distance as the similarity coefficient. Cluster **A1** *Corylus avellana* forests. Cluster **A2** *Ostrya carpinifolia-Fagus sylvatica* forests.Cluster **B** lower montane thermophytic *Fagus sylvatica* forests. Cluster **C** Middle montane, slightly acidic *Fagus sylvatica* forests. Cluster **D** upper montane basiphytic *Fagus sylvatica* forests. Cluster **E** middle montane basiphytic *Fagus sylvatica* forests. Cluster **F** upper-montane acidophytic *Fagus sylvatica* forests.

3) and are rich in thermophilous species, from clusters D and E, which are rich in mesophilous species.

We also analyzed lower cut levels of the dendrogram to see if it was possible to identify floristically and ecologically well-characterized sub-groups. Cutting the dendrogram at level 0.16 we obtained 17 sub-groups of *Fagus sylvatica* forests, two of *Corylus avellana*, while the *Ostrya carpinifolia-Fagus sylvatica* cluster remained undivided. This seemed to be the level at which the differentiation of the plant communities was maximum, as shown in the NMDS we performed separately on each of the seven main clusters with the same methods as above (Suppl. material 5).

The geographical distribution of the clusters (Figure 4) and of the potential vegetation of mesophilous forests in Albania (Figure 5; results of the validation analysis are presented in Suppl. material 4) showed a main gradient from the coast towards inland; along this gradient the thermophytic types are substituted by mesophytic types, in accordance with decreasing water stress, diminishing temperatures and rising altitudes.

Description of clusters and communities

We present each cluster together with a list containing the species with fidelity values higher than 30 (values are given after the species names). The synoptic table of the clusters is given in Table 1, and average, minimum and maximum of stational data of the relevés of each cluster are provided in Suppl. material 6. Within each cluster, we describe the included sub-groups (plant communities), which are coded by the letter of the cluster and a progressive number. The number corresponds with that given in the ordered table of relevés in Suppl. material 7. The syntaxonomic scheme is presented in Appendix 1.

Cluster A1: *Corylus avellana* forests

Diagnostic species: *Teucrium polium 67.6*, *Corylus avellana 66.1*, *Cerastium brachypetalum 55.3*, *Polygala vulgaris 52.5*, *Euphorbia helioscopia 52.5*, *Dorycnium pentaphyllum 52.5*, *Rosa canina 49.1*, *Helianthemum nummularium 48.6*, *Bituminaria bituminosa 45.2*, *Capsella bursa-pastoris 45.2*, *Euphorbia myrsinites 44.5*, *Bellis perennis 43.1*, *Lotus corniculatus 42.8*, *Helleborus odorus 41.9*, *Juglans regia 40.9*, *Dorycnium hirsutum 36.9*, *Stellaria holostea 36.7*, *Poa annua 36.7*, *Oenanthe pimpinelloides 36.7*, *Medicago sativa 36.7*, *Linum usitatissimum 36.7*, *Campanula glomerata 36.7*, *Blackstonia perfoliata 36.7*, *Carpinus orientalis 35.9*, *Saponaria calabrica 33.8*, *Primula vulgaris 33.7*, *Origanum vulgare 33.7*, *Juniperus oxycedrus subsp. oxycedrus 33.0*, *Potentilla reptans 31.3*, *Thymus longicaulis 30.7*

The relevés of this cluster represent a stage of degradation, as indicated by the great number of grassland species and the limited number of nemoral species. Among the nemoral species the most remarkable are *Anemone ranunculoides*, *Carpinus orientalis* and *Primula vulgaris*, which

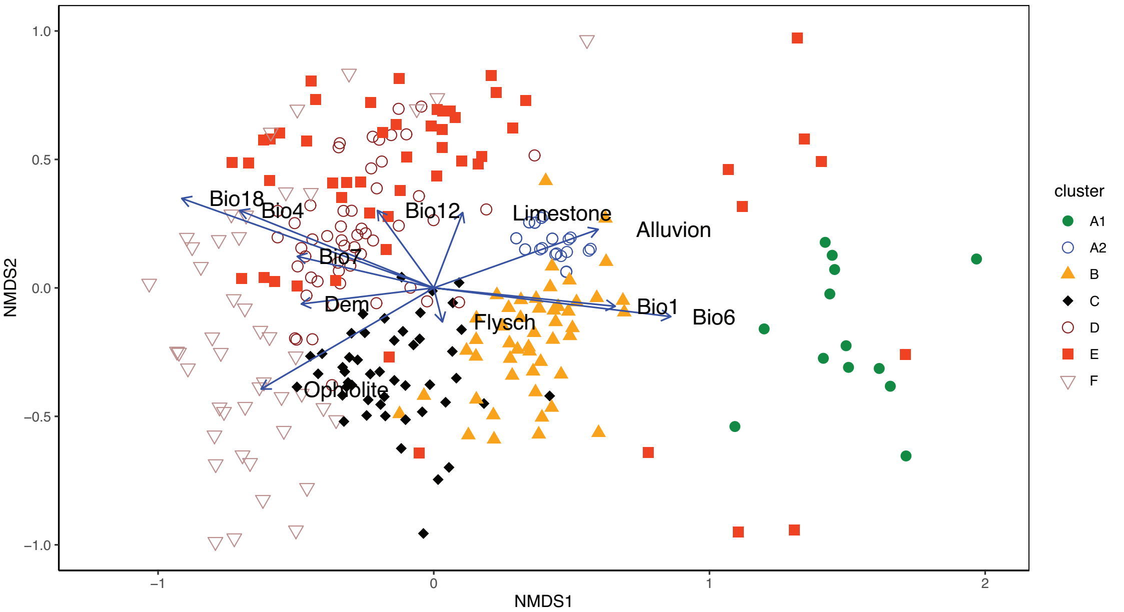

Figure 3. Non-Metric Multidimensional Scaling (NMDS) of relevés using Bray-Curtis dissimilarity index and a maximum of 20 random starts in search of the stable solution. Overlaid vectors represent the following environmental variables: Bio1: annual mean temperature; Bio4 Temperature Seasonality (standard deviation *100); Bio7: temperature annual range; Bio12: annual precipitation; Bio18: precipitation of warmest quarter; geological substrata include Ophiolite, Limestone, Flysch, Alluvion. Cluster **A1** *Corylus avellana* forests. Cluster **A2** *Ostrya carpinifolia-Fagus sylvatica* forests. Cluster **B** lower montane thermophytic *Fagus sylvatica* forests. Cluster **C** middle montane, slightly acidic *Fagus sylvatica* forests. Cluster **D** upper montane basiphytic *Fagus sylvatica* forests. Cluster **E** Middle montane basiphytic *Fagus sylvatica* forests. Cluster **F** Upper-montane acidophytic *Fagus sylvatica* forests.

point to an affinity with forests of the *Carpinion orientalis* (Fanelli et al. 2015; Mucina et al. 2016).

