VEGETATION ECOLOGY AND DIVERSITY

Research Article

Numerical classification and syntaxonomical revision of the Belgrade Forest vegetation (Istanbul, Türkiye)*

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Abstract

The Belgrade Forest, located in the European part of Istanbul, represents an ecological and biogeographical transition zone where nemoral and Mediterranean elements coexist. Although comprehensive phytosociological studies have been conducted in the study area, differences in data structure, sampling intensity, and nomenclatural problems have prevented the establishment of a unified vegetation classification. In the present study, a total of 685 relevés derived from previous surveys were compiled and digitized in TURBOVEG, standardized, and analysed using numerical classification and ordination methods. The vegetation data were classified by TWINSPAN, and diagnostic species were identified based on the phi coefficient and constancy ratio. Detrended correspondence analysis (DCA) was applied to determine major compositional gradients, and Ellenberg-type indicator values were used to interpret ecological differentiation. The analysis resulted in four forest associations and one pseudomaquis community, corresponding to *Alnus glutinosa-Carpinus betulus* riparian forest, *Acer campestre-Carpinus betulus* forests on humid soils, meso-thermophilous mixed beech-oak-hornbeam forests, and pseudomaquis vegetation. Among these associations, *Equiseto telmateiae-Alnetum glutinosae* ass. nov. and *Hyperico calycini-Ericetum arboreae* ass. nov. are here described as new. The principal ecological gradient reflected a transition from humid to relatively dry site conditions, consistent with slope aspect (site exposure to solar radiation) and soil depth variations. The resulting syntaxonomic scheme provides a harmonized framework for the classification and monitoring of forest vegetation in the Belgrade Forest and offers a baseline for assessing future ecological change and restoration priorities.

Keywords

DCA, diagnostic species, phytosociology, syntaxonomy, vegetation classification

Introduction

Forest vegetation of Türkiye has been increasingly studied by foreign and local researchers since the 1960s (Çoban et al. 2016). The Belgrade Forest, an ecologically important remnant of Istanbul's natural forest cover, has attracted numerous local and foreign scientists due to its rich flora and proximity to Istanbul. The first records related to the flora of this region date back to the 16th century (Belon 1553; Wheler 1862; Forskål 1775; Dallaway 1797; De Tchihatchef and De Verneuil 1853). The forest has long attracted scientific interest due to its naturalness and historical significance. During the Ottoman period, the Belgrade Forest was protected under special regulations aimed at safeguarding the city's water resources, whose infrastructure had been developed continuously from the Byzantine through the Ottoman periods (Çolak and Kırca 2013; Kırca and Çolak 2013). There are seven reservoirs

* Topical Collection: "Vegetation classification: from classic to numeric approaches".

within the forest, connected to the city by a joint aqueduct (Çolak et al. 2013). Beyond its cultural heritage, the Belgrade Forest represents a key ecological refuge within the rapidly urbanized landscape of Istanbul (Bayraktar and Yener 2025).

The Belgrade Forest is located in the western Euxine part of the Euro-Siberian phytogeographical region of Türkiye. The flora of Belgrade Forest contains Balkan, Colchic, Mediterranean and Central European elements. The co-occurrence of nemoral and Mediterranean elements supports earlier findings that the forest marks the northern limit of Mediterranean influence in Northwestern Anatolia (Regel 1959). Indeed, the *Quercus petraea* subsp. *iberica* dominated forests approximate continental conditions, whereas the colline *Fagus orientalis* stands, which occur at the limit of the species' natural distribution, develop under the influence of the Black Sea climate.

Previous floristic studies conducted in the Belgrade Forest have reported the presence of 19 tree species, 46 shrub species, and 316 herbaceous species. Among endemic species, *Taraxacum aznavourii* is a local endemic that is only known from its type locality and others are endemic to Northwestern Anatolia (Çolak 2013; Özalp 2013; Özhatay and Yüzbaşıoğlu 2013). This high floristic richness, including the presence of endemic and rare species, underscores the ecological and conservation importance of the Belgrade Forest, highlighting the need for continued monitoring and protection of its biodiversity (Bayraktar and Yener 2025). However, despite this richness, rapid urban expansion and recreational use have increased anthropogenic pressure on these ecosystems (Bayraktar et al. 2024).

The floristic composition of 12 different forest types was first studied by Yaltırık (1963) according to the Braun-Blanquet phytosociological method. Based on this vegetation data, Yaltırık et al. (1983) classified the vegetation of the Belgrade Forest into four plant communities: a) *Carpinus betulus-Acer campestre*, b) *Fagus orientalis-Ilex aquifolia*, c) *Quercus petraea* subsp. *iberica-Lathyrus niger*, d) *Erica arborea-Erica verticillata* communities. A second study was carried out by Yönelli (1986) who combined forest subcommunities to a higher unit named *Quercus petraea* subsp. *iberica-Carpinus betulus* which is composed of *Quercus frainetto*, *Fagus orientalis*, and typical (*Castanea sativa*) subcommunities. In addition, these studies differ in sampling intensity, nomenclatural issues, and the interpretation of diagnostic species, which limit comparability across datasets.

Recent years have witnessed major progress in the digitization and integration of phytosociological data, both in Türkiye and across Europe (Mucina et al. 2016). Large-scale vegetation databases now provide a comprehensive and standardized background for numerical vegetation classification (Chytrý et al. 2016; Mucina et al. 2016). In Türkiye, newly developed forest vegetation databases (Çoban 2017; Çoban and Willner 2019; Bonari et al. 2019) have greatly accelerated the classification of forest communities at higher syntaxonomical ranks such as alliance, order, and class (Kavgacı et al. 2012; Uğurlu et al. 2012; Bonari et al. 2021; Kavgacı et al. 2023). However, the harmonization of classification schemes and the resolution of inconsistencies in syntaxonomical units, particularly at the association level, remain challenging, underscoring the need for more detailed and standardized regional analyses.

Although comprehensive vegetation surveys have been conducted in this forest for decades, a unified and consistent classification has not yet been achieved. Given this long research history and the absence of an integrated syntaxonomic framework, the study aims to harmonize the historical phytosociological data. Accordingly, the main objective is to establish a digitized vegetation database for the Belgrade Forest and to develop a coherent and reproducible syntaxonomic framework.

Material and methods

Study area

The Belgrade Forest is situated between 28°53'25"–29°00'55"E and 41°09'44"–41°14'40"N in the European part of Istanbul. Strandzha (Istranca) Mountains descend progressively southeastwards, ending on a plain around the Bosphorus where the Belgrade Forest is located (Figure 1). The region has an average elevation of 135 m. The highest point is Kartaltepe (230 m) in the north and the lowest is Kurudere (40 m) to the south. The total land area of the Belgrade Forest, including all vegetation types and the reservoirs, is 5,524 hectares, of which 475 ha are openings (OGM 2012a, 2012b, 2012c). In terms of Mayr's silvicultural climate zone classification, the study area falls within the *Castanetum-Fagetum* transition zone (Yaltırık and Efe 1996). Within the study area, there are permanent streams that carry water throughout the year and seasonally flowing streams. In addition, lowland areas with a higher water table are also found. Historical water dams, which have been built since the Byzantine period and continued during the Ottoman period, contribute to the high ecological diversity of the study area.

