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Forest Vegetation of Hardwood Tree Species along the Mirna River in Istria (Croatia)

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ABSTRACT

Background and Purpose: The paper presents the forest vegetation of periodically flooded and wet forests of hardwood tree species along the Mirna River (Istria, Croatia). The main objective was to study the older and less influential stands, and to compare them among themselves and with related syntaxa of the Mediterranean and continental area.

Materials and Methods: The research was conducted on the basis of 33 new phytocoenological relevés and 12 from previous studies, according to the principles of the standard Central European Phytocoenological School.

Results and Conclusions: Based on 45 phytocoenological relevés two main vegetation types were found. In the lowest and periodically flooded habitats grow forests dominated by *Fraxinus angustifolia* and numerous hygrophilous species. In somewhat higher and drier localities, but with a high level of ground waters, grow mixed forests of *Quercus robur*, *Fraxinus angustifolia*, *Ulmus minor* and *Carpinus betulus*, with a greater presence of mesophilous species. The paper analyzes their mutual relationship, phytocoenological affiliation, as well as their position with regard to the related syntaxa of the Mediterranean and continental area. The results suggest isolation and a transitional character of the studied forests, which is a consequence of the biogeographical position in the north Mediterranean, of the ecological conditions, and to a lesser extent of anthropogenic influence.

Keywords: hardwood forests, Mirna River (Istria), floristic composition, differential species, flooded and wet habitats

INTRODUCTION

Mediterranean forests of hardwood trees are very rare nowadays, and one of the best-preserved ones is located on the Istrian Peninsula (Croatia) in the lower course of the Mirna River (better known as the Motovun Forest). The forests along the course of the Mirna River stretch over approximately 1100 ha, and the main tree species are *Quercus robur*, *Fraxinus angustifolia* and *Ulmus minor*, whereas the drier part also holds *Acer campestre* and *Carpinus betulus*. The basic ecological factor for the composition and growth of these forests is the periodically flooding and high groundwater, which reflects on the floristic composition and distribution of syntaxa. In addition, the biogeographical position is specific as it is in the north of the Mediterranean and close to the Dinaric massif, with a strong continental influence.

The first phytocoenological studies [1, 2] presented the entire complex of the Motovun Forest as an autonomous association *Querco robori-Carpinetum betuli* "*submediterraneum*" within the southeast European alliance of oak-hornbeam forests *Erythronio-Carpinion betuli*. This was subsequently, following corrections to the name of the association, also accepted by other phytocoenologists [3, 4]. Brullo and Spampinato [5] classify them in the association *Querco roboris-Carpinetum betuli* within the alliance *Alno-Quercion roboris*. Finally, Trinajstić [6] defined them descriptively as a new association *Carici pendulae-Quercetum roboris*, also within the alliance *Alno-Quercion roboris*. Vukelić [7] advocates for more intensive pyhtocoenological research because the 2009 forest inventory suggests differences in the

composition and structure of stands. According to Vukelić [7], it is not possible to cover the entire forest complex with a single syntaxa.

These different views on nomenclature and syntaxonomy have impelled us to conduct phytocoenological studies of these forest stands in 2016 and 2017. The objective was to survey older and less influential stands, and to compare them among themselves and with related syntaxa of the Mediterranean and continental area. The results of the research should help to define the forest vegetation of this important forest locality, but also of the northern part of the Mediterranean region. When it comes to these issues, the opinions of phytocoenologists are quite varied, which is also evidenced by the overviews of the forest vegetation of Europe or its specific regions [5, 8-12].

MATERIAL AND METHODS

Research Area

The Motovun Forest is situated in the western part of the Istrian Peninsula, in the valley of the Mirna River (43 km long) and its Butoniga tributary (Figure 1). It is some fifteen kilometers away from the sea coast, and only a few more kilometers away from the Dinaric massif Ćićarija (peak Orljak, 1106 m). The terrain altitude ranges between 7 and 17 m, and the forest complexes stretch along 15 km, with the average width of approximately 500 m. Nowadays, the Motovun Forest is known Europe-wide as the habitat of the white and black truffle (*Tuber magnatum* and *Tuber melanosporum*), and the habitat of the Italian agile frog (*Rana latastei*). It is a part of the Natura 2000 ecological network, and 300 ha of the old forest were protected in 1963 as a "special reserve of forest vegetation".