The forests of cluster A1 might be referred to the *Astrantio-Corylion avellanae*, an alliance including the *Corylus* thickets in the Alps and Southern Europe (Mucina et al. 2016). This alliance is usually classified in the class *Crataego-Prunetea*.

These forests occur in Southern Albania (Figures 4, 5) and in the Korab-Koritnik National Park at an altitude of 900–1200 m (average altitude: 1034 m), in a narrow belt below the *Fagus sylvatica* forests. Their restricted occurrence is probably a relict of a more widespread past distribution, that was largely destroyed by human activity.

Cluster A2: *Ostrya carpinifolia–Fagus sylvatica* forests

Diagnostic species: *Carpinus betulus 92.5*, *Galium sylvaticum 83.6*, *Crataegus monogyna 82.1*, *Ajuga reptans 82.1*, *Juniperus communis 80.0*, *Melica uniflora 78.3*, *Ostrya carpinifolia 73.9*, *Clinopodium vulgare 72.6*, *Dactylis glomerata 70.2*, *Brachypodium sylvaticum 66.5*, *Myosotis sylvatica 62.9*, *Acer campestre 59.4*, *Pteridium aquilinum 59.3*, *Rubus idaeus 59.0*, *Anemone nemorosa 58.9*, *Melittis melissophyllum 56.9*, *Daphne mezereum 56.5*, *Asperula taurina 56.3*, *Anthoxanthum odoratum 54.8*, *Ilex aquifolium 53.5*, *Teucrium chamaedrys 51.0*, *Galium odoratum 51.0*, *Lathyrus niger 50.5*, *Hedera helix 50.2*, *Euphorbia amygdaloides 49.7*, *Cornus mas 48.7*, *Geranium robertianum 47.6*, *Daphne laureola 47.1*, *Galium lucidum 44.9*, *Epilobium montanum 43.7*, *Lathyrus venetus 43.3*, *Corylus avellana 43.3*, *Acer obtusatum 43.2*, *Sorbus torminalis 43.0*, *Populus tremula 42.6*, *Veronica chamaedrys 42.3*, *Knautia drymeia 40.7*, *Poa nemoralis 40.4*, *Fraxinus ornus 38.4*, *Galium aparine 38.3*, *Luzula sylvatica 38.2*, *Silene vulgaris 37.3*, *Viburnum lantana 35.4*, *Carex sylvatica 35.4*, *Scilla bifolia 33.4*, *Prunella vulgaris 33.4*, *Pilosella cymosa 33.2*, *Lonicera xylosteum 33.0*, *Aremonia agrimonoides 32.9*, *Dryopteris filix-mas 32.8*, *Athyrium filix-femina 32.4*, *Campanula persicifolia 30.7*

These forests can be found at an altitude of 1000–1400 m (average altitude: 1210 m) in Central Albania (Figures 4, 5), mainly in the surroundings of Tirana. This cluster includes forests with dominance of *Ostrya carpinifolia* and *Fagus sylvatica* and is characterized by several thermophilous species of the *Quercetalia pubescenti-petraeae*. The species of the *Ostryo-Fagenion* are scarce, and thus this cluster probably represents an ecotone between *Ostrya carpinifolia* forests (referable to *Fraxino orni-Ostryion*), which are widespread near Tirana, and beech forests.

The dendrogram divides A2 into two communities, but their floristic differentiation is very poor and based on the frequency of common species rather than on diagnostic species. The distinction is probably due to a higher level of disturbance in one on the two communities.

Table 1. Synoptic table of relevés. The values shown in the table represent the constancy values of the species as percentage frequency. Dark grey species with fidelity >15 and frequency >35; light grey species with fidelity >15 and frequency <35. Non-diagnostic species with frequency <20 are not shown. Cluster A1: *Corylus avellana* forests; Cluster A2: *Ostrya carpinifolia-Fagus sylvatica* forests; Cluster B: lower montane thermophytic *Fagus sylvatica* forests; Cluster C: middle montane, slightly acidic *Fagus sylvatica* forests; Cluster D: upper montane basiphytic *Fagus sylvatica* forests; Cluster E: middle montane basiphytic *Fagus sylvatica* forests; Cluster F: upper-montane acidophytic *Fagus sylvatica* forests. The syntaxonomic reference (diagnostic value) of species follows Table 1 in Willner et al. (2017).

