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Classification of *Quercus trojana* forests in southeastern Europe and Türkiye

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ABSTRACT

This paper deals with *Quercus trojana* forest plant communities on the Balkan Peninsula, in Italy and Türkiye. Many syntaxa were described, but no unified syntaxonomic system based on a numerical analysis of vegetation has been proposed for the whole geographical range of *Quercus trojana*. Previous studies on *Quercus trojana* communities proposed to distinguish the alliance *Quercion trojanae* or the suballiance *Quercenion trojanae*. Here we aim to provide a revised syntaxonomic system of *Quercus trojana* forests in southeastern Europe and Anatolia. The analysed dataset included 246 relevés and 1011 species. Eleven associations and subassociations were identified using hierarchical cluster analysis (the Sørensen index as a dissimilarity measure and the Flexible Beta clustering method). Four subassociations were described as new: *Quercetum trojanae chrysopogonetosum grylli, festucetosum callieri, seslerietosum autumnalis,* and *rutetosum graveolentis*. Balkan and Italian communities belong to *Quercetalia pubescenti-petraeae* (the alliances *Carpinion orientalis* and *Fraxino-Ostryion*) and communities from Türkiye belong partly to *Quercetalia pubescenti-petraeae* (alliance *Quercion crispatae*) and partly to *Querco-Cedretalia libani* (alliance *Querco vulcanicae-Ostryion carpinifoliae*).

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Introduction

Macedonian oak (*Quercus trojana* Webb) is an East Mediterranean semi-evergreen tree or shrub with a disjunct geographic range that extends from the southern Italian Peninsula to the western and southern Balkan Peninsula and western and southern Anatolia (Jalas and Ju 1972–1999). It is found mainly on dry terrains in the Submediterranean regions (mainly on calcareous bedrock, degraded land influenced by soil erosion and on steep slopes), mostly between 200 and 500 m asl, but on south-facing slopes, it rises to 1000 m, and in Türkiye even to 1500 m asl (Šilić 1973; Brus 2012).

Three subspecies are recognized: typical subspecies (within the whole distribution range), subsp. *euboica* (Papaioann.) K.I.Chr. (limited to the island of Euboea, Greece) and subsp. *yaltirikii* Ziel. et al. (Asiatic part of Türkiye). Several varieties and forms were also described in the western Balkan Peninsula (Jovančević 1965). A high phenotypic variation has been reported, particularly for the northwestern margins of the species range in Bosnia and Herzegovina and Montenegro, but no link between geography and phenotypic variation has been confirmed (Ballian et al. 2014).

Forests dominated by *Quercus trojana* are a remarkable phenomenon in southeastern Europe (Horvat et al. 1974). *Quercetum trojanae* was first recognized as a new syntaxon by Hans Em, but his results were not published. The association was validly published by Horvat (1959) as *Quercetum trojanae* with a synoptic table based on Em's phytosociological table. Later Balkan authors mentioned several syntaxa with geographical epithets (*Quercetum trojanae adriaticum, Quercetum trojanae hercegovinicum, Quercetum trojanae macedonicum, Quercetum trojanae metochiense, Quercetum trojanae montenegrinum*) but without relevés (Appendix).

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In Bosnia and Herzegovina, Redžić (2011) indicated three associations characterized by *Q. trojana* (*Quercetum trojanae macedonicum*, *Quercetum trojanae montenegrinum*, and *Pistacio-Quercetum trojanae*) without giving any relevés, and these syntaxa were not confirmed by subsequent field work (Stupar et al. 2015). The latter authors also mentioned that *Quercus trojana* occurs only admixed in other thermophilous oak communities. Furthermore, Operta et al. (2013) described provisionally the association *Paliuro aculeati-Quercetum trojanae*, but again without relevés.

In Croatia, only shrub stands have been described so far (Jasprica and Carić 2002), while forest communities are not mentioned in the syntaxonomical synopsis (Trinajstić 2008), although Tolić (1999) reported Macedonian oak forest stands in Dalmatinska Zagora (east Adriatic coast).

In Montenegro, besides the forest association *Quercetum trojanae montenegrinum* (Blečić and Lakušić 1967), Bulić (1994) provisionally described its degradation stage *Junipero-Quercetum trojanae*. Additionally, the subassociation *Rusco-Carpinetum orientalis quercetosum trojanae* was described from Montenegro (Lakušić et al. 1982).

In the continental part of the *Quercus trojana* distribution range (Kosovo), Rexhepi (1982) described the association *Quercetum trojanae dukagjini*, characterised as a thermophilous, refugial and relict community with substantial anthropogenic impact. Two subassociations were described within this association, *salvietosum* and *teucrietosum*.

In Albania, two physiognomical and ecological forms of the *Quercetum trojanae* were described: savannah-like formation and dense degraded forest (Fanelli et al. 2015).

In North Macedonia, the association *Quercetum trojanae* was first reported by Em (Horvat 1959), but the first relevés of the association were published almost 50 years later by Matevski et al. (2011) from Mt. Galičica.

In Greece, *Quercus trojana* forests have been studied in the north-central and northern Pindus floristic regions. Gerasimidis (2003) classified *Quercus trojana* stands from the foothills of Mt. Vorras, the hilly region northwest of Lake Vegoritida and the submontane area north of the city of Kozani in the association *Quercetum trojanae* and described two subassociations (*juniperetosum oxycedri* and *cornetosum maris*) and few variants and facies (Appendix). The same association was also described from the southeastern part of Mt. Vermio by Chochliouros (2005). Pirini (2011) classified forest stands dominated by *Q. trojana* in the hilly area around Lake Vegoritida in the *Quercus trojana-Carpinus orientalis* community, while more open stands from the same area in the *Quercus trojana-Juniperus oxycedrus* community. Tsaliki et al. (2005) classified the woodland vegetation of *Q. trojana* from the Aoos River valley to the latter community. Furthermore, relevés of Macedonian oak vegetation were sampled on Mt. Gramos (Gamisans and Hebrard 1979), in the Prespa National Park (Vrahnakis et al. 2011), as well as on Mts. Smolikas, Gramos, Vourinos, and Voras as a part of monitoring projects. Forests of *Pinus halepensis* Mill. in which *Quercus trojana* subsp. *eubonica* is found in the shrub layer were classified into *Quercion ilicis* (Mucina and Dimopoulos 2000).

In Italy, forests of *Quercus trojana* were known for a long time as "bosco di fragno" and their particular ecology, structure (Lorenzoni and Chiesura-Lorenzoni 1987) and history (Schirone and Spada 1995) were studied. Forests form both closed and open stands, the latter maintained by intensive grazing. In the first study of the diversity of these forests, Lorenzoni and Chiesura-Lorenzoni (1987) outlined five provisional communities. Later, two associations according to the Braun-Blanquet approach were identified as *Euphorbio apii-Quercetum trojanae* (Bianco et al. 1998) and *Teucrio siculi-Quercetum trojanae* (Biondi et al. 2004).

In Anatolia, four syntaxa of vegetation dominated by *Quercus trojana* were described: *Quercetum macrolepido-trojanae, Quercetum trojano-pubescentis, Cotoneastro nummularii-Quercetum pubescentis quercetosum trojanae,* and *Asyneumo-Quercetum trojanae* (Ketenoglu et al. 2010; Kenar et al. 2020).