This area is characterized by a moderately warm and humid climate with hot summers. According to the data from the Botoniga weather station (29 m MASL, period 1986-2015) the mean annual temperature is 13.0˚C, and the mean annual precipitation is 1004 mm. For comparison, the mean annual temperature in the area of Abruzzo and Molise in the central part of the Adriatic coast in Italy is higher by up to 4˚C, and precipitation is lower by up to 400 mm [13] than in similar conditions in Istria.

Parent material of the Motovun Forest is composed of Eocene marls and sandstone washed down by torrents from the surrounding hills and deposited into the valley of the Mirna and Butoniga rivers. Periodic floods, ground waters and constant depositing of new detritus cause the creation of different hydromorphic soils. They are characterized by excessive wetting and are in the development stage of pseudogley and gley-pseudogley.

The valley of the Mirna River is surrounded by the zonal vegetation of the downy oak and oriental hornbeam (*Querco pubescenti-Carpinetum orientalis*), with a more pronounced featuring of continental beech and oak-beech forests. Thus in the forests of the Mediterranean region we find species of the Illyrian floristic geo-element such as *Primula vulgaris*, *Lonicera caprifolium*, *Knautia drymeia* subsp. *drymeia* and others species characteristic of the order *Fagetalia* and lower syntaxa.

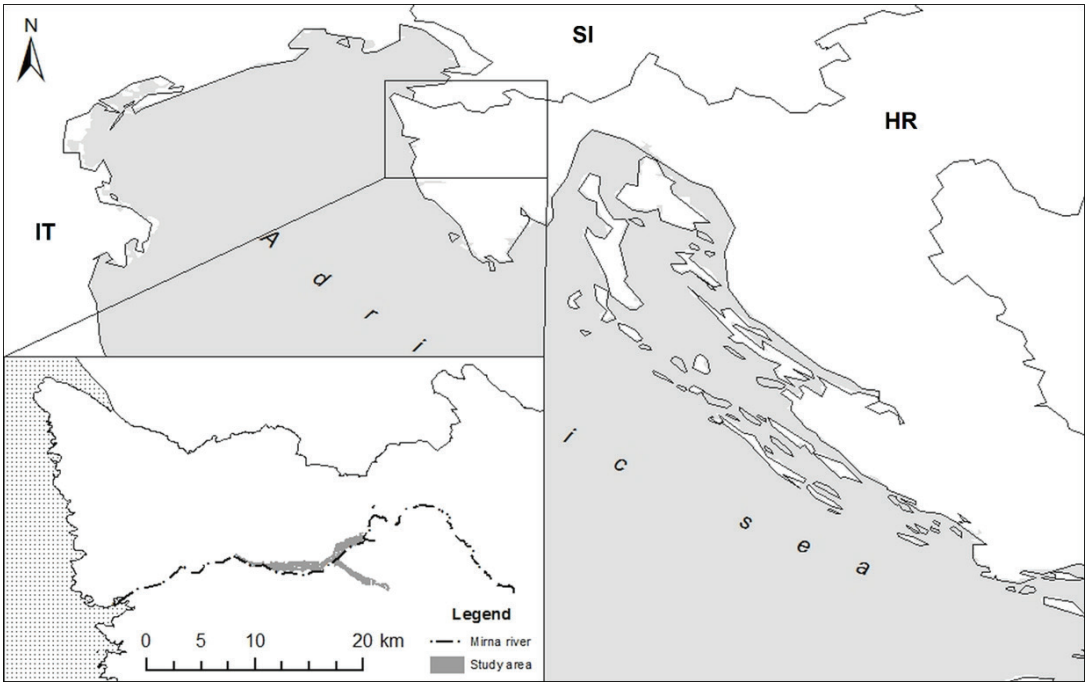

FIGURE 1. Geographical position of the study area.