Cluster code	**A1**	**A2**	**B**	**C**	**D**	**E**	**F**	**Syntaxonomic reference**
Number of relevés	**13**	**24**	**49**	**48**	**52**	**53**	**45**	
Salvia glutinosa	8	33	24	2	15	32	2	*Aremonio-Fagion*
Cardamine enneaphyllos	–	–	–	19	13	4	–	*Aremonio-Fagion*
Knautia drymeia	–	25	2	–	–	2	2	*Ostryo-Fagenion*
Polystichum lonchitis	–	–	–	2	15	2	11	*Lonicero alpigenae-Fagenion*
Lonicera alpigena	–	–	4	–	–	9	7	*Lonicero alpigenae-Fagenion*
Laburnum alpinum	–	–	10	–	2	–	–	*Aremonio-Fagion*
Epimedium alpinum	–	–	–	10	2	4	–	*Ostryo-Fagenion*
Sesleria autumnalis	–	–	8	2	–	–	–	*Ostryo-Fagenion*
Asplenium viride	–	–	–	–	4	–	–	*Lonicero alpigenae-Fagenion*
Euonymus verrucosus	–	–	2	–	–	–	–	*Ostryo-Fagenion*
Gentiana asclepiadea	–	–	–	–	–	–	2	*Aremonio-Fagion*
sum Aremonio-Fagion	**8**	**58**	**50**	**35**	**51**	**53**	**24**	
Lathyrus laxiflorus	8	–	–	–	4	21	2	*Fagion moesiacae*
Physospermum cornubiense	15	–	2	13	–	6	4	*Fagion moesiacae*
Digitalis viridiflora	–	–	–	–	–	6	7	*Fagion moesiacae*
Lathyrus alpestris	–	–	–	10	2	–	–	*Fagion moesiacae*
Campanula sparsa	–	–	6	–	–	2	–	*Fagion moesiacae*
sum Fagion moesiacae	**23**	**0**	**8**	**23**	**6**	**35**	**13**	
Campanula pichleri	–	–	–	4	4	32	29	*Geranio versicoloris-Fagion*
Anemone apennina	15	–	20	6	–	–	–	*Geranio versicoloris-Fagion*
Cyclamen hederifolium	–	–	2	–	–	8	–	*Geranio versicoloris-Fagion*
sum Geranio-Fagion	**15**	**0**	**22**	**10**	**4**	**40**	**29**	
Ostrya carpinifolia	23	100	39	–	–	2	–	thermo-basiphytic beech forests
Clinopodium vulgare	31	100	16	4	–	17	–	thermo-basiphytic beech forests
Crataegus monogyna	–	83	6	–	–	8	–	thermo-basiphytic beech forests
Primula vulgaris	54	50	22	2	2	13	–	thermo-basiphytic beech forests
Festuca heterophylla	23	33	51	10	–	4	7	thermo-basiphytic beech forests
Cornus mas	8	50	20	–	–	4	–	thermo-basiphytic beech forests
Fraxinus ornus	8	50	37	4	–	9	2	thermo-basiphytic beech forests
Acer campestre	8	50	2	–	–	2	–	thermo-basiphytic beech forests
Cephalanthera rubra	–	25	22	8	8	11	–	thermo-basiphytic beech forests
Sorbus torminalis	–	25	–	–	–	4	–	thermo-basiphytic beech forests
Melittis melissophyllum	8	50	4	–	2	2	–	thermo-basiphytic beech forests
Primula veris	–	–	20	–	–	4	–	thermo-basiphytic beech forests
Cephalanthera damasonium	–	–	20	6	8	17	7	thermo-basiphytic beech forests
Viburnum lantana	–	17	2	–	–	–	–	thermo-basiphytic beech forests
Campanula persicifolia	–	17	4	–	–	–	2	thermo-basiphytic beech forests
Campanula trachelium	8	–	8	2	–	–	–	thermo-basiphytic beech forests
Hippocrepis emerus	8	–	4	–	–	6	–	thermo-basiphytic beech forests
Rosa arvensis	8	–	–	2	–	2	–	thermo-basiphytic beech forests
Carex digitata	–	–	–	–	–	–	4	thermo-basiphytic beech forests
Polygonatum odoratum	–	–	2	–	4	–	–	thermo-basiphytic beech forests
Galium odoratum	8	100	10	44	75	32	4	meso-basiphytic beech forest
Lamiastrum galeobdolon	–	50	8	23	62	38	9	meso-basiphytic beech forest
Geranium robertianum	15	83	14	6	42	42	7	meso-basiphytic beech forest
Cardamine bulbifera	8	33	29	27	46	15	2	meso-basiphytic beech forest
Actaea spicata	–	–	–	8	19	–	–	meso-basiphytic beech forest
Carex sylvatica	–	17	2	–	–	–	–	meso-basiphytic beech forest
Polystichum aculeatum	–	–	2	10	2	25	4	meso-basiphytic beech forest
Urtica dioica	8	–	8	–	2	9	–	meso-basiphytic beech forest
Paris quadrifolia	–	–	–	4	4	6	–	meso-basiphytic beech forest
Stachys sylvatica	–	–	–	–	2	–	–	meso-basiphytic beech forest
Vaccinium myrtillus	–	–	–	6	4	6	78	acidophytic beech forests
Calamagrostis arundinacea	–	–	–	–	–	–	11	acidophytic beech forests
Fagus sylvatica	15	100	100	100	100	89	100	
Lactuca muralis	8	75	65	33	63	75	24	
Euphorbia amygdaloides	62	100	24	38	13	34	11	
Fragaria vesca	69	42	78	25	17	28	7	
Aremonia agrimonoides	23	75	61	23	6	42	24	
Helleborus odorus	85	50	78	4	4	28	–	
Anemone nemorosa	–	100	29	10	60	2	27	
Rubus idaeus	23	100	29	25	13	21	16	
Pteridium aquilinum	15	100	29	17	19	32	13	
Acer pseudoplatanus	31	42	59	10	23	40	9	
Veronica chamaedrys	38	75	41	4	13	26	–	
Corylus avellana	100	75	14	–	4	–	–	