Syntaxonomical classification of *Quercus trojana* forests to higher vegetation units differs among authors and regions (Appendix). In the Balkan Peninsula, they were classified into the *Carpinion orientalis* and *Fraxino orni-Ostryion* (*Quercetea pubescentis*) (Horvat 1959; Rexhepi 1982), while the first classification of these forests in Italy was into the *Quercetea ilicis* (Lorenzoni and Chiesura-Lorenzoni 1987; Bianco et al. 1998). Biondi et al. (2004) included the association *Teucrio-Quercetum* into *Carpinion orientalis*, and Di Pietro and Misano (2009) argued that all Italian *Quercus trojana* forests should be included in this alliance. Stands from Türkiye were classified into two alliances, *Quercion crispatae* Akman et al. ex Quézel et al. 1992 and *Querco vulcanicae-Ostryion carpinifoliae* Kavgacı et al. 2021.

Although recognised internationally important from a conservation point of view as a habitat type of Community interest (Annex I of the EU Habitats Directive), *Quercus trojana* forests have never been studied in a supraregional analysis, and for several countries, relevés have been missing. Therefore, the aim of our study is to analyse the species composition

and syntaxonomy of *Quercus trojana* forests in the Balkan and Italian peninsulas and consider them also in a wider context with *Quercus trojana* forests in Türkiye.

Methods

Vegetation sampling

We compiled all available relevés with the dominance of *Quercus trojana* (original and from the literature) made with the Braun-Blanquet method (Braun-Blanquet 1964) from the Balkan Peninsula, Italy, and Türkiye to cover the whole distribution range of *Quercus trojana*, stored in various Turboveg databases (Hennekens and Schaminée 2001). We also sampled *Quercus trojana* forests in Montenegro and Bosnia and Herzegovina as no relevés were available from these countries so far. Altogether, we collected 296 relevés. The height of the tree layer was between 4 and 16 m and that of the shrub layer was between 0.5 and 4 m.

The taxonomy and nomenclature of plant taxa were unified according to the Euro+Med PlantBase (Euro+Med 2024) and of higher syntaxa according to Mucina et al. (2016). According to Euro+Med (2024), the species *Teucrium polium* L. is absent from the Balkans. Consequently, the original identification by Rexhepi (1982) and Pirini (2011) has been revised to *Teucrium capitatum* L.

Data analysis

We performed the analysis in two steps because no vegetation layers were distinguished in the Turkish relevés. Therefore, we compiled two datasets, one from Balkan and Italian peninsulas (we named it Balkan-Italian dataset) and one from the whole study area including both southeastern Europe and Türkiye.

First, we compiled a dataset of relevés from southeastern Europe in which *Quercus trojana* was a dominant or codominant species (merged tree and shrub layers, cover value on the Braun-Blanquet scale equal or higher than 2 (i.e. more than 5%). We removed the relevés in which *Quercus trojana* was recorded only in the shrub or herb layer. Before numerical analyses, we applied a geographical resampling of relevés based on grid cells of 0.75×1.25 degrees in the WGS84 geographic coordinate system. We kept five randomly selected relevés from each syntaxon (according to the authors' original classification) falling in the same grid cell. No resampling was applied for the syntaxa (according to the original sources) with less than 10 relevés. After resampling, we ended up with a matrix of 202 relevés and 949 taxa. Subsequently, we removed taxa identfied only to the genus level and taxa occurring only once, reaching a final number of 642 taxa.

We classified the relevés using the relative Sørensen dissimilarity and the Flexible Beta (β = -0.25; Legendre and Legendre 1998) as the linkage method. Furthermore, we run ordination using Non-metric multidimensional scaling (NMDS). Hellinger transformation was applied to percentage cover values of taxa derived from the original scales.

Species fidelity to each cluster was expressed by the phi (Φ) coefficient (Chytrý et al. 2002), with sizes of all relevé groups virtually equalized (Tichý and Chytrý 2006). In the characteristics of individual syntaxa, diagnostic species with phi > 0.15, constant species with frequency > 50% and dominant species (cover value over 25% in more than 10% of relevés) were selected. Fisher's exact test ($p > 0.05$) was applied to exclude diagnostic species with non-significant occurrence concentration in a particular vegetation unit. Species data were processed in JUICE (Tichý 2002).

For the ecological interpretation of the ordination diagrams, we calculated mean Ellenberg-type indicator values (Tichý et al. 2023) for each relevé and projected them passively onto the NMDS biplot together with altitude.

The classification was made with PC-Ord (McCune and Mefford 1999) in JUICE (Tichý 2002) and ordinations were done with R software using the *vegan* package (Oksanen et al. 2022).

Second, we added 44 relevés from Türkiye to the southeastern European dataset. In this extended dataset, all taxa were merged into one layer as in the Turkish relevés, no vegetation layers were distinguished. We used the same analyses for this extended dataset as for the southeastern European dataset.

Results

In the Balkan-Italian dataset, *Quercus pubescens* Willd., *Fraxinus ornus* L. and *Carpinus orientalis* Mill. occurred in the tree layer beside *Quercus trojana*. Other most frequent species in the whole dataset were *Dactylis glomerata* L., *Teucrium chamaedrys* L., *Asparagus acutifolius* L., *Juniperus oxycedrus* L. (shrub), and *Ruscus aculeatus* L. Species with higher cover and frequency were *Sesleria autumnalis* (Scop.) F. W. Schultz and *Ruscus aculeatus*.

Classification of Balkan-Italian dataset recognized six clusters of relevés (Figure 1). Clusters 1, 2, 3, 4, and 5 represent plant communities of *Quercetum trojanae* from the Balkan Peninsula, and cluster 6 groups relevés from the Italian Peninsula. Relevés of the first three

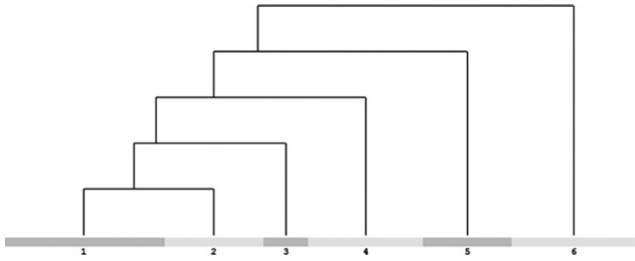

Figure 1. Classification of relevés with *Quercus trojana* from the Balkan and Italian peninsulas (relative Sørensen dissimilarity and Flexible Beta (β = −0.25)). 1 *Quercetum trojanae typicum* (MK, AL, GR, ME), 2 *Quercetum trojanae festucetosum callieri* (GR), 3 *Quercetum trojanae rutetosum graveolentis* (KS), 4 *Quercetum trojanae seslerietosum autumnalis* (ME, BA), 5 *Quercetum trojanae chrysopogonetosum grylli* (GR), 6 *Teucrio siculi-Quercetum trojanae* (IT).

clusters (1–3) and cluster 5 were sampled at high altitudes between 400 and 1400 m asl, while clusters 4 and 6 represent *Quercus trojana* forests at low altitudes (100–600 m asl).

Based on the unsupervised classification and ordination, we distinguished six vegetation types that correspond to previously described associations and subassociations from southeastern Europe.

Description of clusters

Cluster 1: Quercetum trojanae typicum

Diagnostic species (Dg) (phi value*100): *Quercus coccifera* L. (Dm, tree) 17.7, *Quercus coccifera* (shrub) 18.7, *Quercus frainetto* Ten. (Dm, tree) 18.6, *Quercus petraea* (Matt.) Liebl. (Dm, tree) 16.7, *Carpinus orientalis* (Dm, herb) 16.4, *Dorycnium hirsutum* (L.) Ser. 15.8, *Arbutus unedo* L. (Dm, tree) 15.1.