Climate

While the climate of Istanbul is submediterranean, characterized by several arid months in summer, a rapid change in climate is evident towards the Black Sea coast and the Belgrade Forest. According to the Thornthwaite climate classification, the study area is characterized by a humid, mesothermal, oceanic climate with a moderate summer water deficit (Kantarcı 1980; Özhan et al. 2005; Aydın et al. 2008; Arslangündoğdu and Yılmaz 2011). The vegetation period lasts approximately 7.5 months (230 days). Mean annual precipitation is around 1,111 mm, and the mean annual temperature is 12.7 °C (Table 1). In addition, the climate of the Belgrade Forest corresponds to the Euxine type (Aydın et al. 2008).

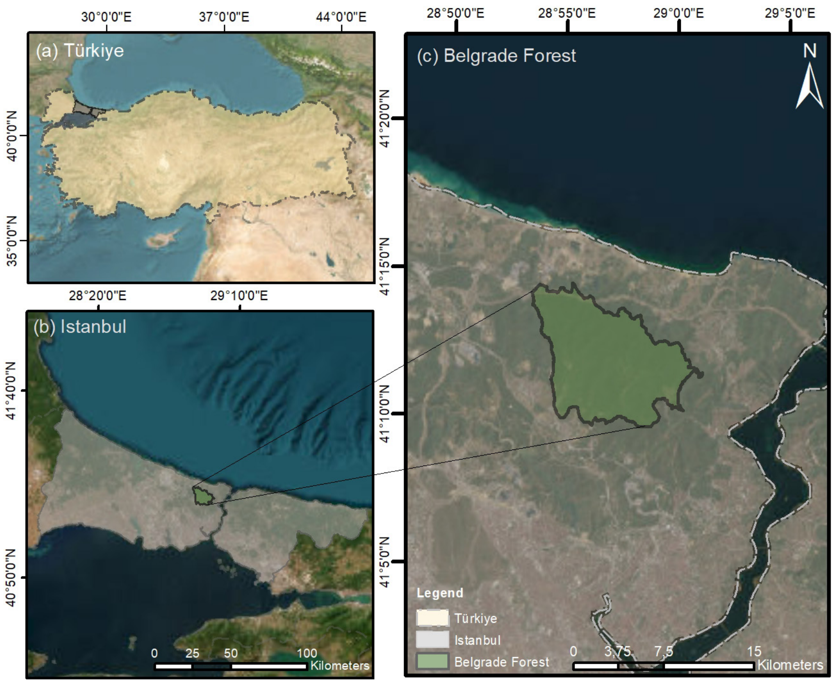

Figure 1. Location of the study area. (**a**) geographic position of Türkiye, (**b**) location of Istanbul within Türkiye, and (**c**) extent of the Belgrade Forest, which constitutes the study area.

Data analysis

Vegetation data sampled according to the Braun-Blanquet method were taken from Yönelli (1986), Yaltırık (1966), Çoban et al. (2019), and Şahin (2022). A total of 685 sample plots (349 species) were gathered and entered into the TURBOVEG database (Hennekens and Schaminée 2001). For consistency, species occurring in different tree layers were combined to ensure comparability among studies. In addition, tree species recorded in the shrub and herb layers were omitted. Subspecies and varieties were combined at the species level. Plants only identified at the genus level were removed.

The data were exported to the JUICE 7.1.3 software (Tichý 2002) and classified using the Two-Way Indicator Species Analysis (TWINSPAN; Hill 1979) with pseudospecies cut levels of 0, 2, 5, 10, and 20. Several alternative cut-level options were tested during preliminary analyses. The final cut-level combination was selected because it yielded the most ecologically coherent and floristically interpretable classification units for the vegetation of the Belgrade Forest. Because the historical and recent plot datasets differed in sampling design and occasionally included ecotonal relevés, a limited expert-based refinement was applied to ensure ecological coherence. Only a small number of relevés were reassigned, and these adjustments improved the ecological distinctness and internal consistency of the final vegetation units.

Diagnostic species were defined using the phi coefficient and Fisher's exact test, the constancy ratio for understorey species, and total cover value for tree species. A species was considered diagnostic only when all criteria were simultaneously met, namely: (1) a phi coefficient ≥ 0.2 and a significant concentration of occurrences ($p < 0.05$, Fisher's exact test), and (2) the constancy of the mean tree cover of the species across all plots within the target unit, at least twice as high as in any other unit of the same rank (Çoban and Willner 2019). Diagnostic species for higher syntaxonomical ranks were taken from Akman (1995) and Mucina et al. (2016). The nomenclature of the associations was revised in accordance with the International Code of Phytosociological Nomenclature (Theurillat et al. 2021).

Unconstrained ordination was applied to identify the major gradients in species composition and thus describe the general pattern in species distribution along the gradients. Vegetation data were recorded using the classical Braun-Blanquet cover–abundance scale (r, +, 1, 2, 3, 4, 5), and for Detrended Correspondence Analysis (DCA) the values were converted to percentage cover and log-transformed prior to ordination. The dataset was subjected to DCA using CANOCO 5 (ter Braak and Šmilauer 2002).

Species richness for each relevé was calculated in JUICE and used to compare floristic differences among vegetation units. Ellenberg-type indicator values were obtained from Tichý et al. (2023) and assigned to all species in the vegetation dataset. For each relevé, mean indicator values were calculated and subsequently averaged at the vegetation-unit level to compare ecological characteristics and to interpret the underlying environmental gradients. Physiographic variables (elevation and slope) were evaluated separately using boxplots to characterize and compare the topographic niche conditions of the identified vegetation units.

Table 1. Climatic data from Bahçeköy meteorological station (1980–2009).

	MONTHS												ANNUAL
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Mean temperature (°C)	4.6	4.3	6.3	10.7	15.2	19.6	22.0	22.1	18.3	14.3	9.5	6.5	12.7
Highest temperature (°C)	18.3	22.2	25.4	32.9	33.9	37.3	40.7	37.9	34.1	33.1	25.2	19.9	40.7
Lowest temperature (°C)	-11.0	-11.4	-8.2	-2.2	0.3	6.1	8.2	8.0	6.4	0.2	-2.8	-7.6	-11.4
Precipitation (mm)	150	111	101	56	44	42	39	64	71	117	133	183	1111
Relative humidity (%)	81.4	78.3	76.9	75.0	77.2	76.6	77.9	78.5	78.4	80.4	80.5	80.6	78.4
Days covered by snow	3.9	5.6	2.0	-	-	-	-	-	-	-	0.1	2.1	13.7
Mean cloudy days	2.5	2.1	2.4	2.3	1.0	0.1	0.1	0.1	0.4	1.3	1.8	1.2	14.3
Wind direction	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE	NE

Results

Classification of forest plant communities

The vegetation of the Belgrade Forest consists of forest and pseudomaquis vegetation. In addition, plantations of *Pinus nigra*, *Pinus sylvestris*, and *Pinus pinaster* were established on degraded shrublands and open areas surrounding the natural forest for experimental and economic purposes. In the classification process, forest vegetation was analyzed separately from pseudomaquis vegetation. The classification of forest vegetation data (654 relevés) distinguished forests on wet soils (*Alnus glutinosa* and *Carpinus betulus*-dominated) and mesophilous beech forests from meso-thermophilous hornbeam and beech forests at the first level of division. At the second level of division, riparian forests and thermophilous oak forests were separated. Mesophilous beech forest was identified at the third level of the division. Pseudomaquis vegetation, which is represented by 19 relevés in the dataset, contains evergreen species mixed with some deciduous species.

As a result of the classification 4 forest associations and 1 pseudomaquis association were distinguished (Table 2), of which 2 associations are here determined as new.

Forest communities

Alnus glutinosa-Carpinus betulus riparian forests (Unit 1)

This riparian forest vegetation type occupies narrow corridors along streambeds. The width of these stands increases where the streambed widens on flatter terrain. The unit is characterized by the highest moisture and soil nutrient indicator values (Figure 3).