Cluster code	A1	A2	B	C	D	E	F	Syntaxonomic reference
Number of relevés	13	24	49	48	52	53	45	
Brachypodium sylvaticum	23	100	24	4	–	26	13	
Hedera helix	31	75	47	–	2	8	–	
Saxifraga rotundifolia	–	42	20	4	27	38	31	
Lathyrus venetus	15	67	31	4	15	11	13	
Dactylis glomerata	15	92	27	–	–	13	2	
Melica uniflora	23	100	18	2	2	2	2	
Doronicum columnae	8	50	37	8	4	23	18	
Abies alba	–	–	6	38	38	11	53	
Juniperus communis	15	100	12	8	–	2	7	
Ajuga reptans	31	100	6	–	–	2	–	
Prenanthes purpurea	–	–	2	27	46	6	53	
Prunella vulgaris	38	50	6	4	–	8	22	
Myosotis sylvatica	31	75	2	–	12	–	–	
Carpinus betulus	–	100	12	–	–	2	–	
Symphytum tuberosum	8	33	35	10	13	6	9	
Daphne mezereum	–	67	12	2	6	9	16	
Luzula sylvatica	8	50	18	13	10	4	9	
Calamintha grandiflora	–	–	18	10	25	47	11	
Asplenium trichomanes	8	25	12	2	17	30	11	
Sanicula europaea	15	–	12	15	38	17	2	
Oxalis acetosella	–	–	–	23	52	21	2	
Orthilia secunda	–	–	2	17	12	13	42	
Juniperus oxycedrus s. oxycedrus	38	–	35	2	–	9	–	
Viola reichenbachiana	–	–	20	23	–	32	7	
Potentilla micrantha	15	25	12	4	8	2	11	
Galium sylvaticum	–	75	–	–	–	2	–	
Teucrium chamaedrys	23	50	–	–	–	4	–	
Poa nemoralis	–	42	10	–	–	13	11	
Ceterach officinarum	8	–	24	2	10	25	7	
Neottia nidus-avis	–	–	18	13	27	15	–	
Rosa species	8	8	41	2	–	4	7	
Dryopteris filix-mas	–	33	6	8	10	6	4	
Bellis perennis	38	–	22	–	–	–	–	
Carex species	–	–	4	–	–	23	31	
Festuca species	–	–	4	–	–	23	31	
Euphorbia myrsinites	38	–	12	–	–	8	–	
Teucrium polium	54	–	2	–	–	2	–	
Carpinus orientalis	31	–	16	–	–	6	–	
Ilex aquifolium	–	42	8	–	–	2	–	
Rosa canina	38	–	10	2	–	–	–	
Viola species	–	–	–	2	42	4	2	
Asperula taurina	–	42	2	4	–	–	–	
Acer obtusatum	–	33	2	6	–	6	–	
Epilobium montanum	–	33	–	–	–	13	–	
Geum urbanum	–	–	14	–	6	26	–	
Athyrium filix-femina	–	25	2	2	10	4	2	
Viola odorata	23	–	12	6	–	2	–	
Cerastium brachypetalum	38	–	4	–	–	–	–	
Pilosella cymosa	–	25	14	–	–	2	–	
Scilla bifolia	–	25	6	–	10	–	–	
Pinus nigra	–	–	2	–	–	–	38	
Thymus longicaulis	23	–	2	–	–	6	9	
Erica carnea	–	–	–	2	–	–	36	
Lathyrus niger	–	33	–	–	–	–	4	
Acer platanoides	–	8	20	–	6	2	–	
Helianthemum nummularium	31	–	2	–	–	2	–	
Origanum vulgare	23	–	10	–	–	2	–	
Silene vulgaris	–	25	2	–	–	4	4	
Anthoxanthum odoratum	–	33	–	–	–	–	–	
Dorycnium pentaphyllum	31	–	–	–	–	–	–	
Euphorbia helioscopia	31	–	–	–	–	–	–	
Polygala vulgaris	31	–	–	–	–	–	–	
Pinus peuce	–	–	–	2	–	–	29	
Dorycnium hirsutum	23	–	6	–	–	2	–	
Rhamnus alpina s. fallax	–	–	6	–	2	21	2	
Sorbus aucuparia	–	–	6	–	2	–	22	
Populus tremula	–	25	–	–	–	2	2	
Galium lucidum	–	25	–	–	–	2	–	
Juglans regia	23	–	–	–	–	4	–	
Daphne laureola	–	25	–	–	–	–	–	
Lotus corniculatus	23	–	2	–	–	–	–	
Capsella bursa-pastoris	23	–	–	–	–	–	–	
Bituminaria bituminosa	23	–	–	–	–	–	–	
Hepatica nobilis	–	–	–	2	–	–	20	
Milium effusum	–	–	–	21	–	–	–	
Primula elatior	–	–	20	–	–	–	–	

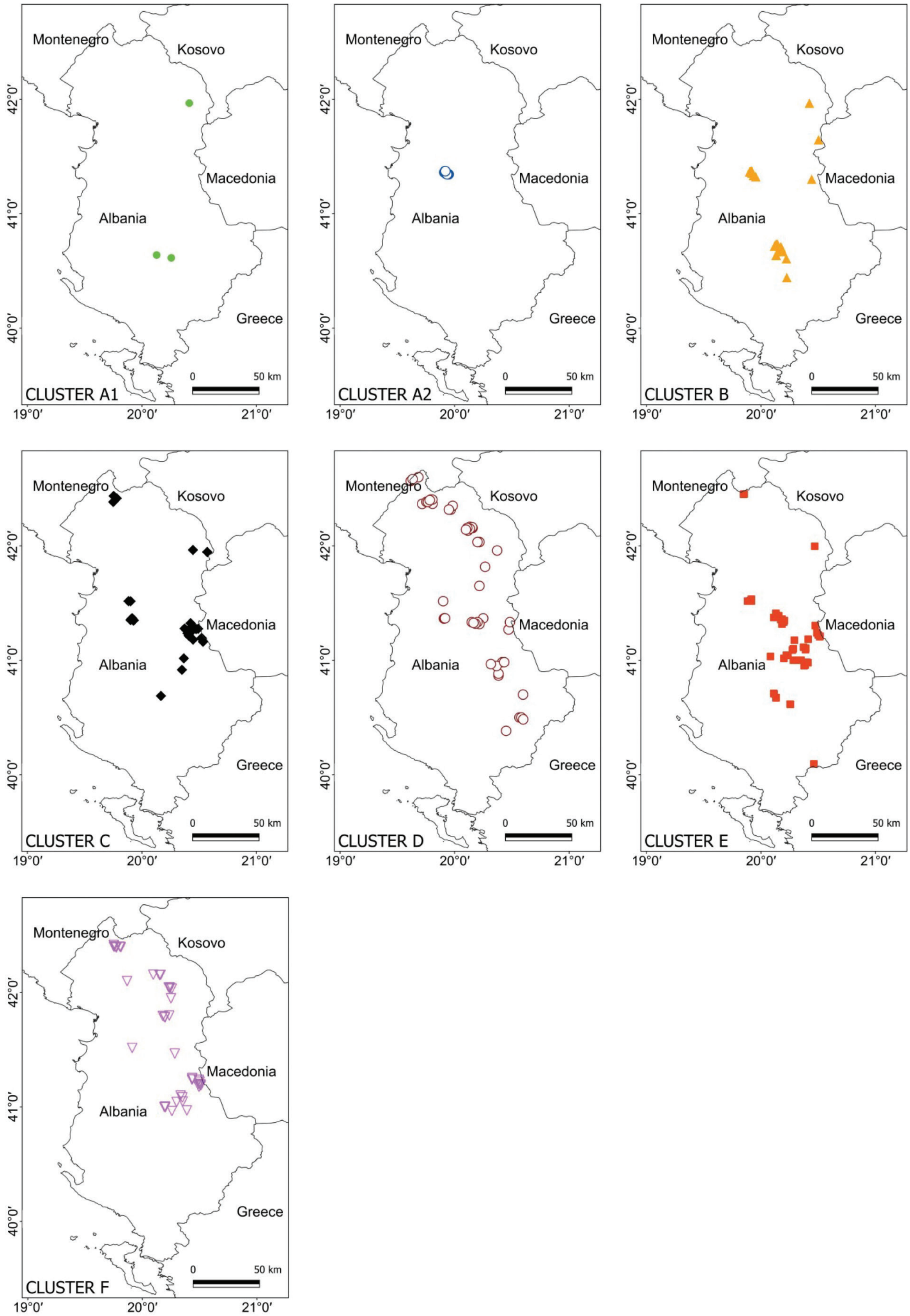

Figure 4. Distribution maps of the seven clusters of relevés. Symbols in the maps represent the sampling locations. Cluster **A1** *Corylus avellana* forests. Cluster **A2** *Ostrya carpinifolia-Fagus sylvatica* forests. Cluster **B** lower montane thermophytic *Fagus sylvatica* forests. Cluster **C** middle montane, slightly acidic *Fagus sylvatica* forests. Cluster **D** upper montane basiphytic *Fagus sylvatica* forests. Cluster **E** middle montane basiphytic *Fagus sylvatica* forests. Cluster **F** upper-montane acidophytic *Fagus sylvatica* forests.