Constant species (C) (percentage frequency): *Quercus trojana* (Dm, tree) 100, *Dactylis glomerata* 71.

Dominant species (Dm) (frequency of species with cover higher than 25% and in more than 10% of relevés): *Quercus trojana* (C) 65, *Carpinus orientalis* (C) 22.

The typical subassociation is characterized mostly by the dominant tree species and species of the *Quercetea pubescentis* and *Carpino-Fagetea* classes, while elements of *Quercetea ilicis* only enter the stands at the margins of the range of this subassociation (Greece). Species of the *Quercetea pubescentis* are the most frequent in this subassociation. The altitudinal range is between 400 and 1000 m asl. This subassociation occurs in Albania, North Macedonia and Greece.

Cluster 2: Quercetum trojanae festucetosum callieri

Diagnostic species: *Brachypodium pinnatum* (L.) P.Beauv. 33.9, *Festuca callieri* (Hack.) Markgr. 30.8, *Anisantha sterilis* (L.) Nevski (Dm) 27.2, *Galium heldreichii* Halácsy 21.5, *Festuca valesiaca* Gaudin 19.6, *Dactylis glomerata* (C, Dm) 19.3, *Crupina vulgaris* Cass. 17.6, *Geocaryum capillifolium* (Guss.) Coss. 17.0, *Viola kitaibeliana* Schult. 16.9, *Koeleria lobata* (M.Bieb.) Roem. & Schult. 15.7, *Geranium robertianum* L. 15.5

Constant species: *Quercus trojana* (Dm, tree) 100, *Dactylis glomerata* (Dg, Dm) 84, *Teucrium chamaedrys* 75, *Quercus trojana* (shrub) 72, *Brachypodium pinnatum* 72, *Silene italica* (L.) Pers. 69, *Juniperus oxycedrus* (shrub) 66, *Quercus trojana* (herb) 53

Dominant species: *Quercus trojana* (C) 81, *Dactylis glomerata* (Dg, C) 12

The tree layer is composed of *Quercus trojana* and rarely present *Quercus pubescens* and *Carpinus orientalis,* while other oaks, *Fraxinus ornus,* and *Ostrya carpinifolia* are not present at all. South-European species such as *Festuca callieri* and *Galium heldreichii* are present in the herb layer, while *Ruscus aculeatus* is absent. Species of the *Festuco-Brometea* class are also frequent. This subassociation is found at altitudes between 700 and 1350 m asl near lakes Prespa and Vegoritida in Greece.

Cluster 3: Quercetum trojanae rutetosum graveolentis

Diagnostic species: *Ruta graveolens* L. 25.6, *Fragaria vesca* L. 23.9, *Acanthus hungaricus* (Borbás) Baen. 22.5, *Vincetoxicum hirundinaria* Medik. 21.3, *Crataegus laciniata* Ucria 20.6, *Colutea arborescens* L. 20.6, *Malus sylvestris* (L.) Mill. 20.4, *Stachys scardica* (Griseb.) Hayek 19.3, *Quercus cerris* 18.6, *Silene nemoralis* Waldst. & Kit. 18.4, *Linaria vulgaris* Mill. 18.4, *Crataegus pentagyna* Willd. 18.4, *Anemone apennina* L. 17.7, *Digitalis lanata* Ehrh. 17.6, *Ulmus procera* Salisb. 17.3, *Prunus avium* (L.) L. 17.1, *Myosotis stricta* Roem. & Schult. 17.1, *Mercurialis perennis* L. 17.0, *Viola odorata* L. 16.9, *Pyrus communis* L. 16.1, *Primula acaulis* (L.) L. 16.1, *Teucrium montanum* L. 15.9, *Silene nutans* L. 15.9, *Sedum acre* L. 15.9, *Polygonatum odoratum* (Mill.) Druce 15.9, *Laser trilobum* (L.) Borkh. 15.9, *Hypericum barbatum* Jacq. 15.9, *Crocus*

veluchensis Herb. 15.9, *Cirsium vulgare* (Savi) Ten. 15.9, *Centaurea micrantha* Hoffmanns. & Link 15.9, *Euphorbia myrsinites* L. 15.3, *Origanum vulgare* L. 15.2, *Campanula persicifolia* L. 15.2, *Scutellaria orientalis* L. 15.1

Constant species: *Quercus trojana* (Dm, tree) 100, *Quercus pubescens* (tree) 86, *Fraxinus ornus* (tree) 79, *Quercus cerris* (tree) 71, *Acer monspessulanum* L. (tree) 64, *Sanguisorba minor* 64, *Colutea arborescens* (shrub) 64, *Fragaria vesca* 54, *Teucrium capitatum* 57, *Cornus mas* L. (shrub) 50, *Carpinus orientalis* (tree) 50, *Helleborus odorus* Willd. 50, *Euphorbia myrsinites* L. 50, *Pistacia terebinthus* L. (shrub) 50, *Stachys scardica* 50, *Ruta graveolens* 50, *Acanthus hungaricus* 50, *Cyclamen hederifolium* 50, *Vincetoxicum hirundinaria* 50

Dominant species: *Quercus trojana* (C) 93

The tree layer is dominated by *Quercus trojana*, accompanied by several more mesophilous trees (*Quercus pubescens, Quercus cerris, Fraxinus ornus, Carpinus orientalis,* and *Ostrya carpinifolia*). Characteristic species of other *Quercus trojana* vegetation units (e.g. *Ruscus aculeatus*, *Brachypodium* spp., and *Achnatherum bromoides*) are absent in the herb layer. Species of the *Quercetea ilicis* (e.g. *Asparagus acutifolius*) are also missing, indicating a more mesic character of the community due to high altitude. This subassociation is found only in Kosovo and has a continental character compared to other subassociations, mainly because of higher representation of continental species (Figure 4).

Cluster 4: Quercetum trojanae seslerietosum autumnalis

Diagnostic species: *Sesleria autumnalis* (C, Dm) 48.7, *Brachypodium rupestre* (Host) Roem. & Schult. (Dm) 29.8, *Bunium alpinum* Waldst. & Kit. 26.3, *Crocus dalmaticus* Vis. 24.6, *Paliurus spina-christi* Mill. 23.8, *Cyclamen hederifolium* Aiton (C) 23.1, *Carex halleriana* Asso 22.4, *Festuca stricta* subsp. *sulcata* (Hack.) Pils 22.3, *Briza maxima* L. 21.8, *Galanthus reginae-olgae* Orph. 20.5, *Fraxinus ornus* 19.6, *Hieracium heterogynum* (Froel.) Gutermann 19.0, *Cephalaria leucantha* (L.) Roem. & Schult. 19.0, *Galium corrudifolium* Vill. 18.9, *Achnatherum bromoides* (L.) P.Beauv. 18.9, *Hypericum perforatum* L. 18.4, *Vincetoxicum huteri* Vis. & Asch. 18.2, *Colchicum autumnale* L. 17.9, *Quercus pubescens* 17.8, *Geranium columbinum* L. 17.5, *Dioscorea communis* (L.) Caddick & Wilkin 17.2, *Vicia sativa* L. 16.9, *Seseli montanum* subsp. *tommasinii* (Rchb. f.) Arcang. *1* 6.3, *Medicago prostrata* Jacq. 16.2, *Sonchus oleraceus* L. 16.1, *Pseudoturritis turrita* (L.) Al-Shehbaz 15.8, *Carpinus orientalis* 15.5, *Pistacia terebinthus* 15.2, *Petteria ramentacea* (Sieber) C. Presl 15.1