Data Sampling

Studies of the forest vegetation were conducted following the principles of the standard phytocoenological school [14]. The field phytocoenological survey was conducted on 28 plots in the period from April to mid-July 2016, whereas five unpublished relevés of *Fraxinus angustifolia* stands originate from the ecological vegetation study of hydrological issues of the Motovun Forest [15]. In addition to these relevés, the statistical analysis also includes 12 relevés from previous studies [2]. Positions of new relevés in the WGS84 Coordinate Reference System are listed in the Appendix 1. The surface of the plots was 400 m², inclination 0˚, and the terrain altitude ranged between 10 and 18 m. The plant nomenclature is aligned with the *Flora Croatica Database* [16], and mosses with Atherton *et al.* [17]. Syntaxonomic nomenclature of higher units mostly follows the overviews by Biondi *et al.* [18] for *Fraxinus angustifolia* stands, and Košir *et al.* [19] for mixed hardwood stands. The local syntaxa from previous studies are presented in their original form, whereby a part of the syntaxa is described according to ICPN [20], and a part of them followed the multidimensional distribution of vegetation units [21]. The original names of the syntaxa with their authors and year of publication are listed in the supplementary materials (Appendix 2).

Data Analysis

Vegetation relevés were entered into the TURBOVEG database [22]. Cover-abundance values of the species appearing in several layers were combined in the TURBOVEG program [22], with every plant species being considered with total cover-abundance, regardless of the number of structural layers of the individual relevé in which it appears. Hierarchical clustering was performed in the R package (www.r-project.org) [23]. Bray-Curtis dissimilarity index [24], and square-root transformation of species percentage cover-abundance values were used. In the phytocoenological analysis, we separated our 33 analytical relevés into two types and compared them with the presence class of related phytocoenoses of the Mediterranean and continental part of the southwestern rim of the Pannonian Plain. The diagnostic species were determined using the JUICE 7.0 program [25], based on the analysis of fidelity measure.

The mosses were not recorded in the majority of studies, hence they were not taken into consideration in statistical analyses. Individual species and subspecies were consolidated under a species aggregate.

RESULTS AND DISCUSSION

The statistical analysis clearly classifies the 33 relevés of the Motovun Forest into two clusters or vegetation types. The first type with 23 phytocoenological relevés represents mixed stands of *Quercus robur*, *Fraxinus angustifolia*, *Ulmus minor* and *Carpinus betulus*, whereas the second type with 10 phytocoenological relevés is dominated by *Fraxinus angustifolia*. Both types were in further analyses separately compared to the floristically and chorologically related syntaxa of southern Europe and continental forests of the southwestern part of the Pannonian Plain - western part of the Pannonian sector of the Pannonian-Carpathian floristic province *sensu* [26]. All of the compared syntaxa are listed in Table 1 under their original names, authors, and numbers of relevés.

Forests Dominated by *Fraxinus angustifolia*

The dendrogram on Figure 2 compares the presence classes of 16 *Fraxinus angustifolia* syntaxa in 23 columns. Of the syntaxa of the Mediterranean area, the most significant association is *Carici remotae-Fraxinetum oxycarpae*, while continental forests are represented by the association *Leucojo-Fraxinetum angustifoliae*. The dendrogram clearly separates Mediterranean forests of narrow-leaved ash from continental forests. In the first cluster which encompasses Mediterranean forests of narrow-leaved ash, two sub-clusters are clearly singled out. The studied forests along the Mirna River are classified in the sub-cluster 1a representing the association *Carici remotae-Fraxinetum oxycarpae*. Accordingly, we attached them to this association.