Cluster B: lower montane thermophytic *Fagus sylvatica* forests

Diagnostic species: *Primula elatior 42.4*, *Rosa species 42.2*, *Primula veris 37.9*, *Crocus veluchensis 37.9*, *Helleborus odorus 35.9*, *Festuca heterophylla 34.5*, *Fragaria vesca 33.3*, *Geranium aristatum 32.9*, *Polygala nicaeensis 32.7*, *Erythronium dens-canis 32.7*, *Doronicum austriacum 31.1*

This cluster is among the best differentiated in the dataset, with many important diagnostic species. This forest type occurs in a belt with a strong maritime influence in Central and Southern Albania, but it is also present in the mountains of Northern Albania. The position in the NMDS diagram indicates that cluster B occupies the lower belt (lower montane; the average altitude of distribution is 1187 m).

The cluster includes many species of the suballiance *Lathyro veneti-Fagenion* (*Acer obtusatum*, *Cyclamen hederifolium*, *Lilium chalcedonicum*) although with very low frequency; also a few species of *Aremonio-Fagion* s.l. (*Laburnum alpinum*, *Salvia glutinosa*) and *Geranio striati-Fagion* (*Anemone apennina*) are present with high frequency. These species suggest that this cluster is related to the suballiance *Lathyro veneti-Fagenion*. The diagnostic species of this suballiance are numerous but rare. However, the geographical position and overall floristic composition rather suggests an assignment to the *Doronico orientalis-Fagenion moesiacae*.

Cluster B can be differentiated into two communities: B/1 occurs from 900 to 1200 m in the area of Dajti, in central Albania. It is well characterized by the presence of *Cephalanthera rubra*, *Neottia nidus-avis* and *Rhamnus alpina* subsp. *fallax*. All these species also occur in other clusters but show a clear optimum here.

B/2 is characterized by the presence of *Ilex aquifolium* that is widespread also in the *Fagus sylvatica* forests of Southern Italy. The species is present with low frequency, but it was probably more common in the past, having been selectively destroyed by humans. Other diagnostic species are *Doronicum columnae*, *Hedera helix*, *Euphorbia amygdaloides*, *Sanicula europaea*, *Poa nemoralis*, *Festuca heterophylla*, and *Erythronium dens-canis*. *Ostrya carpinifolia* is also present, but this is probably due to catenal contact with *O. carpinifolia* communities present on steeper slopes. This community occurs from 900 to 1500 m in Dajti and Tomorr but also in Northern Albania. One of the relevés that was previously referred to the *Calamintho grandiflorae-Fagetum* Rizovski & Džekov ex Matevski et al. 2011 (De Sanctis et al. 2018) belongs here. Another distinction between cluster B/1 and B/2 is the presence of *Pteridium aquilinum* and *Fragaria vesca* in B/2, indicating an intense disturbance by fire.

Cluster C: middle montane, slightly acidic *Fagus sylvatica* forests

Diagnostic species: *Milium effusum 42.9*

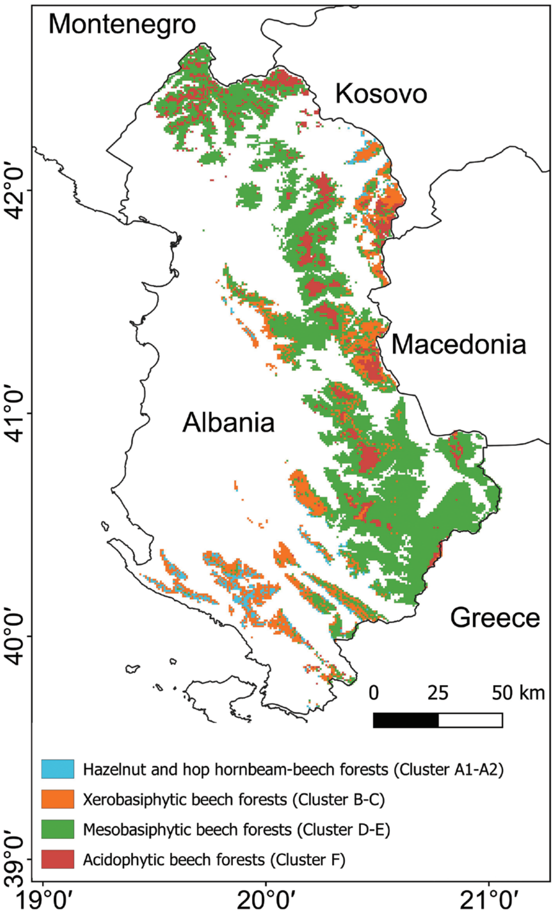

Figure 5. Map of the potential distribution of the four main groups of relevés resulting from random forest procedure. Cluster **A1** *Corylus avellana* forests. Cluster **A2** *Ostrya carpinifolia-Fagus sylvatica* forests. Cluster **B** lower montane thermophytic *Fagus sylvatica* forests. Cluster **C** middle montane, slightly acidic *Fagus sylvatica* forests. Cluster **D** upper montane basiphytic *Fagus sylvatica* forests. Cluster **E** middle montane basiphytic *Fagus sylvatica* forests. Cluster **F** upper-montane acidophytic *Fagus sylvatica* forests.

Cluster C occurs on average at higher altitudes than cluster B (1300–1600 m; average altitude: 1412 m) but occupies more or less the same Northern-Central sector of Albania (Figures 4, 5). The cluster contains some species of thermo-basiphytic *Fagus sylvatica* forests, which, however, do not have high frequency (*Cephalanthera damasonium*, *Hepatica nobilis*, *Primula vulgaris* etc.). A few species of *Geranio striati-Fagion* and *Lathyro veneti-Fagenion* are present (*Lathyrus venetus*, *Anemone apennina*, *Laburnum anagyroides*, *Lilium chalcedonicum*) but with lower frequency than in cluster B. The most characteristic species are diagnostic of the *Doronico orientalis-Fagenion moesiacae* (*Physospermum cornubiense*, *Lathyrus alpestris*).