Constant species: *Quercus trojana* (Dm) (tree) 100, *Fraxinus ornus* (shrub) 86, *Cyclamen hederifolium* (Dg) 86**,** *Sesleria autumnalis* (Dg, Dm) 86, *Carex halleriana* 78, *Asparagus acutifolius* 78, *Quercus trojana* (shrub) 73, *Quercus trojana* (herb) 73, *Dioscorea communis* 68, *Quercus pubescens* (herb) 65, *Carpinus orientalis* (shrub) 62, *Ruscus aculeatus* 62, *Achnatherum bromoides* 59, *Bunium alpinum* 54, *Brachypodium rupestre* 54

Dominant species: *Quercus trojana* (C) 95, *Sesleria autumnalis* (Dg, C) 27, *Ruscus aculeatus* 11, *Achnatherum bromoides* (Dg) 11

The tree layer is dominated by *Quercus trojana*, which is sometimes the only tree species. The shrub layer is well developed, with *Juniperus oxycedrus*, *Paliurus spina-christi,* and *Hippocrepis emerus* (L.) Lassen exhibiting the highest frequency. Stands are open and, therefore, characterized by many grasses (e.g. *Sesleria autumnalis* and *Brachypodium rupestre*) and species of the *Festuco-Brometea* class. Relevés of cluster 4 were sampled in the northwestern part of the association's distribution range in the Balkan Peninsula (Bosnia and Herzegovina and Montenegro, Figure 4) at low altitudes. However, under Mediterranean climate, they can be found up to 900 m asl.

Cluster 5: Quercetum trojanae chrysopogonetosum grylli

Diagnostic species: *Thymus boissieri* Halácsy 24.7, *Rostraria cristata* (L.) Tzvelev 24.7, *Astragalus sericophyllus* Griseb. 22.8, *Chrysopogon gryllus* (L.) Trin. 21.7, *Holosteum umbellatum* L. 21.6, *Scabiosa webbiana* D. Don 21.5, *Anthyllis vulneraria* L. 21.0, *Crupina crupinastrum* (Moris) Vis. 20.3, *Asparagus acutifolius* 20.1, *Scutellaria rupestris* Boiss. & Heldr. 19.5, *Asperula purpurea* (L.) Ehrend. 19.5, *Salvia officinalis* L. 18.4, *Micromeria cremnophila* Boiss. & Heldr. 18.4, *Melica ciliata* L. 18.4, *Centaurea grisebachii* (Nyman) Heldr. 18.1, *Stachys iva* Griseb. 17.9, *Clinopodium suaveolens* (Sm.) Kuntze 17.5, *Onosma heterophylla* Griseb. 17.4, *Thesium humile* Vahl 17.2, *Matthiola fruticulosa* subsp. *valesiaca* (Gaudin) P.W.Ball 17.2, *Linum nodiflorum* L. 17.2, *Allium paniculatum* L. 17.2, *Seseli pallasii* Besser 15.9, *Inula aschersoniana* Janka 15.8, *and Alyssum montanum* L. 15.4

Constant species: *Quercus trojana* (Dm) 100, *Juniperus oxycedrus* (shrub) 89, *Teucrium capitatum* 75, *Achnatherum bromoides* 75, *Asparagus acutifolius* (shrub) 71, *Salvia officinalis* 64, *Rostraria cristata* 64, *Asperula purpurea* 57, *Hippocrepis emerus* 54, *Chrysopogon gryllus* 54, *Anthyllis vulneraria* 50, *Ruscus aculeatus* 50, and *Carpinus orientalis* (shrub) 50

Dominant species: *Quercus trojana* (C) 46

Quercus trojana is the only dominant tree species. The shrub layer is well developed (cover of 30%–80%), with a high frequency of taxa of the tree layer (i.e., *Quercus trojana*, *Fraxinus ornus,* and *Carpinus orientalis*), as well as shrubs such as *Juniperus oxycedrus*, *Phillyrea latifolia* L., *Cistus creticus* L., *Salvia officinalis,* and *Asparagus acutifolius*. In the herb layer, *Chrysopogon gryllus* physiognomically stands out, while species of *Rhamno-Prunetea* and *Carpino-Fagetea* are absent. All relevés of cluster 5 are from the area around Lake Vegoritida in Greece (Figure 4).

Cluster 6: Euphorbio apii-Quercetum trojanae

Diagnostic species: *Rubia peregrina* L. (C) 42.8, *Allium subhirsutum* L. 39.8, *Pistacia lentiscus* L. 34.3, *Poa trivialis* subsp. *sylvicola* (Guss.) H.Lindb. 30.9, *Euphorbia apios* L. *30.7*, *Rosa sempervirens* L. 28.6, *Aegonychon purpurocaeruleum* (L.) Holub 24.5, *Prunus spinosa* L. 23.4, *Euonymus europaeus* L. 22.6, *Geranium sanguineum* L. 22.2, *Carex distachya* Desf. 21.1, *Stachys officinalis* (L.) Trevis. 20.4, *Ruscus aculeatus* (C) 20.4, *Asparagus acutifolius* 20.3, *Klasea flavescens* subsp. *cichoracea* (L.) Greuter & Wagenitz 20.2, *Quercus ilex* L. (tree) 20.0, *Asphodelus ramosus* L. 19.9, *Crataegus monogyna* Jacq. 19.0, *Calicotome villosa* (Poir.) Link 18.1, *Viola alba* Besser 18.0, *Stachys cretica* subsp. *salviifolia* L. 17.6, *Cyclamen repandum* Sibth. & Sm. 17.6, *Crepis leontodontoides* All. 17.4, *Quercus pubescens* (C) 16.8, *Potentilla detommasii* Ten. 16.8, *Festuca rubra* L. 16.8, *Ranunculus bulbosus* L. 16.5, *Paeonia mascula* (L.) Mill. 15.4, *Crepis vesicaria* L. 15.4, *Teucrium siculum* (Raf.) Guss. 15.2, *Silene latifolia* Poir.15.2, *Ranunculus neapolitanus* Ten. 15.1, *Quercus ilex* (shrub) 15.1, *Lathyrus sylvestris* L. 15.1

Constant species: *Quercus trojana* (Dm, tree) 100, *Asparagus aculeatus* (Dg) 88, *Crataegus monogyna* (shrub) 85, *Allium subhirsutum* 85, *Rubia peregrina* (Dg) 85, *Ruscus aculeatus* (Dg) 83, *Quercus pubescens* (Dg, tree) 75, *Viola alba* 60, *Silene italica* 58, *Aegonychon purpurocaeruleum* 58, *Geranium sanguineum* 55, *Rosa sempervirens* 53, *Phillyrea latifolia* (shrub) 53, and *Euphorbia apios* 53

Dominant species: *Quercus trojana* (C) 100, *Carpinus orientalis* 22, and *Ruscus aculeatus* (Dg, C) 12

The tree layer is dominated by *Quercus trojana*, while *Quercus pubescens* is a codominant species. The shrub layer is well developed with *Crataegus monogyna*, *Pistacia lentiscus,* and *Prunus spinosa*. The herb layer is well developed with subdominant species *Asparagus acutifolius*, *Rubia peregrina* and *Ruscus aculeatus*. Species of *Carpino-Fagetea* are rare, while species of *Quercetea ilicis* such as *Rubia peregrina*, *Quercus ilex*, *Clematis flammula* L., and *Osyris alba* L. are frequent. Stands of cluster 6 are characteristic of the limestone plains in the Apulia region on the Italian Peninsula known as "Murge" (Figure 4).