The association *Carici remotae-Fraxinetum oxycarpae* was established in the territory of Abruzzo in Italy [27, 28], and later on also in other parts of the Apennine Peninsula [29-35] and southern Europe [36, 37]. This community occupies lowland localities along river banks or depressions between deposits which are under the influence of the periodically flooding or high groundwater. According to the majority of cited papers, the diagnostically most important species for this association are: *Fraxinus angustifolia*, *Carex remota*, *Ulmus minor*, *Rumex sanguineus*, *Ranunculus lanuginosus*, *Oenanthe pimpinelloides*, *Carex pendula* and *Carex divulsa*.

In the studied forests along the Mirna River, the dominant ash stands stretch over several separate localities in the wettest and lowest parts of the studied area. These are shallower depressions with occasional surface waters. The tree layer is characterized by the complete domination of the narrow-leaved ash and co-domination of the European white elm, while the common oak is individually rarely present, and the common hornbeam is completely missing. In addition to the ash, elm and the mentioned diagnostic species, in the composition of the studied forests sociologically important are the species common in flooded and wet forests (such as *Carex riparia*, *Lycopus europaeus*, *Cardamine pratensis*, *Leucojum aestivum*, *Galium palustre*, *Ranunculus repens*, *Lysimachia nummularia* and others).

In its great area, the association *Carici remotae-Fraxinetum oxycarpae* demonstrates floristic variability, which was also demonstrated in the stands we studied in Croatia. They hold a number of species that have not been reported or are rare in other regions. These are primarily *Crataegus laevigata*, *Cardamine pratensis*, *Deschampsia cespitosa*, *Lysimachia nummularia*, *Alisma plantago-aquatica* and *Lycopus europaeus*. These species were singled out as differential for the new sub-association *crataegetosum laevigatae*, the holotype of which is relevé number 4 in Table 2 (according to Weber *et al.* [20]). Great diagnostic significance is also proper to *Carex riparia*, although it has already been set as a differential species of the sub-association *Carici remotae-Fraxinetum oxycarpae caricetosum cuprinae* [37].

Besides the association *Carici remotae-Fraxinetum oxycarpae*, in southern Europe several similar syntaxa have

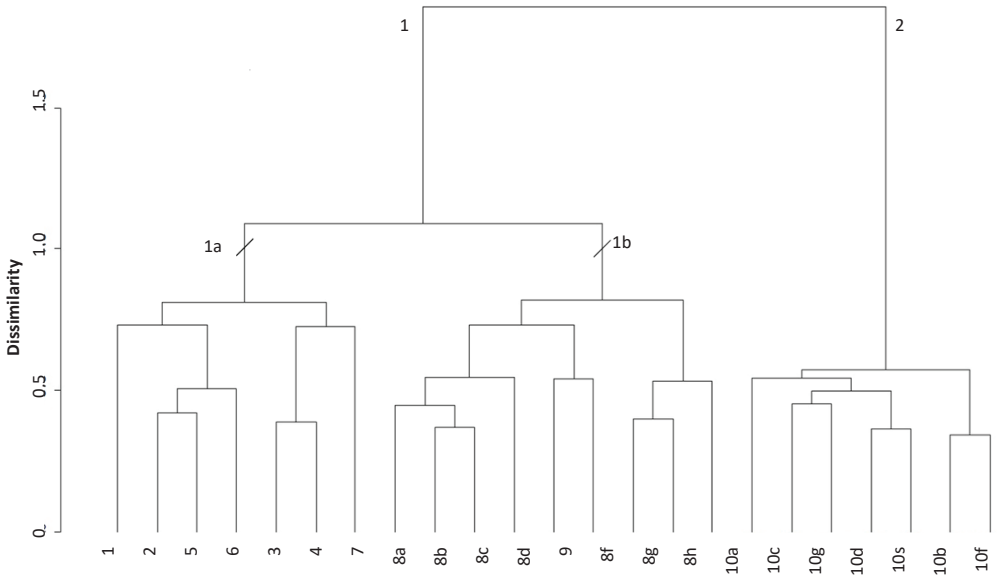

FIGURE 2. Dendrogram of the compared *Fraxinus angustiflolia* syntaxa.