Cluster C can be differentiated into four communities, some of which correspond to associations identified in the *Fagus sylvatica* forests of Shebenik-Jabllanice National Park by De Sanctis et al. (2018).

C/1 is characterized by *Epimedium alpinum*, *Allium ursinum*, *Viola odorata*, *Symphytum tuberosum*, and *Milium effusum*. It was previously described as *Epimedio alpini-Fagetum sylvaticae* Fanelli (De Sanctis et al. 2018), and it occurs in Shebenik, but also in Korab, at an altitude of 1100–1300 m We checked the herbarium material and we can confirm that *Epimedium alpinum* belongs to the subsp. *alpinum* and not to the recently described subspecies *albanicum* (Shuka et al. 2019).

C/2 is characterized by *Milium effusum* (which is shared with the previous cluster), *Lathraea squamaria*, *Abies alba* and *Orthilia secunda*. This community was referred to the *Orthilio secundae-Fagetum* in De Sanctis et al. (2018), but it probably represents a distinct type that can be described after more material is collected to assess its variability and its relationship with other associations. It shows many affinities with cluster D/3. This cluster occurs at 1300–1600 m and only in Shebenik area.

C/3 is well characterized by *Cardamine bulbifera*, *Cardamine enneaphyllos*, *Dryopteris carthusiana* and *Neottia nidus-avis*. *Orthilia secunda* is also present. This community was identified with the *Calamintho grandiflorae-Fagetum* due to its similarity with a stand of this community in Galicicia mountains (Matevski et al. 2011; De Sanctis et al. 2018). The community occurs at Shebenik, Korab and the Dajtj range at an altitude varying from 1200 to 1900 m, but in general in an alti-montane belt.

C/4 is poorly characterized by *Lilium martagon*. It occurs in Dajtj at an altitude of 1500–1600 m, and probably represents only a variant of B/2 at higher altitudes.

Cluster D: upper montane basiphytic *Fagus sylvatica* forests

Diagnostic species: *Oxalis acetosella 44.7*, *Actaea spicata 32.1*, *Lamium galeobdolon 31.7*, *Galium odoratum 30.1*

A high number of meso-basiphytic *Fagus sylvatica* forest species is present in cluster D (*Actaea spicata*, *Cardamine bulbifera*, *Galium odoratum*, *Lamium galeobdolon* etc.) and a few ferns of *Lonicero alpigenae-Fagenion*, but with low frequency (*Polystichum lonchitis*, *Asplenium viridis*, *Gymnocarpium dryopteris*).

This cluster is widespread throughout Albania (Figures 4, 5). It usually occurs at altitudes from 950 to 1500 m, but in general these forests are more common in the range 1400–1500 m (average altitude: 1447 m).

Cluster D can be differentiated into four communities: D/1 is characterized by *Luzula sylvatica*, *Gymnocarpium dryopteris*, *Euphorbia amygdaloides*, *Calamintha grandiflora*, *Epipactis helleborine*, *Scilla bifolia*, *Dryopteris filix-mas*, *Daphne mezereum* and *Salvia glutinosa*. It is related to the associations usually referred to *Aremonio-Fagion* or to *Lonicero alpigenae-Fagenion* in the Dinarides (Marincek et al. 1992). The forests of this type can be found in the Shebenik range at an altitude of 1000–1800 m and in the Albanian Alps.

D/2 is diagnosed by *Potentilla micrantha*, *Lathyrus venetus*, *Paris quadrifolia*, *Cephalanthera damasonium* and *Lathyrus laxiflorus*. It is similar to the *Lathyro alpestri-Fagetum* Bergmeier 1990 (in particular for the presence of *Lathyrus venetus* and *Cephalanthera damasonium*) which occurs in Central Eastern Greece in moderately warm habitats (Bergmeier and Dimopoulos 2001).

D/3 is mainly characterized by the abundance of *Abies alba*, a species which is present in other clusters but reaches its optimum here. Other species such as *Orthilia secunda* and *Cardamine enneaphyllos* are frequent in this cluster. In summary this community represents an "Abieti-Fagetum" but is clearly different from the *Fagus sylvatica-Abies alba* forests of the Dinarides and Alps and probably deserves recognition as a distinct association. It thrives in all the mountains of Albania, but it is particularly well represented in SE Albania. It generally occurs at an altitude from 1500 to 1700 m but can extend down to 950 m.

D/4 is characterized by *Aremonia agrimonioides*, *Calamintha grandiflora* and *Lathyrus venetus*. These species are present also in other communities and are widespread in the southern Balkans (Willner et al. 2017; Dzwonko and Loster 2000) but are particularly well represented here. The first 3 relevés of this cluster are very well characterized by a set of species (*Hesperis matronalis*, *Aquilegia vulgaris*, *Moehringia muscosa*, *Selaginella helvetica*) which are typical of ravines and shaded situations and probably are transgressive from some other community (perhaps related to *Tilio-Acerion*). This community is present in the Albanian Alps and in the Dajtj range in central Albania at an altitude varying from 1000 to 1800 m.

Cluster E: middle montane basiphytic *Fagus sylvatica* forests

Diagnostic species: *Calamintha grandiflora 34.7*, *Geranium macrorrhizum 34.0*, *Rhamnus alpina subsp. fallax 32.4*, *Geum urbanum 32.4*, *Polystichum aculeatum 31.1*, *Campanula pichleri 30.4*, *Allium ursinum 30.0*

This cluster clearly belongs to the suballiance *Doronico columnae-Fagenion*. Willner et al. (2017) recognized this suballiance in the meso-basiphytic *Fagus sylvatica* forests, but they could not identify any characteristic species for it. Marinšek et al. (2013) identified several diagnostic species for SE Europe, many of which are present in our plots, although with relatively low frequency: *Abies borisii-regis*, *Potentilla micrantha*, *Campanula sparsa*. Several species of mesophytic forests are also present (*Geranium robertianum*, *Cardamine bulbifera*, *Polystichum aculeatum*, *Galium odoratum*, *Lamium galeobdolon* etc.). A few species of *Doronico orientalis-Fagenion moesiacae* are present with high frequency (*Geum urbanum*, *Lathyrus laxiflorus*). The suballiance is referred to the *Fagion moesiacae* in Marinšek et al. (2013) and in Willner et al. (2017).

This cluster is mainly distributed in central Albania but is also present in the North and South (Figures 4, 5). It spans a wide altitudinal range from 1100 to 1900 m (average altitude: 1390 m).