Diagnostic species: *Fraxinus angustifolia*, *Laurocerasus officinalis*, *Rubus sanctus*, *Polystichum setiferum*, *Carex extensa*, *Circaea lutetiana*, *Equisetum telmateia*, *Athyrium filix–foemina*, *Phytolacca americana*, *Sambucus ebulus*, *Conyza canadensis*, *Rumex acetosella*, *Lycopus europaeus*, *Plantago major*, *Nectaroscordum siculum*, *Rubus caesius*, *Torilis japonica*, *Anagallis arvensis*, *Polygonum persicaria*, *Bromus hordeaceus*, *Polygonum hydropiper*, *Bidens tripartita*, *Juncus bufonius*, *Arctium minus*, *Oxalis corniculata*, *Calamintha nepeta*, *Ludwigia palustris*, *Petasites hybridus*, *Urtica dioica*

Dominant species: *Alnus glutinosa*, *Carpinus betulus*

Related syntaxa: None

Acer campestre-Carpinus betulus forests on humid soils (Unit 2)

Carpinus betulus forms mainly mixed stands in valleys composed of *Acer campestre*, *Alnus glutinosa*, and *Quercus robur*. This unit occurs under humid soil conditions but has lower moisture and nutrient indicator values compared to Unit 1. Species richness is higher than in Unit 1, with a mean species number of 28.9 (Figures 2, 3).

Diagnostic species: *Euonymus europeaus*, *Brachypodium sylvaticum*, *Ajuga reptans*, *Ranunculus constantinopolitanus*, *Cardamine bulbifera*, *Mercurialis perennis*, *Ranunculus ficaria*, *Melica uniflora*, *Arum italicum*, *Sanicula europaea*, *Fritillaria pontica*, *Galanthus plicatus*, *Ranunculus velutinus*, *Aegopodium podagraria*, *Heracleum sphondylium*, *Lathraea squamaria*, *Humulus lupulus*, *Cyclamen coum*, *Carex remota*

Dominant species: *Acer campestre*, *Carpinus betulus*, *Tilia argentea*

Related syntaxa: *Geranio robertiani-Carpinetum betuli* Kavgacı et al. 2011, *Trachystemo orientalis-Carpinetum betuli* Kavgacı et al. 2016

Mesophilous oak, hornbeam and beech forests

Mesophilous *Fagus orientalis* forest (Unit 3)

Pure *Fagus orientalis* forests occur only on northern exposures (N, NE, NW) with deep soils. *Fagus orientalis* dominates the tree layer with high total cover, accompanied by *Carpinus betulus*. The main difference from other communities is that oaks are not present in their structure. The unit has higher moisture and soil nutrient indicator values but lower light indicator values compared to the oak-dominated unit (Unit 4–5) (Figure 3). Species richness (mean species number 16.9) is lowest in this unit due to dense tree cover (Figure 2). For this reason, this unit is represented by few diagnostic species (Table 2).

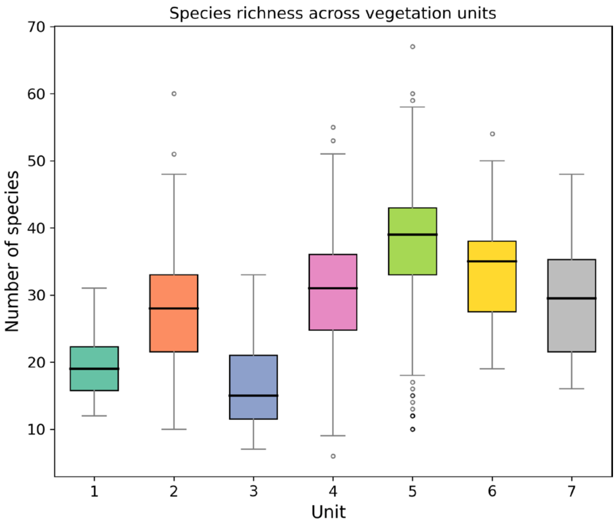

Figure 2. Box and Whiskers plots of plant communities according to species richness.

Diagnostic species: *Scilla bifolia*, *Ilex aquifolium* agg., *Polypodium vulgare*

Dominant species: *Fagus orientalis*

Related syntaxa: *Cyclamini coi-Fagetum orientalis* Tzonev at al. 2006, *Ilici colchicae-Fagetum orientalis* Quézel et al. 1992, *Rubo hirti-Fagetum orientalis* Özen 2010

Thermophilous *Fagus orientalis, Quercus petraea,* and *Carpinus betulus* forests (Unit 4–5)

This unit is dominated by *Fagus orientalis*, *Quercus petraea*, *Carpinus betulus*, *Quercus frainetto*, and *Quercus cerris* in the tree layer and generally occurs on sunny exposures on relatively shallow soils. These site conditions are reflected in the mean indicator values as follows: lower moisture and soil nutrient indicator values, but higher light indicator values (Figure 3). This community forms varied stand tree composition from the edge of valley bottoms to hill ridges over a wide ecological gradient. Natural stand composition has been changed in many places (Yaltırık 1968), which makes consistent classification difficult. For this reason, the unit has a higher species richness and also many common species with degraded pseudomaquis stands (Figures 2, 4).

Diagnostic species: *Cirsium hypoleucum*, *Carex brizoides*, *Galium paschale*, *Cephalanthera longifolia*, *Hypericum calycinum*, *Stellaria holostea*, *Brachypodium pinnatum*, *Sesleria argentea*, *Lathyrus laxiflorus*, *Rubia peregrina*, *Dactylis glomerata*, *Veronica chamaedrys*, *Lathyrus niger*, *Iris sintenisii*, *Rubia tinctorum*, *Prunella grandiflora*, *Prunus* x *domestica*, *Hieracium racemosum*, *Vicia cracca*, *Salvia virgata*, *Molinia caerulea*

Dominant species: *Castanea sativa*, *Quercus cerris*, *Quercus petraea*

Related syntaxa: *Salvio forsskaolei-Quercetum cerridis* Akman et al. ex Quézel et al. 1992, *Fago orientalis-Quercetum ibericae* Altay et al. 2015

Based on the classification, this unit could be divided into two subunits, but without distinct diagnostic species. Unit 4 can be differentiated by the co-dominance of the *Fagus orientalis* in the tree layer and *Festuca drymeja* in the herb layer. Unit 5 can be differentiated by the dominance of *Quercus frainetto* in tree layer and *Erica arborea*, *Galium verum*, and *Brachypodium pinnatum* in the understorey layer that indicates drier site conditions. This difference is also reflected in the moisture and soil nutrient indicator values, as well as in the richness (Figures 2, 3) (Table 2).

Pseudomaquis community (Unit 6)

The pseudomaquis vegetation community is found in large forest openings and degraded forest areas on sunny exposures of the study area. This community has many common species with the oak forests of unit 5 with poor canopy cover. The occurrence of tree species such as *Quercus frainetto* and *Quercus petraea* in shrubby form (Yaltırık 1963) indicate forest disturbances (Table 2).