been described with the domination of *Fraxinus angustifolia* [5, 38-43]. Douda *et al.* [10] consider the majority of them to be synonyms for the association *Lithospermo purpureocaerulei-Ulmetum minoris*, which they included into the middle Mediterranean alliance *Populion albae*. The studied forests in Istria fit only partially into such a broadly understood association and its affiliation to the alliance *Populion albae*. They lack important diagnostic species for this association and alliance such as *Bryonia dioica*, *Rubus ulmifolius*, *Iris foetidissima*, *Asparagus acutifolius*, *Celtis australis*, *Rubia peregrina*, *Smilax aspera*, *Oenanthe pimpinelloides*, *Rosa sempervirens*, *Tamus communis*, *Populus alba* and others.

In the previous studies, the community *Carici remotae-Fraxinetum oxycarpae* was classified into different alliances: *Alno-Ulmion*, *Alno-Quercion roboris*, *Alnion incanae*, *Carici remotae-Fraxinion oxycarpae*, *Populion albae* [5, 9, 10, 18, 29, 31, 37]. Our research shows a high coincidence with the alliance *Carici remotae-Fraxinion oxycarpae*, as it is defined in the syntaxonomic overview of the vegetation of Italy [9, 18]. In the cited papers, the species *Fraxinus angustifolia* subsp. *oxycarpa*, *Ulmus minor* subsp. *minor*, *Ranunculus lanuginosus*, *Carex remota*, *Rumex sanguineus*, *Carex pendula* and *C. divulsa* are listed as diagnostic species for it. Without going into the internal differentiation of the species *Fraxinus angustifolia* and *Ulmus minor*, the composition of species corresponds very well to the studied stands along the Mirna River. In the latest review of the vegetation of Europe [12], the *Carici remotae-Fraxinion oxycarpae* is listed as a synonym for the alliance *Lauro nobilis-Fraxinion angustifoliae*. However, the issue of syntaxonomy will continue to be the subject of many discussions.

Mixed Forests Dominated by *Quercus robur, Fraxinus angustifolia, Ulmus minor* and *Carpinus betulus*

Mixed hardwood forests of the studied area are presented with 23 new relevés in Table 3. They grow in drier terrains which are up to 2 m higher than the previous community. They are flooded only in some areas and very rarely, only in extremely wet years in early spring or late fall. The type of soil is pseudogley on alluvial deposits, and such conditions have also reflected on the floristic composition with fewer hygrophytes and more mesophilous species.

The first phytocoenological relevés of such stands were published by Lausi [44] from northeastern Italy along the Po River, and somewhat later by Bertović [2] from the valley of the Mirna River in the Croatian part of Istria. They described them as autonomous associations under different but invalid names, hence Marinček [45] suggested the name *Asparago tenuifolii-Quercetum roboris*. The majority of papers classify the studied forests into the alliance *Erythronio-Carpinion* [1-4, 19]. However, Brullo & Spampinato [5] and Trinajstić [6] classify them into the alliance *Alno-Quercion roboris*. Due to the different nomenclature and syntaxonomic characterization and their status, we surveyed them phytocoenologically in more detail and in further analyses

compared them with 10 related syntaxa in 23 synthetic columns (Table 1, Figure 3). The compared syntaxa originate from the north-Adriatic Mediterranean area and southwestern rim of the Pannonian Plain.

The statistical analysis demonstrated the separation of the compared syntaxa into two main clusters: the first one represents drier communities with a significant presence of mesophilous species from alliances within the order *Fagetalia*, and the other one contains communities in periodically flooded and moist habitats with the main subassociation *Genisto elatae-Quercetum roboris caricetosum remotae* (Table 1 numbers 15 a-b, 16 a-f, and 19) within the alliance *Alnion incanae*. In the first cluster, one can distinguish between three sub-clusters: the first one represents *Carpinetum* communities of central and eastern Croatia and the studied area (1a); the second one more humid syntaxa of Slovenia classified in the alliances *Alnion incanae* and *Fraxino angustifoliae-Carpinion betuli* (1b); and the third one the association *Fraxino pannonicae-Quercetum roboris* from northern Italy, which is classified in the alliance *Alno-Quercion roboris* (1c).