NMDS ordination (Figure 2) of Balkan and Italian relevés shows a great similarity between the *Quercetum trojanae* subassociations (clusters 1, 2, 3, 4, and 5), while relevés from Italy (6) are clearly discriminated from *Quercetum trojanae* subassociations. The first axis correlates with all the projected indicator values and altitude. On the left side, there are *Quercus trojana* communities that thrive in a more Submediterranean climate, while on the right side, there are communities in a more continental climate with low winter temperatures and higher precipitation in winter.

Classification and NMDS ordination of *Quercus trojana* forests from the whole distribution range shows a division of forests from Türkiye (clusters 7–10) from the Balkan and Italian forests along the first axis. Turkish forests also show a higher floristic heterogeneity, while the Balkan and Italian communities are more homogeneous (Appendix and Figures 3, 5, and 6).

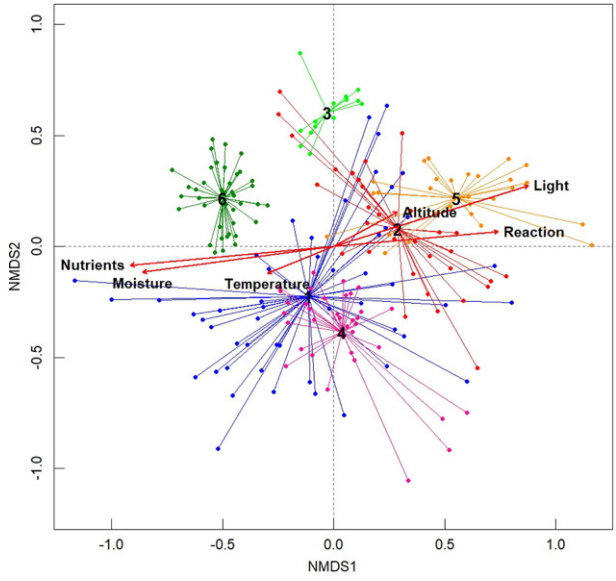

Figure 2. Spider diagram of NMDS ordination of relevés with *Quercus trojana* from the Balkan and Italian peninsulas. Numbers represent cluster centroids, lines link the relevés to cluster centroids, and red arrows represent Ellenberg-type indicator values and altitude. 1 *Quercetum trojanae typicum* (MK, AL, GR, and ME), 2 *Quercetum trojanae festucetosum callieri* (GR), 3 *Quercetum trojanae rutetosum graveolentis* (KS), 4 *Quercetum trojanae seslerietosum autumnalis* (ME, BA), 5 *Quercetum trojanae chrysopogonetosum grylli* (GR), 6 *Euphorbio apii-Quercetum trojanae* (IT).

Syntaxonomical scheme of Quercus trojana *forests from the Balkan and Italian peninsulas and Türkiye*

Quercetea pubescentis Doing-Kraft ex Scamoni et Passarge 1959
Quercetalia pubescenti-petraeae Klika 1933
Carpinion orientalis Horvat 1958
Quercetum trojanae Horvat 1959
Quercetum trojanae typicum
Neotypus hoc loco: Matevski et al. (2011), Table 14, relevé 4
Quercetum trojanae chrysopogonetosum grylli subass. nova
Holotypus: Pirini (2011), relevé 35
Quercetum trojanae festucetosum callieri subass. nova
Holotypus: Gerasimidis (2003), Table 1, relevé 27
Quercetum trojanae seslerietosum autumnalis subass. nova
Holotypus: see Annotation 1
Quercetum trojanae rutetosum graveolentis subass. nova (syn. *Quercetum trojanae dukagjini* Rexhepi 1982 nom. inval. (Art. 3h, Art. 5a), *Quercetum trojanae metohiense* Glišić 1965 nom. nud.)
Lectotypus hoc loco: Rexhepi (1982), Table 1, relevé 5.
Teucrio siculi-Quercetum trojanae Bianco et al. 1998
(syn. *Euphorbio apii-Quercetum trojanae* Biondi et al. 2004)
Quercion crispatae Akman et al. ex Quézel et al. 1992
Quercetum macrolepido-trojanae Akman, Barbero, et Quézel 1979
Quercetum trojano-pubescentis Hamzaoğlu, Duran et Menemen 2002
Cotoneastro nummularii-Quercetum pubescentis Kenar et al. 2020 *quercetosum trojanae* Kenar et al. 2020
Querco-Cedretalia libani Barbero et al. 1974
Querco vulcanicae-Ostryion carpinifoliae Kavgacı et al. 2021
Asyneumo michauxioidis-Quercetum trojanae Ocakverdi et Cetik ex Kavgacı et al. 2021

Annotation 1

Typus relevé (holotype) of the *Quercetum trojanae seslerietosum autumnalis* Šilc et al. subass. nov.

Montenegro, Velja Gorana, 5 May 2022, 100 m^2, 222 m asl, NW, 20°, cover tree layer: 70%, shrub layer: 60%, herb layer: 50%, tree height 16 m, 41.9866, 19.2497, authors DS, MSV, UŠ.

E3: *Quercus trojana* 4

E2: *Carpinus orientalis* 3, *Fraxinus ornus* 1, *Quercus pubescens* 1, *Rubus ulmifolius* Schott +, *Phlomis fruticosa* L. +, *Quercus trojana* +, *Juniperus oxycedrus* +, *Paliurus spina-christi* +

E1: *Sesleria autumnalis* 3, *Brachypodium rupestre* 1, *Briza maxima* 1, *Phlomis fruticosa* 1, *Carex halleriana* 1, *Cyclamen hederifolium* 1, *Pilosella bauhini* (Schult.) Arv.-Touv. +, *Micromeria juliana* (L.) Benth. ex Rchb. +, *Asperula aristata* L. f. +, *Pistacia terebinthus* +, *Carpinus orientalis* +, *Acer monspessulanum* +, *Juniperus oxycedrus* +, *Urospermum picroides* (L.) F.W.Schmidt +, *Lens ervoides* (Brign.) Grande +, *Asplenium ceterach* L. +,

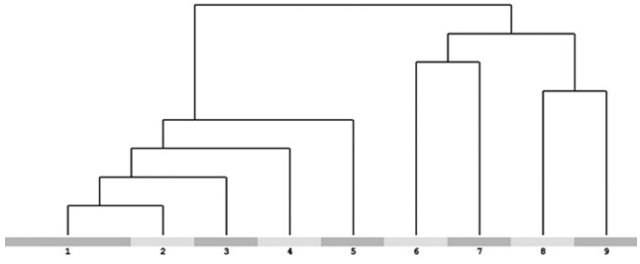

Figure 3. Classification of *Quercus trojana* forests in southeastern Europe and Türkiye (relative Sørensen and Flexible Beta (β = −0.25)). 1 *Quercetum trojanae typicum* (MK, AL, GR, and ME) & *Quercetum trojanae festucetosum callieri* (GR), 2 *Quercetum trojanae seslerietosum autumnalis* (ME, BA), 3 *Quercetum trojanae rutetosum graveolentis* (KS), 4 *Quercetum trojanae chrysopogonetosum grylli* (GR), 5 *Euphorbio apii-Quercetum trojanae* (IT), 6 *Cotoneastro nummularii-Quercetum pubescentis quercetosum trojanae* (TR), 7 *Quercetum trojano-pubescentis* (TR), 8 *Asyneumo-Quercetum trojanae* (TR), and 9 *Quercetum macrolepido-trojanae* (TR).