Diagnostic species: *Chamaecytisus pygmaeus*, *Calluna vulgaris*, *Phillyrea latifolia*, *Quercus infectoria*, *Pyrus elaeagnifolia*, *Pyracantha coccinea*, *Genista tinctoria*, *Pyrus malus*, *Cornus sanguinea*, *Prunus spinosa*, *Dorycnium graecum*, *Osyris alba*, *Genista carinalis*, *Stachys thirkei*, *Holcus lanatus*, *Briza maxima*, *Trifolium stellatum*, *Lavandula stoechas*, *Carlina vulgaris*, *Crocus pulchellus*, *Cynosurus cristatus*, *Dorycnium pentaphyllum*, *Filago vulgaris*, *Anthemis tinctoria*, *Ferulago confusa*, *Luzula multiflora*, *Agrimonia eupatoria*, *Spartium junceum*, *Saccharum strictum*, *Galium verum* and others.

Dominant species: *Erica arborea*, *Erica manipuliflora*, *Arbutus unedo*, *Cistus salviifolius*, *Cistus creticus*

Plantation forests

Plantation areas are dominated by *Pinus nigra*, *Pinus sylvestris*, and *Pinus pinaster* (Unit 7). The stands are accompanied mainly by *Carpinus betulus*, *Pinus brutia*, *Quercus petraea*, and several shrub species such as *Erica arborea*, *Erica manipuliflora*, *Pyracantha coccinea*, and *Quercus coccifera*, along with a range of typical herb-layer species (Table 2). Species richness is relatively low (mean species number 28.9).

Ecological differentiation of forest communities

DCA presents a high compositional diversity (gradient length is 4.79 SD units) on the first axis which represents the strongest gradient in the data. The first axis explains 8.67% of species variation which is less on other axes. The first axis is associated with an increasing moisture gradient from left to right. When the two vegetation datasets were compared, it was found that the data set of Yaltırık

Table 2. Abbreviated percentage constancy synoptic table of vegetation data. T, Tree layer; H, Herb layer. Grey: diagnostic species. Non-diagnostic species with less than 25% constancy were omitted (See Suppl. material 2 for the full table).

Unit	Layer	1	2	3	4	5	6	7
Number of relevés		36	35	35	256	292	19	12
Deciduous tree species								
Alnus glutinosa	T	**100**	57	.	1	.	.	.
Fraxinus angustifolia	T	**17**	6	.	.	.	.	8
Carpinus betulus	T	50	**100**	26	60	71	.	25
Acer campestre	T	.	**60**	.	1	3	.	.
Tilia argentea	T	6	9	.	3	1	.	8
Fagus orientalis	T	42	31	**100**	**91**	22	.	17
Quercus petraea	T	6	20	.	93	**93**	21	42
Quercus frainetto	T	.	34	.	29	**68**	26	33
Castanea sativa	T	11	20	11	48	38	.	25
Quercus cerris	T	.	.	.	4	**8**	.	8
Quercus robur	T	**6**	29	.	.	1	.	8
Coniferous tree species (non-native)								
Pinus nigra	T	.	.	.	.	.	.	**75**
Pinus pinaster	T	.	.	.	.	.	.	**25**
Pinus sylvestris	T	.	.	.	.	.	.	**17**
Pinus strobus	T	.	.	.	.	.	.	**8**
Pinus brutia	T	.	.	.	.	.	.	**8**
Shrub species								
Laurocerasus officinalis	S	33	.	14	3	.	5	.
Euonymus europeaus	S	.	20	.	.	.	.	.
Ilex aquifolium agg.	S	8	.	20	3	.	.	.
Prunus x domestica	S	.	.	.	2	10	.	.
Cistus salviifolius	S	.	.	.	2	22	89	42
Chamaecytisus pygmaeus	S	.	.	.	1	16	84	25
Calluna vulgaris	S	.	.	.	2	12	74	17
Erica arborea	S	.	.	11	32	69	95	58
Erica manipuliflora	S	.	.	.	1	3	63	17
Pyracantha coccinea	S	.	3	3	3	27	58	33
Arbutus unedo	S	.	.	.	14	33	53	25
Phillyrea latifolia	S	.	.	.	5	19	42	42
Cistus creticus	S	.	.	.	1	2	37	8
Quercus infectoria	S	.	.	.	.	.	37	8
Pyrus elaeagnifolia	S	.	.	.	.	3	32	17
Genista tinctoria	S	.	.	.	4	24	32	17
Pyrus malus	S	.	.	.	.	.	16	.
Cornus sanguinea	S	.	.	.	1	2	11	.
Prunus spinosa	S	.	.	.	2	2	11	8
Daphne pontica	S	42	74	80	94	93	58	50
Sorbus torminalis	S	3	51	34	82	84	42	58
Mespilus germanica	S	19	31	14	69	78	32	33
Crataegus monogyna	S	14	40	11	33	75	68	58
Corylus avellana	S	64	51	6	16	8	.	33
Ligustrum vulgare	S	14	63	3	5	19	21	17
Rosa canina	S	3	3	.	2	9	5	25
Diagnostic species of Unit 1								
Rubus sanctus	H	56	3	.	.	6	11	.
Polystichum setiferum	H	53	17	14	10	1	.	.
Carex extensa	H	53	.	.	.	.	.	.
Circaea lutetiana	H	50	9	3	2	1	.	.
Equisetum telmateia	H	39	6	6	1	.	.	.
Athyrium filix-foemina	H	39	.	3	1	.	.	.
Phytolacca americana	H	31	.	.	.	.	.	.
Sambucus ebulus	H	25	.	3	1	.	.	.
Conyza canadensis	H	22	.	.	.	.	.	.
Rumex acetosella	H	17	.	.	.	.	5	.
Bromus hordeaceus	H	17	.	.	.	.	.	.
Polygonum hydropiper	H	17	.	.	.	.	.	.
Urtica dioica	H	17	.	.	.	.	.	.
Lycopus europaeus	H	14	6	3	1	.	.	.
Bidens tripartita	H	14	.	.	.	.	.	.
Calamintha nepeta	H	14	.	.	.	.	.	.
Plantago major	H	11	.	3	1	1	.	.
Nectaroscordum siculum	H	11	6	.	.	.	.	.
Anagallis arvensis	H	11	.	.	1	.	.	.