In Cluster E four communities can be identified: E/1 is diagnosed by a set of species (*Sorbus graeca*, *Epipactis helleborine*, *Lilium martagon*) that is also present in community C/4, and by *Bromus ramosus*, *Cardamine enneaphyllos*, and *Brachypodium sylvaticum*, which are also present in cluster C. The community is therefore relatively well characterized but shows some affinities to cluster C that possibly represents an altitudinal variant. The community occurs usually at 1300–1900 m, but can extend down to 1100 m. The community occurs near Librazhd and near Tirana in central Albania.

E/2 is well characterized among Albanian *Fagus sylvatica* woods by *Allium ursinum*, *Epilobium montanum*, and *Hesperis matronalis* (which is also present in a few relevés of cluster D/4). *Abies alba* is also present, but with low frequency. The community occurs in a wide altitudinal range from 1100 to 1900 m It occurs in Central Albania near Tirana.

E/3 is well characterized by *Oxalis acetosella*, *Sanicula europaea*, *Luzula forsteri*, *Euphorbia amygdaloides*, *Daphne mezereum*, *Urtica dioica*, and *Polystichum aculeatum*. *Cephalanthera rubra* is also present, but more typical of community B/2. The community is very close and possibly identical to the *Lamiastro montani-Fagetum* described from a limited area in Northern Greece (Bergmeier and Dimopoulus 2001) due to the presence of *Oxalis acetosella*, *Hordelymus europaeus*, *Lathyrus laxiflorus*, but a few important species of the latter (*Anemone ranunculoides*, *Paris quadrifolia*) are lacking. The community generally grows at an altitude of 1300–1500 m particularly in central Albania near Tirana and in the Shebenik range.

E/4 is a poorly characterized community distinct particularly because of the presence of *Euphorbia amygdaloides* and *Pinus heldreichii*. It occurs in Korab and Tomorr on limestones at an altitude of about 1800 m.

Cluster F: upper-montane acidophytic *Fagus sylvatica* forests

Diagnostic species: *Vaccinium myrtillus 77.3*, *Pinus nigra 56.6*, *Erica carnea 54.6*, *Pinus peuce 48.6*, *Hepatica nobilis 39.3*, *Orthilia secunda 37.3*, *Sorbus aucuparia 35.9*, *Prenanthes purpurea 35.4*, *Buxus sempervirens 34.1*, *Carex species 33.9*, *Abies alba 32.5*, *Calamagrostis arundinacea 31.1*

This cluster includes several species of acidophytic *Fagus sylvatica* forests with high frequency and abundance (*Calamagrostis arundinacea*, *Vaccinium myrtillus*). At the same time, some species of *Lonicero alpigenae-Fagenion* have their optimum in or are restricted to this cluster, even though with low frequency (*Polystichum lonchitis*, *Lonicera alpigena*, *Luzula multiflora*, *Gymnocarpium dryopteris*). Another interesting acidophilous species is *Erica carnea*. The forests corresponding to this cluster usually develop on acidic soils, so we are inclined to refer to the cluster as acidophytic beech forests. This cluster occurs at an altitude of 1000–1890 m (average altitude: 1470 m) and is restricted to Northern and Central Albania (Figures 4, 5).

Cluster F can be differentiated into three communities: F/1 is characterized by mesophytic species with thermophytic affinity such as *Sanicula europaea*, *Euphorbia amygdaloides*, *Doronicum columnae*, *Calamintha grandiflora* and *Anemone nemorosa*. These species are probably transgressive from other community. This community develops at an altitude of 800–1100 m and therefore represents the lowest forests among the acidophytic ones. The cluster occurs mainly in the Shebenik range.

F/2 is differentiated mainly by *Pinus peuce*, which transgresses from communities of the *Pinion peucis* (De Sanctis et al. 2018), whereas F/3 is characterized by the presence of *Pinus nigra* which again transgresses from communities of the *Erico-Pinetea*. F/2 generally occurs at altitude of 1500–1800 m and F/3 at 900–1000 m.

All three communities are similar to the *Orthilio secundae-Fagetum* (Bergmeier and Dimopoulos 2001). However, the Albanian communities are also floristically distinct, showing some affinities to the communities of the Dinarides, as suggested by the presence of some species of the *Lonicero alpigenae-Fagenion*.

Discussion

Three alliances are traditionally recognized among the basiphytic *Fagus sylvatica* forests of the Balkans: *Aremonio-Fagion*, *Fagion moesiacae* and *Geranio striati-Fagion* (Marinšek et al. 2013). The alliances are recognized based on regional endemics and of species with narrow ranges. Our relevés show some influence from all three alliances, with the thermo-basiphytic forests (B, C) having affinities to the *Geranio striati-Fagion*, the meso-basiphytic forests to the *Aremonio-Fagion* (D, E) and the acidophytic (F) forests to the *Luzulo-Fagion sylvaticae*. However, the floristic characterization is poor, with only few species from these alliances occurring in our data set. Moreover, the delimitation and floristic definition of these alliances provided in the revisions covering different geographical contexts (Marinček et al. 1992; Dzwonko and Loster 2000; Bergmeier and Dimopoulos 2001) is contradictory and therefore difficult to apply to the Albanian forests.

The system of Albanian forests fits better with the ecological classification in Willner et al. (2017). We found two main clusters corresponding to thermo-basiphytic and mesophytic *Fagus sylvatica* forests, respectively. Mesophytic *Fagus sylvatica* forests were in turn divided into acidophytic (cluster F) and meso-basiphytic *Fagus sylvatica* forests (clusters E and D). These three main clusters could be further divided into seven clusters corresponding to narrower ecological groups. The attribution to existing suballiances is relatively straightforward using the diagnostic species indicated in Willner et al. (2017) and in Marinšek et al. (2013) and leads to the classification presented in the syntaxonomic scheme at the end of the paper, with meso-basiphytic *Fagus sylvatica* forests referred to as *Fagion moesiacae* and acidophytic *Fagus sylvatica* forests presumably to *Luzulo-Fagion*.

Ecologically, the seven units (A–F) are well characterized, with each forest type occupying a different section of the ecological space with minimal overlap (see Figure 3). We have a main climatic gradient corresponding to the altitudinal belts and a second gradient separating forests according to substrata. The system is very similar to that of Willner (2002) for Southern Central European forests, where also a main division in altitudinal belt and a secondary division according to substrata has been proposed. In our case, however, the second gradient seems to be a combination of soil properties and Mediterranean influence. It separates cluster B and C, which show some Mediterranean influence, from D and E, that are not influenced by Mediterranean climate.