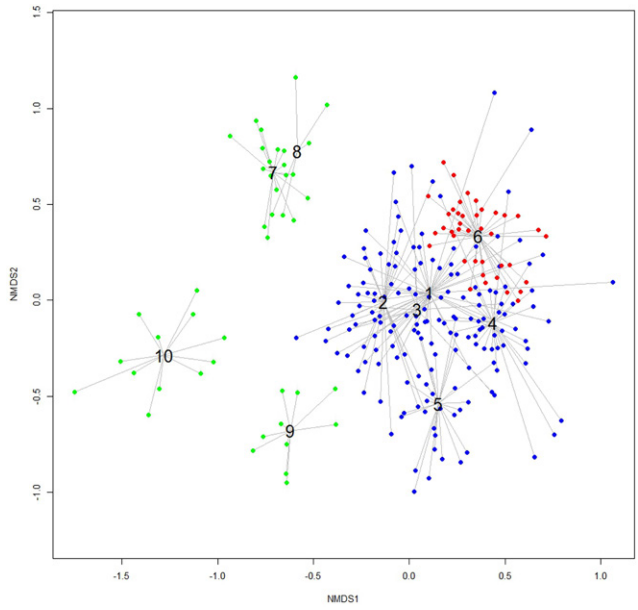

Figure 4. NMDS ordination of relevés with *Quercus trojana* from southeastern Europe and Türkiye: 1 *Quercetum trojanae typicum* (MK, AL, GR, ME), 2 *Quercetum trojanae festucetosum callieri* (GR), 3 *Quercetum trojanae rutetosum graveolentis* (KS), 4 *Quercetum trojanae seslerietosum autumnalis* (ME, BA), 5 *Quercetum trojanae chrysopogonetosum grylli* (GR), 6 *Euphorbio apii-Quercetum trojanae* (IT), 7 *Cotoneastro nummularii-Quercetum pubescentis quercetosum trojanae* (TR), 8 *Quercetum trojano-pubescentis* (TR), 9 *Asyneumo-Quercetum trojanae* (TR), and 10 *Quercetum macrolepido-trojanae* (TR). Red dots represent relevés from the Italian Peninsula, blue from the Balkan Peninsula and green from Anatolia.

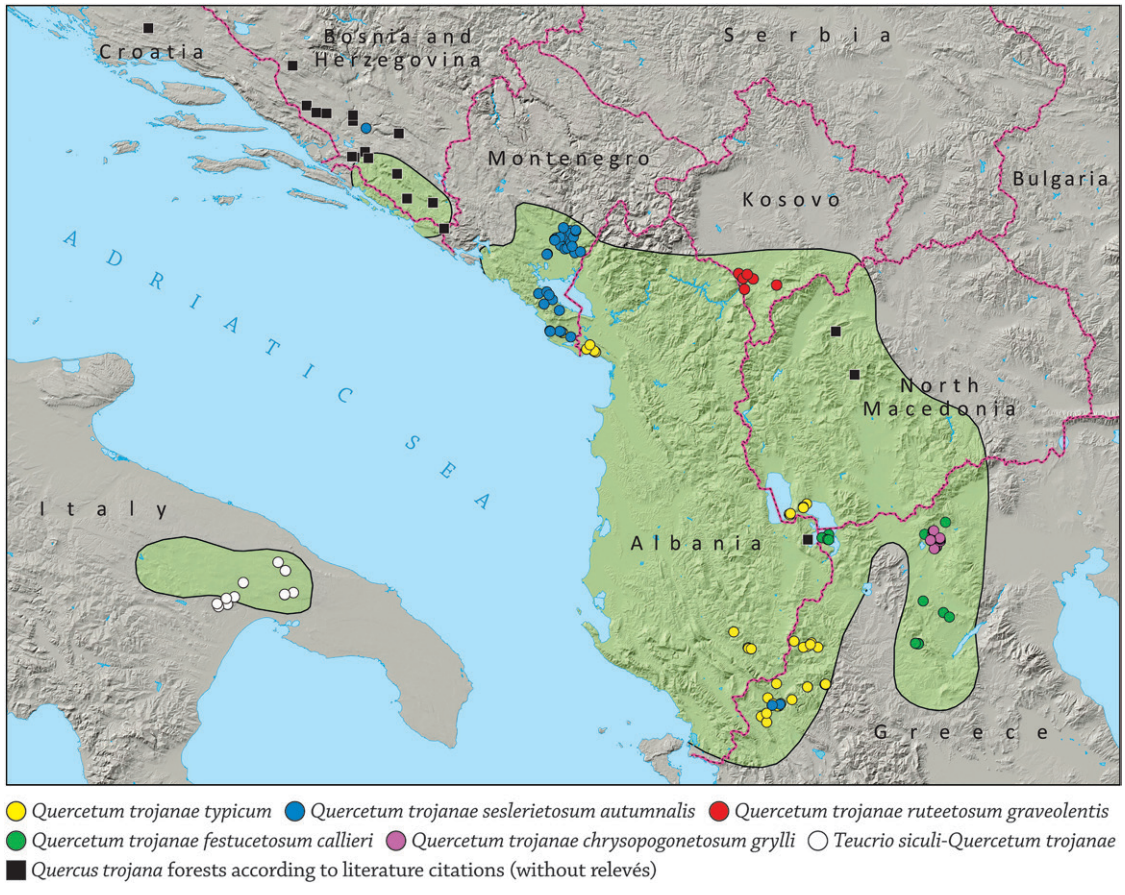

Figure 5. *Quercus trojana* forest relevés on the Balkan and Italian peninsulas. Light green area—distribution range of *Quercus trojana* according to Caudullo et al. (2017).

Figure 6. *Quercus trojana* forest relevés in Türkiye. Light yellow area—distribution range of *Quercus trojana* according to Caudullo et al. (2017).

Rhagadiolus stellatus (L.) Gaertn. +, *Galium aparine* L. +, *Geranium purpureum* Vill. +, *Vicia hirsuta* (L.) Gray +, *Hedera helix* L. +, *Quercus pubescens* +, *Dioscorea communis* +, *Viola alba* +, *Teucrium capitatum* +, *Achnatherum bromoides* +, *Hieracium heterogynum* +, *Asplenium trichomanes* L. +, *Leontodon tuberosus* L. +, *Ptilostemon strictus* (Ten.) Greuter +, *Vicia sativa* L. +, *Ruscus aculeatus* +, *Aethionema saxatile* (L.) W.T.Aiton +, *Iris tuberosa* L. +, *Salvia officinalis* +

Discussion

Characteristic and differential species

Quercus trojana, Acer obtusatum L., and *Quercus pubescens* were reported in the literature as characteristic species of the association *Quercetum trojanae* (Horvat 1959; Horvat et al. 1974). Gerasimidis (2003) mentioned solely *Quercus trojana* as a characteristic species, while Matevski et al. (2011) also listed the following diagnostic species in the herb layer: *Acanthus hungaricus, Anthoxanthum odoratum* L., *Bellis perennis* L., *Crepis vesicaria, Ononis pusilla* L., and *Medicago lupulina* L. Based on our analysis, only *Carpinus orientalis, Sesleria autumnalis, Teucrium capitatum, Cornus mas, Hippocrepis emerus,* and *Brachypodium pinnatum* can be considered as the diagnostic species of the association within the dataset of *Quercus trojana* forests, but for obtaining a better characteristic species group, it will be necessary to make a comparative analysis of all the communities within the *Quercetea pubescentis.*

We could not confirm subassociations, variants and facies described by Gerasimidis (2003), although he suggested that these syntaxa differ in terms of geography, ecology and floristic composition. The relevés of both subassociations described by Gerasimidis (2003) were grouped in one cluster in our analysis, well defined mostly by *Festuca callieri*, a species of the southern and eastern Balkan Peninsula. Other differential species, according to Gerasimidis (2003), such as *Juniperus oxycedrus* and *Cornus mas*, are also present in other clusters. Gerasimidis (2003) also mentioned the absence of *Quercus coccifera* in these forests, but we found it in stands of the typical subassociation in Greece (Mastrogianni et al. 2023). Co-occurrence of *Quercus trojana* and *Quercus coccifera* is possible in case of degradation of typical stands or in places outside the main distribution range of *Q. trojana* (Gerasimidis 2003).