Unit	Layer	1	2	3	4	5	6	7
Number of relevés		36	35	35	256	292	19	12
Arctium minus	H	11	3	.	.	.	.	.
Rubus caesius	H	8	.	.	.	.	.	.
Torilis japonica	H	8	.	.	.	.	.	.
Juncus bufonius	H	8	.	.	.	.	.	.
Polygonum persicaria	H	6	.	.	.	.	.	.
Oxalis corniculata	H	6	.	.	.	.	.	.
Ludwigia palustris	H	6	.	.	.	.	.	.
Petasites hybridus	H	6	.	.	.	.	.	.
Diagnostic species of Unit 2								
Brachypodium sylvaticum	H	.	57	.	12	15	5	8
Ajuga reptans	H	6	46	6	11	13	5	.
Ranunculus constantinopolitanus	H	6	43	9	6	10	11	.
Cardamine bulbifera	H	3	40	3	2	.	.	.
Mercurialis perennis	H	8	37	9	4	4	.	.
Ranunculus ficaria	H	3	34	.	.	.	.	.
Melica uniflora	H	.	34	14	13	10	.	.
Arum italicum	H	.	31	.	1	1	5	.
Sanicula europaea	H	.	31	.	7	7	.	.
Fritillaria pontica	H	.	23	.	.	1	.	.
Galanthus plicatus	H	11	20	.	1	.	.	.
Carex remota	H	3	17	6	3	1	.	.
Cyclamen coum	H	.	11	3	2	1	.	.
Humulus lupulus	H	.	9	.	.	.	.	.
Ranunculus velutinus	H	.	6	.	.	1	.	.
Aegopodium podagraria	H	.	6	.	.	.	.	.
Heracleum sphondylium	H	.	6	.	.	.	.	.
Lathraea squamaria	H	.	6	.	.	1	.	.
Diagnostic species of Unit 3								
Scilla bifolia	H	.	17	31	.	.	.	.
Polypodium vulgare	H	.	.	14	5	3	.	8
Diagnostic species of Unit 4–5								
Hypericum calycinum	H	.	11	17	68	92	79	58
Cirsium hypoleucum	H	.	6	9	61	46	16	42
Stellaria holostea	H	.	17	9	57	80	74	17
Brachypodium pinnatum	H	.	.	6	57	85	84	67
Sesleria argentea	H	.	.	17	54	42	47	.
Lathyrus laxiflorus	H	3	.	.	43	62	32	17
Rubia peregrina	H	.	6	.	43	46	26	33
Carex brizoides	H	.	6	17	41	29	11	17
Dactylis glomerata	H	3	17	11	39	79	89	50
Galium paschale	H	.	3	3	29	38	5	.
Veronica chamaedrys	H	.	11	11	29	70	37	17
Cephalanthera longifolia	H	.	.	3	26	26	5	25
Lathyrus niger	H	.	.	.	24	58	21	17
Iris sintenisii	H	.	.	.	20	38	26	42
Salvia virgata	H	.	3	.	18	36	21	50
Molinia caerulea	H	.	3	.	18	27	21	8
Rubia tinctorum	H	.	.	.	10	11	.	.
Vicia cracca	H	.	.	.	9	46	42	17
Hieracium racemosum	H	.	3	.	6	22	5	.
Prunella grandiflora	H	.	.	.	4	7	.	8
Diagnostic species of Unit 6								
Galium verum	H	.	.	.	11	60	95	25
Dorycnium graecum	H	.	.	.	2	11	68	17
Osyris alba	H	.	.	.	2	10	42	.
Genista carinalis	H	.	.	.	1	11	42	33
Stachys thirkei	H	.	.	.	.	1	37	.
Holcus lanatus	H	3	.	.	2	5	37	.
Briza maxima	H	.	.	.	1	1	37	.
Trifolium stellatum	H	.	.	.	.	.	26	.
Lavandula stoechas	H	.	.	.	.	.	26	.
Carlina vulgaris	H	.	.	.	.	1	26	.
Crocus pulchellus	H	.	6	.	1	1	26	.
Cynosurus cristatus	H	.	.	.	1	1	26	8
Dorycnium pentaphyllum	H	.	.	.	1	7	21	17
Filago vulgaris	H	.	.	.	1	.	21	.
Anthemis tinctoria	H	.	3	.	1	1	21	.
Ferulago confusa	H	.	.	.	.	1	21	8

Unit	Layer	1	2	3	4	5	6	7
Number of relevés		36	35	35	256	292	19	12
Luzula multiflora	H	.	.	.	1	7	21	.
Agrimonia eupatoria	H	.	.	.	.	1	21	8
Spartium junceum	H	.	.	.	.	.	21	.
Saccharum strictum	H	.	3	.	.	1	21	8
Trifolium arvense	H	.	.	.	.	.	16	.
Odontites verna	H	.	.	.	.	.	16	.
Colchicum micranthum	H	.	.	.	1	5	16	.
Anthoxanthum odoratum	H	.	.	.	.	2	16	.
Linum bienne	H	.	.	.	.	.	16	.
Briza media	H	.	.	.	1	9	16	8
Hypericum perforatum	H	.	.	.	1	1	11	8
Petrorhagia prolifera	H	.	.	.	.	.	11	.
Stachys germenica	H	.	.	.	.	1	11	17
Origanum vulgare	H	.	.	.	1	1	11	8
Pulicaria odora	H	.	.	.	.	2	11	.
Briza minor	H	.	.	.	.	4	11	.
Lathyrus nissolia	H	.	.	.	.	4	11	8
Pilosella piloselloides	H	.	.	.	.	1	11	8
Plantago lanceolata	H	.	.	.	.	.	5	.
Lupinus varius	H	.	.	.	.	.	5	.
Calycotome spinosa	H	.	.	.	.	.	5	.
Carpinetalia betuli								
Pteridium aquilinum	H	3	37	29	84	85	89	100
Epimedium pubigerum	H	36	63	86	93	68	26	50
Trachystemon orientalis	H	78	91	86	62	12	.	25
Carex flacca	H	47	6	26	84	91	79	83
Viola sieheana	H	17	66	34	54	75	42	67
Campanula persicifolia	H	3	23	23	59	62	.	17
Asperula involucrata	H	.	3	.	3	30	32	8
Salvia forskahlei	H	8	26	14	14	20	.	.
Rhododendro pontici-Fagetalia orientalis								
Smilax excelsa	H	81	69	66	96	91	42	50
Lapsana communis	H	.	20	.	38	77	32	8
Rubus hirtus	H	6	66	51	61	32	16	67
Ruscus hypoglossum	H	14	43	37	52	19	.	33
Carpino-Fagetea sylvaticae								
Hedera helix	H	75	57	69	98	89	5	.
Viola odorata	H	3	31	17	77	78	26	33
Carex sylvatica	H	3	77	77	58	48	11	25
Galeobdolon luteum	H	78	74	71	21	5	.	.
Symphytum tuberosum	H	3	37	9	45	49	.	17
Euphorbia amygdaloides	H	.	34	3	42	20	.	17
Luzula forsteri	H	8	40	34	33	40	21	.
Lilium martagon	H	33	34	.	7	2	.	8
Vincetoxicum hirundinaria	H	.	.	.	1	4	.	33
Tamus communis	H	22	3	.	21	25	.	.
Quercetea pubescentis								
Primula vulgaris	H	28	49	43	73	54	11	33
Rubus canescens	H	69	17	3	33	36	11	25
Geranium asphodeloides	H	.	49	11	7	18	26	8
Teucrium chamaedrys	H	.	.	.	.	4	11	33
Alno glutinosae-Populetea albae								
Carex pendula	H	78	29	.	1	.	.	.
Poa trivialis	H	3	23	9	14	45	16	8
Geum urbanum	H	28	31	.	4	7	.	.
Quercetea ilicis								
Ruscus aculeatus	H	53	69	46	79	59	.	42
Other species								
Fragaria vesca	H	6	51	17	63	73	21	42
Festuca drymeja	H	8	9	26	55	11	.	33
Polystichum aculeatum	H	.	54	54	.	.	.	.
Festuca arundinacea	H	.	37	46	2	.	11	.
Ornithogalum longipes	H	.	31	31	.	.	.	.
Potentilla micrantha	H	.	31	29	2	6	16	.
Hypericum bithynicum	H	.	.	.	7	28	21	.
Agrostis stolonifera	H	.	.	3	2	7	11	25
Sanguisorba minor	H	.	3	.	.	1	.	25