The studied forests in the valley of the Mirna River demonstrate affiliation with the sub-cluster 1a, where the dominant forests are oak-hornbeam forests of drier type of central and eastern Croatia. They grow along the course of the Sava River and are connected to the studied forests in Istria, primarily by the great presence of *Carpinus betulus*, *Acer campestre* and other mesophilous species. The floristic and sociological relationships between individual cluster groups were analyzed based on the fidelity of species using the JUICE 7.0 program [25]. We took a total of 216 phytocoenological relevés in the analysis from the main syntaxa representing an individual group (Table 4).

The analysis has shown that the studied forests of the Mediterranean area differ from continental forests in wetter habitats (cluster 2 – *Genisto elatae-Quercetum roboris caricetosum remotae* = *Fraxino pannonicae-Ulmetum glabrae sensu* Douda et al. 2016.) in the lack of a large number of species of wetland and flooded habitats (for instance, *Iris pseudacorus*, *Genista tinctoria*, *Stachys palustris*, *Caltha palustris*, *Carex strigosa*, *Mentha aquatica*, *Carex vesicaria*, *C. elongata*, *Lythrum salicaria*, *Euphorbia palustris*, *Myosotis palustris* etc.). In relation to the Mediterranean hardwood forests (subcluster 1c, column 4 in Table 1) in forests along the Mirna River, there are no southern European species represented in the communities of the alliance *Populion albae*. These species are *Iris foetidissima*, *Rubus ulmifolius*, *Quercus ilex*, *Holcus lanatus*, *Populus alba*, *Cyclamen repandum*, *Hypericum androsaemum*, *Moehringia trinervia*, *Luzula forstery*, and with a smaller presence in the Mediterranean forests there are also *Aristolochia pallida*, *Laurus nobilis*, *Smilax aspera*, *Rosa sempervires*, *Clematis vitalba*, *Asparagus acutifolius* and other species.

The studied stands demonstrate a differential character towards all of the compared syntaxa through a higher presence of the species *Primula vulgaris*, *Vinca minor*, *Lonicera caprifolium*, *Ranunculus lanuginosus*, *Arum italicum*, *Carex pendula*, *Ligustrum vulgare*, *Corylus avellana*, *Ruscus aculeatus*, *Viburnum opulus*, *Aegopodium podagraria*, *Listera ovata*, *Cornus sanguinea*, *Symphytum tuberosum*, and also *Carpinus betulus*, *Acer campestre* and *Ulmus minor*. The majority of these species tend to be distributed in the drier oak-hornbeam and beech forests (alliances *Carpinion betuli*, *Erythronio-Carpinion*, order *Fagetalia*). Hence, in the majority of studies to date, they