According to our analysis, subassociations of *Quercetum trojanae* show considerable differences in

the composition of the herb layer, which reflects their ecology (e.g. subass. *chrysopogonetosum grylli* is most heliophilous and with narrower altitudinal range; Figure 2), but also phytogeographical differences (e.g. subass. *seslerietosum autumnalis* is distributed within the Dinaric Alps, while *festucetosum callieri* and *chrysopogonetosum grylli* within the Pindus Mountains; Figure 4).

Italian associations are distinguished by *Quercion ilicis* species: *Allium subhirsutum, Pistacia lentiscus,* and *Rubia peregrina,* which was the main argument for their original classification into the *Quercetea ilicis*. Although two associations were described before, all the Italian relevés stayed together in our analyses, and we could not distinguish them. It seems that *Euphorbio-Quercetum trojanae* is a typical aspect of the Macedonian oak forests in Apulia, while *Teucrio-Quercetum trojanae* is more an ecotone between *Euphorbio-Quercetum trojanae* and *Quercion ilicis* than a distinct association. Di Pietro and Misano (2009) suggested that differences between the two Apulian syntaxa are edaphic and not geographical, as proposed previously by Biondi et al. (2004).

Syntaxonomy

Syntaxonomy of thermophilous shrub and forest communities in southeastern Europe is not always straightforward because the same woody species are dominant in structurally different vegetation types. For instance, *Quercus trojana* is considered a typical dominant species of pseudomacchia (Adamović 1909; Bergmeier et al. 2004), šibljak (Bergmeier et al. 2010), and forest (Horvat et al. 1974). Its stands can be low forests in the coastal lowlands, but also well-developed forest stands inland and at higher altitudes. Physiognomy and floristic composition are also significantly influenced by human impact. Stands are frequently used as coppice or wood pastures (grazing by goats and sheep). Fires are frequent, soils are shallow and affected by erosion. In the Balkan Peninsula, stands can be very diverse, including, on the one hand, very open, savanna-like woodlands, with scattered trees that reach up to 8 m. In this case, grassland species are more abundant in the understory. On the other hand, there are forests with closed canopy and trees up to 16 m, which are usually found on deeper soils and at higher altitudes. In Italy, trees are also up to 8 m high, but stands are closed.

Concerning ecological and structural characteristics, *Quercus trojana* forests are very similar to two other vegetation types in the Mediterranean, namely Mediterranean *Pinus* and *Quercus suber* forests (Agrillo and Attorre 2018; Bonari et al. 2021). In all of these three vegetation types, the floristic composition of the understory is very different in open and closed stands, and the reasons are very similar, including disturbance within stands, human impact, livestock grazing, fires and cork production in the case of *Q. suber* stands.

Macedonian oak forests were more widely distributed in the past, but overgrazing, cutting, frequent fires and conversion into agricultural land were the reasons for a decrease in the area occupied by these forests (Lakušić et al. 1982; Gerasimidis 2003; Misano and Di Pietro 2007). Therefore, a dynamic mosaic of *Quercus trojana* stands is developed in the landscape. All these characteristics and impacts make syntaxonomical classification difficult.

Syntaxonomical classification of the Macedonian oak stands in the Balkan Peninsula to higher vegetation units has not always been unequivocal although they were mostly classified into the *Carpinion orientalis* alliance. The separate alliance *Quercion trojanae* (Lakušić et al. 1982; Operta et al. 2013) or the suballiance *Quercenion trojanae* (Stefanović and Fabijanić 1969; Horvat et al. 1974; Misano and Di Pietro 2007) were mentioned, but no syntaxonomical analysis has been made. In Italy, as already mentioned, they were first considered as the *Quercetea ilicis* vegetation, since they are found mainly in the lowlands in the belt of evergreen forests, in a narrower altitudinal range (300–450 m asl) than in the Balkan Peninsula (90–1400 m asl). Later, Di Pietro and Misano (2009) concluded that they should be included in the *Carpinion orientalis* alliance since *Quercus trojana* is deciduous while characteristic species of macchia are only present in disturbed stands.

Horvat (1959) further proposed the division of the *Carpinion orientalis* alliance into two geographically defined suballiances (*dinaricum* and *aegaeicum*). Differential species of *Carpinion orientalis dinaricum* are well represented in *Q. trojana* forests (e.g. *Sesleria autumnalis* and *Petteria ramentacea*) and are characteristic of some subassociations. In contrast, species of the *aegaeicum* suballiance (e.g. *Syringa vulgaris* and *Helleborus cyclophyllus*) are absent in our dataset.

In Italy, the alliance *Carpinion orientalis* is further subdivided into four suballiances, and *Quercus trojana* forests are classified within *Lauro nobilis-Quercenion pubescentis* Ubaldi 1995, where they represent the most xerothermic part of this suballiance (Blasi et al. 2004). The differential species of the suballiance are well represented in Italian stands, while they are rare on the Balkan Peninsula. *Quercetea ilicis* species that are characteristic of *Q. trojana* stands in Italy are also lacking in the Balkan stands. In our opinion, such a classification is probably not suitable for the Balkan

Peninsula, which is the centre of the distribution of *Quercus trojana*. Further analysis that will include a wider dataset with all communities of *Carpinion orientalis* is needed to test the validity of this suballiance.

Our analysis shows a clear distinction between southeastern European *Quercus trojana* forests and those in Türkiye (Figures 3 and 4). It is in accordance with recent analyses from Türkiye (Kavgacı et al. 2021; 2023). Turkish associations are syntaxonomically and geographically differentiated into the Black Sea group and the Mediterranean group. Forests from the Euxinian region of Türkiye near the Black Sea are classified into the same order as those in southeastern Europe but in a different alliance, *Quercion crispatae*, which is distinguished by the endemic subspecies *Quercus pubescens* subsp. *crispata* (Kavgacı et al. 2023). In contrast, Macedonian oak forests from the Mediterranean region of Türkiye (*Querco vulcanicae-Ostryion carpinifoliae*) are classified even in a different order, *Querco-Cedretalia libani* (Kavgacı et al. 2021). Besides dominance and constancy of *Ostrya carpinifolia* in the tree layer, this supra-mediterranean forest is characterized by the presence of endemic species such as *Asyneuma michauxioides*, *Ferulago aucheri,* and *Galium peplidifolium*.

Conservation

Quercus trojana is not a protected species, but its forests are listed on Annex I of the EU Habitat Directive as 9250 *Quercus trojana* woods with two subtypes: (1) Helleno-Balkanic Trojan oak woods and (2) Apulian Trojan oak woods (European Commission 2013). The conservation status and habitat condition of *Quercus trojana* forests differs between countries. In Greece, it is considered as favourable (FV), in Italy as unfavourable-inadequate (U1), while in Croatia, these stands are not studied in detail and are not included in the Natura 2000 Habitat list (European Environment Agency 2020). Other non-EU countries considered in our study do not do not fully implement Habitat Directive, yet. In Montenegro, these forests are mentioned among habitats of European interest (Milanović et al. 2021) and a major part of the stands are under zoo-anthropogenic pressure, which positively influences species richness but significantly degrades their structure. In Bosnia and Herzegovina, this habitat type is found as low (coppiced) and degraded forests (Milanović et al. 2015).