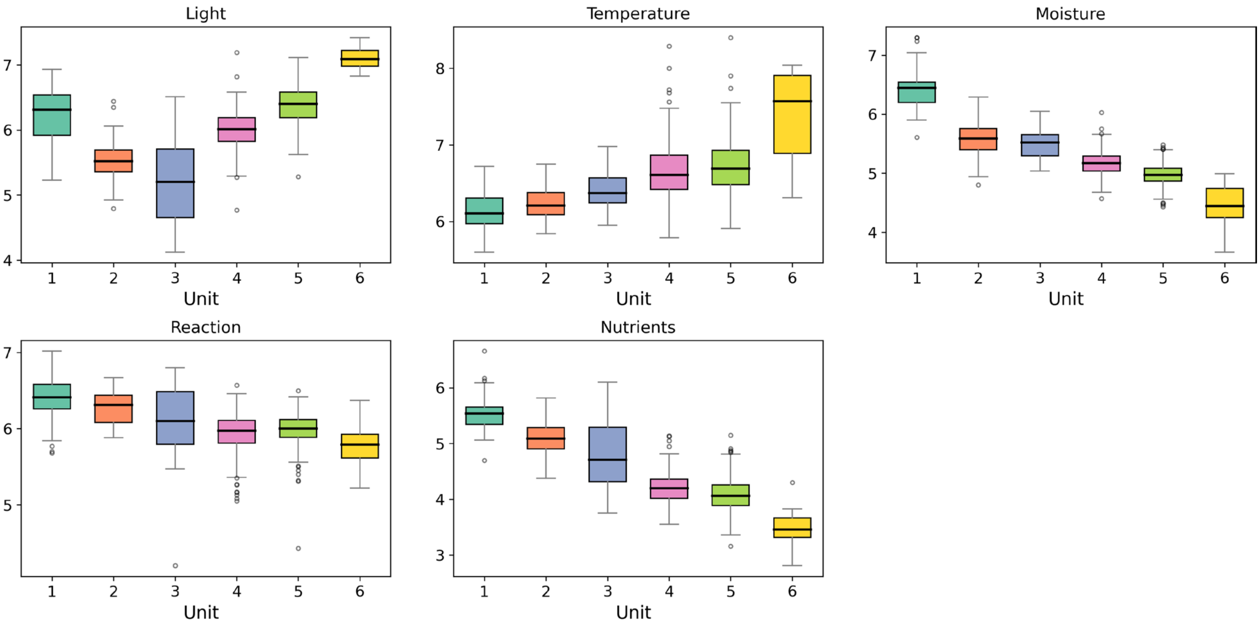

Figure 3. Mean Ellenberg-type indicator values of vegetation units.

(1963) is more heterogeneous (5.2 SD) compared to the vegetation data set of Yönelli (1986) (3.838 SD).

In the ordination diagram, humid *Alnus glutinosa* and *Carpinus betulus* dominated forest (Units 1 and 2) and mesophilous beech forest are clearly separated from meso-thermophilous *Fagus orientalis* and *Quercus petraea* dominated forests along the first axis. In addition, similarities in species composition between pseudomaquis (Unit 6) and *Quercus petraea* dominated forest are evident in the ordination space (Figure 4).

Streams and topographical differences affect the distribution of forest communities in the study area. Although elevational differences are not very strong, slope and aspect are the factors contributing to shaping microclimatical conditions. For instance, *Fagus orientalis* dominated forest (Unit 3) occurs on steeper slopes (around 30–40 degrees) and at relatively higher elevations (Figure 5).

The synoptic table summarizes the floristic composition and constancy values of the six vegetation units and 1 plantation forest identified in the Belgrade Forest (Table 2). Each unit exhibits distinct combinations of diagnostic, constant, and accompanying species reflecting ecological gradients and physiognomic differentiation within the forest. Tree-layer composition is dominated by *Fagus orientalis*, *Carpinus betulus*, and *Quercus petraea* in the mesic units, whereas *Pinus nigra* and *Pinus pinaster* prevail in the plantation stands. The herb layer reveals a clear transition from mesophilous nemoral elements (*Mercurialis perennis*, *Melica uniflora*, *Brachypodium sylvaticum*) toward thermophilous and acidophilous taxa (*Erica arborea*, *Cistus creticus*, *Brachypodium pinnatum*) in the southern and degraded sites.

Discussion

The flora of the Belgrade Forest, which contains Balkan, Colchic, Mediterranean and Central European floristic elements, does not present a uniform structure in terms of phytogeographical composition. More than half of the floristic composition belongs to European floristic elements (Yaltırık 1963). The dominant tree species are *Quercus* spp., which cover 75% of the total area, followed by *Fagus orientalis*, *Carpinus betulus*, and *Castanea sativa*. Although the tree layer has similarities with Central European forests, the understory layer, especially forest openings and meadows, has Mediterranean influence (Acatay 1943; Bornmüller 1897).

According to Aydın et al. (2008), dominant woodland types of the Belgrade Forest are Thracian mixed oak-woods and (Thracian)-Euxine beech woods. In addition to pure and mixed stands of the study area, a pseudomaquis vegetation also occurs in forest surroundings. Among the Mediterranean floristic elements, species such as *Erica arborea*, *Erica manipuliflora*, *Calluna vulgaris*, *Arbutus unedo*, *Cistus salviifolius*, *Cistus creticus*, and *Spartium junceum* are found in both forest openings and open areas. Their presence is influenced not only by climatic conditions but also by anthropogenic factors. Soil erosion following forest destruction caused shallow soil conditions, which allowed the development of pseudomaquis vegetation (Irmak 1940).

Previous studies differ considerably in sampling design and in the range of forest types they represent. Yaltırık (1963) sampled twelve stand types that varied in tree composition, age, structure, and canopy density, whereas Yönelli (1986) focused predominantly on *Quercus petraea* and *Carpinus betulus* stands and classified the forest into *Quercus frainetto*, *Fagus orientalis*, and typical *Castanea sativa* subcommunities under the *Quercus petraea* subsp. *iberica-Carpinus betulus* community. As a result, communities with narrow distributions, such as riparian *Alnus glutinosa* forests (Unit 1), *Acer campestre-Carpinus betulus* stands on humid soils (Unit 2), and *Chamaecytisus pygmaeus-Erica manipuliflora* pseudomaquis (Unit

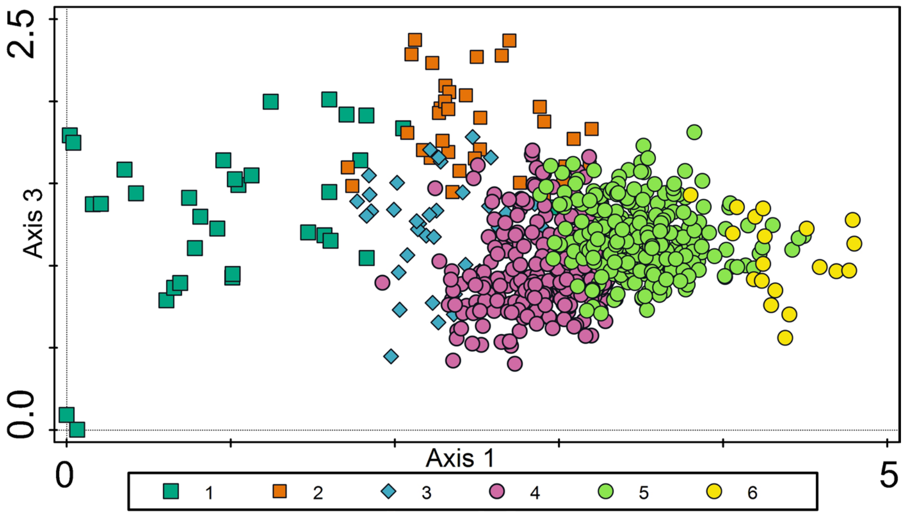

Figure 4. Detrended Correspondence Analysis (DCA) ordination diagram of forest vegetation in the Belgrade Forest based on species composition.

6), were not adequately represented in Yönelli's dataset. In contrast, the relevés of Yaltırık (1963) encompass most vegetation types of the Belgrade Forest. More recently, humid biotopes were described by Şahin (2022), providing complementary information. Standardization of all datasets was therefore essential to achieve a consistent and comparable classification, including the combining of vegetation layers, the removal of tree species recorded in shrub and herb layers, the exclusion of genus-level taxa and the elimination of biased plots. These procedures ensured a coherent and ecologically interpretable dataset.