We identified 17 communities of *Fagus sylvatica* forest. Considering the limited area of the study, this is a very high diversity, which is similar to most of the Dinarides and Eastern Alps (Horvat et al. 1974; Willner 2002). *Fagus sylvatica* probably has an ecological optimum in this part of Europe, due to high rainfall and suitable soils. This results not only in the high number of communities but also in a high number of higher syntaxonomic units. The variety of mesophilous forests and the local coexistence of many different types is well represented in the map (Figure 5) of the four main groups of mesophilous forests of Albania.

In contrast to *Fagus sylvatica* forest, the *Corylus avellana* forests are relatively homogenous and easy to interpret. In our opinion the closest relationship can be found to the *Astrantio-Corylion* Passarge 1978. However, there are differences with the thickets of Central Europe, since the Albanian *Corylion* occupies a specific ecological position, in a belt below the *Fagus sylvatica* forests in both Central and Southern Albania, in relatively oceanic conditions. The climate of this belt is probably very similar to the microclimate of ravines, cool and oceanic, and this climatic similarity might explain the apparently contradictory geomorphological context. Nonetheless our relevés are from very disturbed (mainly fires) *Corylus avellana* forests, and we defer a more detailed account of this type of forest to a future study.

Scrutiny of the map of potential vegetation of mesophilous forests in Albania (Figure 5) shows a few clear patterns. From the coast inwards, thermophytic types are substituted by mesophytic types, in accordance with decreasing water stress, diminishing temperatures and rising altitudes. Nonetheless, since the morphology of the Albanian ranges is quite corrugated, different forest types can occur in close proximity to each other.

Another interesting pattern is the absolute dominance of thermophytic types in the south. Southern Albania is, in fact, phytogeographically distinct from the rest of the country and transitional towards northern Greece as already highlighted in previous studies (Markgraf 1932).

Conclusion

The mesophilous vegetation of Albania presents a high diversity, with seven groups of forest and many communities. This diversity is partly related to the variety of climates and substrates, but also to the optimal conditions for mesophilous species in the Western Balkans due to the high rainfall and relatively warm climate.

Our material fits nicely in the ecological system of Willner et al. (2017), with the suballiances *Doronico orientalis-Fagenion moesiacae*, *Doronico columnae-Fagenion* and the alliance *Luzulo-Fagion*.

Although we were able to fit the majority of data analyzed in this study into existing syntaxa, we must not forget that Albanian mesophilous forests present a relevant degree of originality. The reason lies most likely in the climate of Albania, which is a unique combination of features belonging to both Central European and Mediterranean climate: it is warm like Southern Italy and Greece, but is characterized by a relatively high humidity, like the Dinarides. This uniqueness is reflected in the striking percentage of endemics of the Albanian flora (Barina et al. 2018).

If the issue of higher units of Albanian *Fagus sylvatica* forests is relatively straightforward, the identification of the associations is still in need of further studies. In fact, the clusters that we considered at the level of association are characterized usually not by character species but by combinations of differential species. This is a situation that occurs frequently in *Fagus sylvatica* forests (see for instance Willner 2002). Nonetheless, many of our clusters are well characterized, and we refrain from a formal description of undescribed associations only because we defer such a step to further local studies analyzing in depth the ecological characterization and the catenal relationships of these forest types.

Data availability

Plot data are included in the Suppl. material 7.

Author contributions

G.F., P.H. and M.D.S. conceived the study, A.F. and M.D.S. run the statistical analysis, and M.M, E.M., F.A. and V.E.C. contributed to the interpretation of results.

Acknowledgements

This study was carried out within the framework of the IUCN Project “Institutional Support to the Albanian Ministry of Environment, Forest and Water Administration (MoEFWA) for Sustainable Biodiversity Conservation and Use in Protected Areas and the Management of Waste” funded by the IDC (Italian Development Cooperation) and of the NaturAL Project – IPA 2013 “Strengthening national capacity in nature protection – preparation for Natura 2000 network" funded by the European Union. We thank the Linguistic Editor Lynda Weekes for the accurate language revision.

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Supplementary material

Supplementary material 1
The average, minimum, maximum and standard deviation of the 19 bioclimatic CHELSA variables related to the *Fagus sylvatica* area of distribution in Albania according the Vegetation Map of Europe
Link: https://doi.org/10.3897/VCS/2020/54942.suppl1

Supplementary material 2
Lithological substrata of Albania obtained through our grouping of the geological substrata provided by the Geological Map of Albania
Link: https://doi.org/10.3897/VCS/2020/54942.suppl2

Supplementary material 3
The average, minimum, maximum of site and layer data of all relevés
Link: https://doi.org/10.3897/VCS/2020/54942.suppl3

Supplementary material 4
Random Forest validation: Cramer's V index for cross-classification table and out-of-bag classification error
Link: https://doi.org/10.3897/VCS/2020/54942.suppl4

Supplementary material 5
Non-Metric Multidimensional Scaling (NMDS) ordination of relevés for each cluster
Link: https://doi.org/10.3897/VCS/2020/54942.suppl5

Supplementary material 6
The average, minimum, maximum of site and layer data of the relevés of each cluster
Link: https://doi.org/10.3897/VCS/2020/54942.suppl6

Supplementary material 7
Ordered relevés table
Link: https://doi.org/10.3897/VCS/2020/54942.suppl7

Appendix 1

Syntaxonomic scheme. Corresponding clusters are given in brackets.

Crataego-Prunetea Tx. 1962 nom. conserv. propos.
- ***Prunetalia spinosae*** Tx. 1952
  - ***Astrantio-Corylion avellanae*** Passarge 1978 (**A1**)

Quercetea pubescentis Doing-Kraft ex Scamoni et Passarge 1959
- ***Quercetalia pubescenti-petraeae*** Klika 1933
  - ***Fraxino orni-Ostryion*** Tomažič 1940 (**A2**)

Carpino-Fagetea sylvaticae Jakucs ex Passarge 1968
- ***Fagetalia sylvaticae*** Pawlowski 1928
  - ***Fagion moesiacae*** Blecic et Lakusic 1970
    - *Doronico orientalis-Fagenion moesiacae* Marinšek, Čarni et Šilc 2013 (**B**)
    - *Doronico columnae-Fagenion moesiacae* Dzwonko, Loster, Dubiel et Drenkovski 1999 (**C**, **D, E**)
- ***Luzulo-Fagetalia sylvaticae*** Scamoni et Passarge 1959
  - ***Luzulo-Fagion sylvaticae*** Lohmeyer et Tx. in Tx. 1954 (**F**)