Misano and Di Pietro (2007) listed several impacts on *Quercus trojana* forests: incorrect silviculture (short rotations and intensive cutting), phytosanitary problems with forest pests and oak dieback (Sicoli et al. 1998), fragmentation, land abandonment, overgrazing, fires, and illegal cutting. These are the main reasons for the decreasing of the already diminished historical area of *Quercus trojana* forests.

Quercus trojana forests were also frequently used as wood-pasture habitats, and maintenance or re-establishment of forest grazing could be used to maintain or even restore them (Bergmeier et al. 2010). If managed properly, their species diversity is high. The problem is that such agro-pastoral ecosystems are not consistently included in the EU Habitat Directive and their management is inconsistently defined. Some stands should be managed as natural forest and others as wood-pasture.

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Appendix

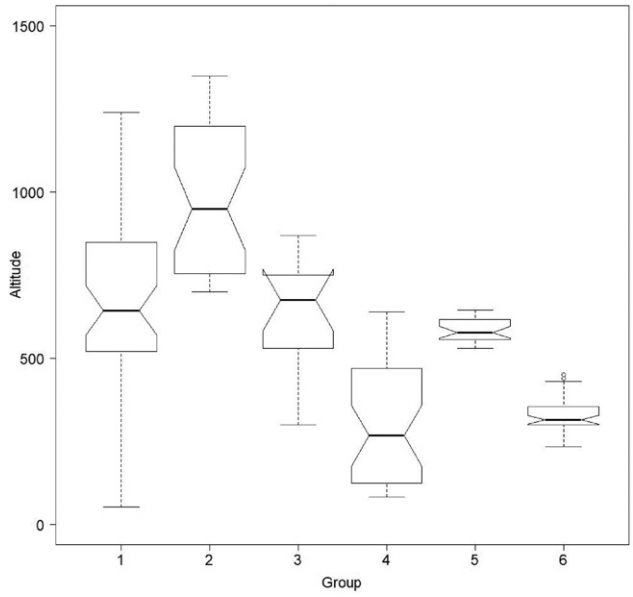

Figure A1. Altitudinal ranges of clusters. *1. Quercetum trojanae typicum* (MK, AL, GR, ME), *2 Quercetum trojanae festucetosum callieri* (GR), *3 Quercetum trojanae rutetosum graveolentis* (KS), *4 Quercetum trojanae seslerietosum autumnalis* (ME, BH), *5 Quercetum trojanae chysopogonetosum grylli* (GR), *6 Teucrio siculi-Quercetum trojanae* (IT).

Table A1. Survey of described *Quercus trojana* syntaxa and their original classification into the alliance.

Plant community	Original classification	Country	References
Quercetum macedonicae Em ex Horvat 1959	*Ostryo-Carpinion orientalis* or *Carpinion orientalis*	North Macedonia, Bosnia and Herzegovina	Horvat 1959, Redžić 2011
Quercetum trojanae montenegrinum Blečić et Lakušić 1975 nom. nud.	*Carpinion orientalis* Blečić et Lakušić 1966	Montenegro, Bosnia and Herzegovina	Blečić and Lakušić 1967, Redžić 2011
Quercetum trojanae hercegovinicum Stefanović 1962 nom. nud.	*Ostryo-Carpinion orientalis*	Bosnia and Herzegovina	Stefanović 1986
Paliuro aculeati-Quercetum trojanae ass. prov. 2018	*Quercion trojanae* Rexhepi 1938 ???	Bosnia and Herzegovina	Operta et al. 2013
Quercetum trojanae metochiense Glišić 1965	*Ostryo-Carpinion orientalis*	Kosovo	Kojić et al. 1998, Amidžić et al. 2012
Pistacio-Quercetum trojanae Redžić 2011 nom. nud.	*Ostryo-Carpinion orientalis*	Bosnia and Herzegovina	Redžić 2011
Junipero-Quercetum trojanae Bulić 1989 prov.	*Ostryo-Carpinion orientalis*	Montenegro	Bulić 1994
Quercetum trojanae dukagjinii Rexhepi 1982	*Ostryo-Carpinion orientalis*	Kosovo	Rexhepi 1982
Quercetum trojanae juniperetosum oxycedri Gerasimidis 2003	*Ostryo-Carpinion orientalis*	Greece	Gerasimidis 2003
Quercetum trojanae cornetosum maris Gerasimidis 2003	*Ostryo-Carpinion orientalis*	Greece	Gerasimidis 2003
Quercus trojana-Carpinus orientalis comm.	*Fraxino orni-Ostryion*	Greece	Pirini 2011
Quercus trojana-Juniperus oxycedrus comm.	*Orno-Cotinetalia*	Greece	Pirini 2011
Quercetum trojanae	*Ostryo-Carpinion orientalis*	Greece	Chochliouros 2005
Quercus trojana-Juniperus oxycedrus comm.	vegetation types resemble *Ostryo-Carpinion orientalis*	Greece	Tsaliki et al. 2005
Euphorbio apii-Quercetum trojanae Bianco et al. 1998	*Quercion ilicis*	Italy	Bianco et al. 1998
Teucrio siculi-Quercetum trojanae Biondi et al. 2004	*Ostryo-Carpinion orientalis*	Italy	Biondi et al. 2004
Quercetum ilicis quercetosum trojanae	*Quercion ilicis*	Italy	Lorenzoni and Chiesura-Lorenzoni 1987
Quercetum trojanae pistacietosum lentisci	*Quercion ilicis*	Italy	Lorenzoni and Chiesura-Lorenzoni 1987
Quercetum trojanae quercetosum pubescentis	*Quercion ilicis*	Italy	Lorenzoni and Chiesura-Lorenzoni 1987
Quercetum trojanae quercetosum cerris	*Quercion ilicis*	Italy	Lorenzoni and Chiesura-Lorenzoni 1987
Quercetum trojanae quercetosum cocciferae	*Quercion ilicis*	Italy	Lorenzoni and Chiesura-Lorenzoni 1987
Quercetum macrolepido-trojanae Akman, Barbéro et Quézel 1979	*Quercion anatolicae* Akman, Barbéro et Quézel 1979	Türkiye	Akman et al. 1979
Quercetum trojano-pubescentis Hamzaoglu, Duran et Menemen 2002	*Quercion crispatae* Akman et al. ex Quézel et al. 1992 (syn. *Quercion anatolicae* Akman et al. 1979	Türkiye	Hamzaoglu et al. 2002
Cotoneastro nummularii-Quercetum pubescentis Kenar et al. 2020 *quercetosum trojanae* Kenar et al. 2020	*Quercion crispatae* Akman et al. ex Quézel et al. 1992 (syn. *Quercion anatolicae* Akman et al. 1979)	Türkiye	Kenar et al. 2020
Asyneumo-Quercetum trojanae Ocakverdi et Cetik ex Kavgacı et al. 2021	*Querco vulcanicae-Ostryion carpinifoliae* Kavgacı et al. 2021 (*Ostryo carpinifoliae-Quercion pseudocerridis)*	Türkiye	Ocakverdi and Cetik 1987