The *Acer campestre-Carpinus betulus* community on humid soils (Unit 2) predominantly contains diagnostic species of the class *Carpino-Fagetea sylvaticae*. Species such as *Euonymus europaeus*, *Corylus avellana*, *Sanicula europaea*, *Cardamine bulbifera*, and *Mercurialis perennis* are commonly found in *Fagus orientalis* and *Abies nordmanniana* forests in Northwestern Anatolia (Çoban and Willner 2019), in *Fagus sylvatica* forests in Europe (Tzonev et al. 2006; Willner et al. 2017), and in Great Britain (Rodwell 1998). These species are generally absent from the *Fagus orientalis* forests (Unit 3) but preferentially occur in Unit 2. This floristic pattern supports assigning the community to the *Carpinetalia betuli* order and the class *Carpino-Fagetea sylvaticae*.

The *Alnus glutinosa-Carpinus betulus* riparian forest (Unit 1) is confined to streambeds feeding the reservoir system. Comparable riparian communities have been described from İğneada (*Geranio robertiani-Carpinetum betuli* Kavgacı et al. 2011) and Bursa-Yeniköy (*Apocyno veneti-Fraxinetum angustifoliae* (Özen 2010) Kavgacı et al. 2016), however, both show low floristic similarity to the Belgrade Forest (8% and 18%, according to the Sørensen similarity index, respectively). Consequently, Unit 1 is described here as a new association, *Equiseto telmateiae-Alnetum glutinosae* ass. nov. In contrast, Unit 2 shows greater affinity to the association *Trachystemono orientalis-Carpinetum betuli* described from drier sites in the İğneada floodplain forest and is therefore assigned accordingly.

According to Willner et al. (2017), *Fagus orientalis* forests are mainly divided into thermo-basiphytic and meso-basiphytic beech forests in Anatolia. Çoban and Willner (2019) indicated that thermo-basiphytic beech forests lack distinct characteristics species as they share the diagnostic species with thermophilous oak and mixed broadleaved forests. For this reason, both thermophilous beech forests and mesic beech and fir-beech forests were classified under the alliance *Fagion orientalis*. Thermophilous beech forests were included under the suballiance *Fagenion orientalis* Çoban and Willner 2019.

Aydın et al. (2008) conducted a field excursion in northwestern of Türkiye including the Belgrade Forest and took three vegetation plots in order to determine forest communities. They named the *Fagus orientalis*-dominated forest (Unit 3) as *Ilici colchicae-Fagetum orientalis* Akman, Barbéro et Quézel 1978. This association occurs on a higher elevational belt (750–1250 m) in Kastamonu-Cide region with a different floristic composition such as the existence of *Rhododendron ponticum* and *Rhododendron luteum* which are absent in the Belgrade Forest. For this reason, Çoban and Willner (2019) accepted *Cyclamini coi-Fagetum orientalis* Tzonev et al. 2006 for this unit which was described from a low elevational belt of Strandzha Mountains similar to Belgrade Forest. The type relevé of this unit has a high similarity (66%) with the *Fagus orientalis*-dominated forest of the study area.

In this study, the classification of *Quercus petraea*-dominated forests into a physiognomically coherent unit proved to be challenging. The tree-layer composition exhibited considerable heterogeneity, reflecting a range of stand structures. Such variation may be attributable to long-term degradation processes that have altered forest structure and tree-species diversity. *Quercus petraea*-dominated forests were classified as *Salvio forskahlei-Quercetum cerris quercetosum frainetto* Akman et al. ex Quezel et al. 1992 (Aydın et al. 2008) and *Tanaceto cinerei-Quercetum ibericae* Kavgacı et al. 2010 (Kavgacı et al. 2010). Kavgacı et al. (2010) suggested that *Quercus ibericae*-dom-

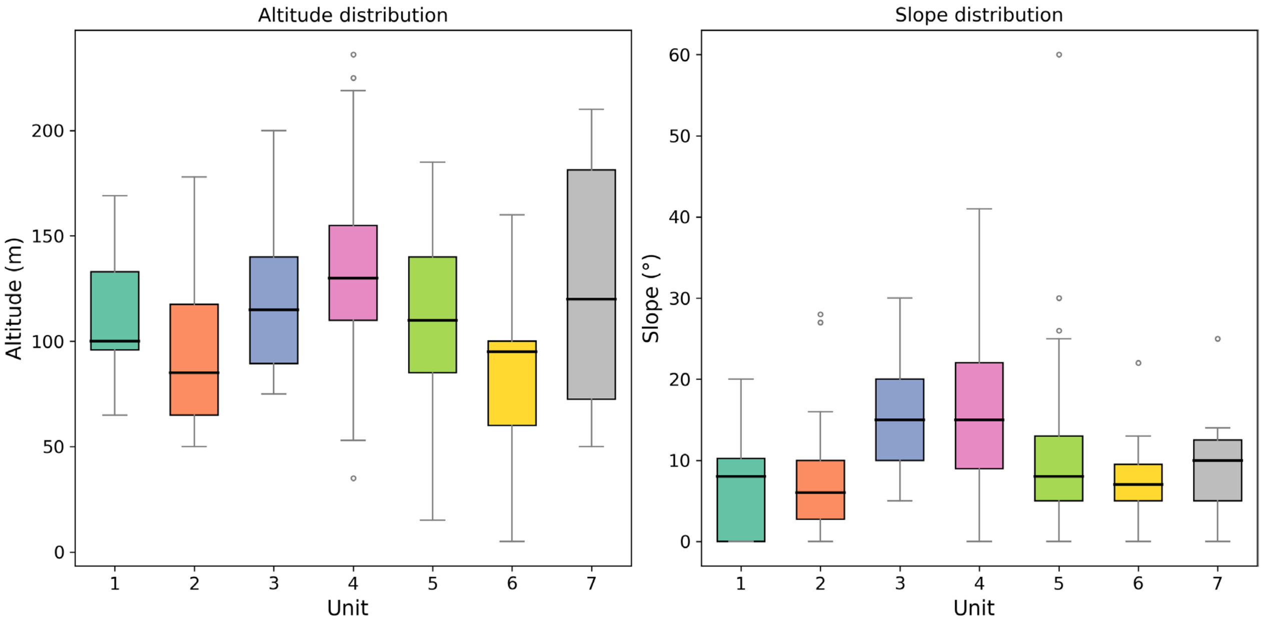

Figure 5. Niche space of vegetation units based on elevation (m) and slope degrees.

inated forests in Northwestern Thrace show similar features to those from the Belgrade Forest and must be classified under *Tanaceto cinerei-Quercetum petraea* subsp. *ibericae* Kavgacı et al. 2010. However, the floristic similarity between this community and *Quercus petraea* subsp. *ibericae* dominated forest was found to be 46%. In addition, *Tanacetum corymbosum* subsp. *cinereum* is not found in the Belgrade Forest. For this reason, *Salvio forskahlei-Quercetum cerris* is more suitable for *Quercus petraea*-dominated forests (Unit 4–5). According to Akman (1995), *Quercus frainetto-Quercus cerris* forests occur on non-calcareous metamorphic bedrocks on a wide area in the southern parts of the Marmara Sea. These forests were defined as *Salvio forskahlei-Quercetum cerridis* which were subdivided into *quercetosum frainetto* and *helleboretosum orientalis* subassociations. The former subassociation occurs on relatively more humid part of the distribution area of the association (Quézel et al. 1992). However, *Fagus orientalis* co-dominated unit of this association was accepted as another subassociation, namely as *Salvio forskahlei-Quercetum cerridis fagetosum orientalis*, which has a transitional character between mesophilous beech forests (Unit 3) and thermophilous beech and oak forests (Unit 5).

Maquis vegetation was not adequately studied in western Euxine region. Therefore, it was not possible to assign pseudomaquis vegetation to a validly published and physiognomically similar association. Özyiğit et al. (2014) described two maquis associations in İstanbul Princes'Island as *Arbuto unedonis-Phillyretum latifoliae* Özyiğit et al. 2014 and *Phillyreo latifoliae-Pinetum brutiae* Schwarz 1936. However, both units differ from that of the study area in terms of dominant species and also similarity of species composition (5% similarity). For this reason, pseudomaquis vegetation which mostly occurs on degraded forest openings was defined as a new association. Çoban et al. (2019) also reported distribution of this association on powerline corridors which are periodically cleared for forest fire prevention around Belgrade Forest.

Based on the results of the numerical analyses, the following syntaxonomic scheme could be proposed:

Alno glutinosae-Populetea albae P. Fukarek et Fabijanić 1968
Alno-Fraxinetalia excelsioris Passarge 1968
Alno-Quercion roboris Horvat 1950
Equiseto telmateiae-Alnetum glutinosae ass. nov. (Unit 1)

Holotypus (Suppl. material 1, Relevé 5)
Location: Ayvad Bendi, relevé area (m²): 400; 41.2151015°N, 28.94198553°E, elevation: 96 m a.s.l., slope: 13°
Tree layer: *Alnus glutinosa* 4, *Carpinus betulus* 2
Shrub layer: *Corylus avellana* 1
Herb layer: *Equisetum telmateia* 4, *Galeobdolon luteum* 4, *Carex extensa* 4, *Carex pendula* 3, *Athyrium filix-foemina* 2, *Phytolacca americana* 2, *Sambucus ebulus* 2, *Circaea lutetiana* 2, *Lycopus europaeus* 1, *Tamus communis* 1, *Polygonum hydropiper* 1, *Polystichum setiferum* 1, *Rubus canescens* 1, *Rumex acetosella* 1, *Rubus hirtus* 1, *Smilax excelsa* 1, *Torilis japonica* 1, *Trachystemon orientalis* +, *Geum urbanum* +, *Urtica dioica* +, *Mercurialis perennis* +, *Conyza canadensis* +, *Calamintha nepeta* +, *Oxalis corniculata* r, *Lamium purpureum* r, *Bidens tripartita* r

Carpino-Fagetea sylvaticae Jakucs ex Passarge 1968
Carpinetalia betuli P. Fukarek 1968
Trachystemono orientalis-Carpinion betuli Çoban et Willner 2019
Trachystemo orientalis-Carpinetum betuli Kavgacı et al. 2011 (Unit 2)

Rhododendro pontici-Fagetalia orientalis (Soó 1964) Passarge 1981
Fagion orientalis Soó 1964
Fagenion orientalis Çoban et Willner 2019
Cyclamini coi-Fagetum orientalis Tzonev at al. 2006 (Unit 3)

Quercetea pubescentis Doing-Kraft ex Scamoni et Passarge 1959
Quercetalia pubescenti–petraeae Klika1933
Quercion confertae Horvat 1958
Salvio forskhali-Quercetum cerridis fagetosum orientalis subass. nov. (Unit 4)

Holotypus (Suppl. material 1, Relevé 258)
Location: Belgrade Forest, relevé area (m^2): 400; elevation: 130 m a.s.l., slope: 22°
Tree layer: *Fagus orientalis* 3, *Quercus petraea* 3, *Quercus frainetto* 2, *Quercus cerris* 1
Shrub layer: *Hedera helix* 1, *Daphne pontica* +, *Ruscus aculeatus* r
Herb layer: *Epimedium pubigerum* 4, *Carex flacca* 1, *Festuca drymeja* 1, *Euphorbia amygdaloides* +, *Brachypodium pinnatum* +, *Hypericum calycinum* +, *Lathyrus laxiflorus* +, *Primula vulgaris* +, *Pteridium aquilinum* +, *Rubus hirtus* +, *Smilax excelsa* +, *Symphytum tuberosum* +, *Iris sintenisi*i r, *Carex brizoides* r, *Campanula persicifolia* r, *Cephalanthera longifolia* r, *Rubia tinctorum* r, *Fragaria vesca* r, *Galium paschale* r, *Cirsium hypoleucum* r, *Tamus communis* r
quercetosum frainetto Barbéro et Quézel 1979 (Unit 5)

Quercetea ilicis Br.-Bl. ex A. Bolòs et O. De Bolòs in A. Bolòs y Vayreda 1950
Quercetalia ilicis Br.-Bl. ex Molinier 1934
Quercion ilicis Br.-Bl. ex Molinier 1934
Hyperico calycini-Ericetum arboreae ass. nov. (Unit 6)

Holotypus (Suppl. material 1, Relevé 656)
Location: Kemerburgaz-Burunsuz, relevé area (m^2): 100; elevation: 40 m a.s.l., aspect: south, slope: 5°
Tree layer: *Quercus petraea* +
Shrub layer: *Erica arborea* 4, *Cistus salviifolius* 3, *Arbutus unedo* 3, *Erica manipuliflora* 2, *Chamaecytisus pygmaeus* 2, *Calluna vulgaris* 1, *Pyracantha coccinea* +, *Genista tinctoria* +
Herb layer: *Sesleria argentea* 5, *Pteridium aquilinum* 5, *Hypericum calycinum* 3, *Carex flacca* 3, *Dorycnium graecum* 2, *Lavandula stoechas* 1, *Genista carinalis* 1, *Holcus lanatus* +, *Carlina vulgaris* +, *Dactylis glomerata* +, *Briza maxima* +, *Galium verum* +, *Brachypodium pinnatum* +

Conclusions

This study reconciles vegetation surveys to provide a coherent and reproducible vegetation typology for the Belgrade Forest. The resulting syntaxonomic scheme, supported by diagnostic species and DCA gradients, clarifies the delimitation of mesophilous beech, meso-thermophilous mixed oak–beech–hornbeam and riparian forest communities, and distinguishes pseudomaquis under degraded conditions. These outcomes establish a standardized baseline for long-term monitoring and management, particularly for tracking secondary succession and prioritizing restoration.

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Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

No ethical statement was reported.

Use of AI

No use of AI was reported.

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Author contributions

Süleyman Çoban, Conceptualization, Data compiling, Methodology, Research design, Data analysis, Statistical interpretation, Drafting of the manuscript, Manuscript revision and response to reviewers. Selim Bayraktar, Conceptualization, Data compiling, Methodology, Research design, Drafting of the manuscript, Statistical interpretation, Review and editing, Manuscript revision and response to reviewers, Corresponding author. Nilüfer Şahin, Data providing, Contribution to manuscript writing and revisions.

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Data availability

All of the data that support the findings of this study are available in the main text or Supplementary Information.

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Supplementary material 1

Detailed vegetation table

Authors: Süleyman Çoban, Selim Bayraktar, Nilüfer Şahin

Data type: xlsx

Link: https://doi.org/10.3897/ved.177153.suppl1

Supplementary material 2

Full synoptic table

Authors: Süleyman Çoban, Selim Bayraktar, Nilüfer Şahin

Data type: xlsx

Link: https://doi.org/10.3897/ved.177153.suppl2