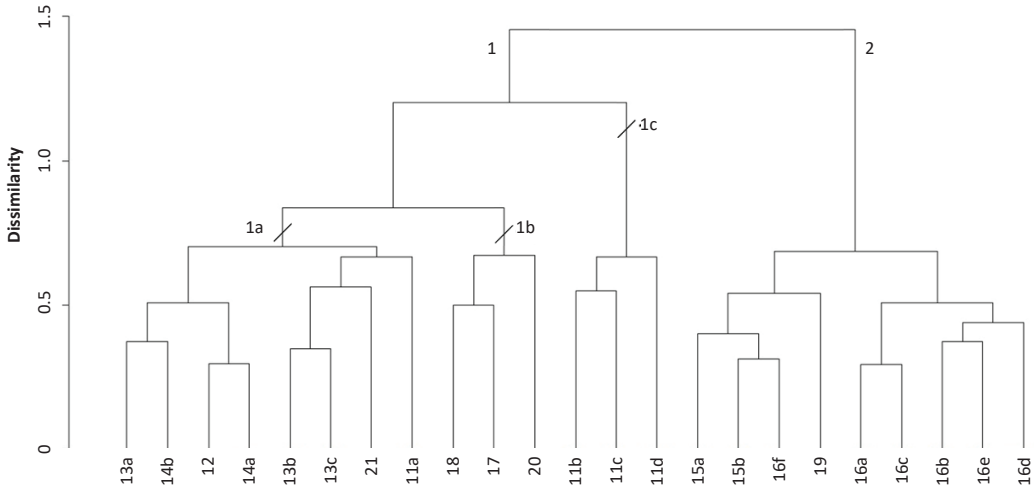

FIGURE 3. Dendrogram of the compared mixed hardwood syntaxa.

TABLE 1. List of literature sources and phytocoenological relevés in the analysis. The numbers of relevés correspond to the numbers in the dendrogram on Figure 2 and Figure 3.

Syntaxa	Source	No of relevés
***Fraxinus angustifolia* forests (Figure 2)**		
Mediterranean area		
1. *Corno-Fraxinetum angustifoliae*	Mercedal & Vilar [37]	6
2. *Viburno lantanae-Ulmetum minoris*	Mercedal & Vilar [37]	39
3. *Ficario ranunculoidis-Fraxinetum angustifoliae*	Mercedal & Vilar [37]	77
4. *Aro italici-Ulmetum minoris*	Mercedal & Vilar [37]	53
5. *Rusco-Fraxinetum angustifoliae*	Gesti et al. [42]	34
6. *Alno glutinosae-Fraxinetum angustifoliae*	Mercedal & Vilar [37]	23
7. *Junco-Fraxinetum oxycarpae*	Mercedal & Vilar [37]	4
8a. *Carici remotae-Fraxinetum oxycarpae populetosum albae*	Pedrotti [27]	5
8b. *Carici remotae-Fraxinetum oxycarpae populetosum albae*	Pedrotti & Cortini Pedrotti [29]	17
8c. *Carici remotae-Fraxinetum oxycarpae populetosum albae*	Pedrotti [30]	8
8d. *Carici remotae-Fraxinetum oxycarpae alnetosum glutinosae*	Gellini *et al.* [31]	8
8e. *Carici remotae-Fraxinetum oxycarpae iridetosum foetidissimae*	Conti & Pirone [33]	10
8f. *Carici remotae-Fraxinetum oxycarpae quercetosum roboris*	Mercedal & Vilar [37]	12
8g. *Carici remotae-Fraxinetum oxycarpae quercetosum pubescentis*	Mercedal & Vilar [37]	9
8h. *Carici remotae-Fraxinetum oxycarpae caricetosum cuprinae*	Mercedal & Vilar [37]	11
9. *Carici remotae-Fraxinetum oxycarpae crataegetosum laevigatae*	this paper	10
Continental area		
10a. *Leucojo-Fraxinetum typicum* and *alnetosum glutinosae*	Glavač [49]	23
10b. *Leucojo-Fraxinetum typicum*	Baričević [50]	5
10c. *Leucojo-Fraxinetum typicum*	Škvorc *et al.* [51]	14
10d. *Leucojo-Fraxinetum alnetosum glutinosae*	Rauš [46]	5
10e. *Leucojo-Fraxinetum alnetosum glutinosae*	Rauš [52]	5
10f. *Leucojo-Fraxinetum alnetosum glutinosae*	Baričević [50]	5
10g. *Leucojo-Fraxinetum alnetosum glutinosae*	Rauš *et al.* [53]	6
Mixed hardwood forests (Figure 3)		
Mediterranean area		
11a. *Fraxino-Quercetum roboris*	Gellini *et al.* [31]	15
11b. *Fraxino-Quercetum roboris*	Manzi [32]	5
11c. *Fraxino-Quercetum roboris*	Brullo & Spampinato [35]	15
11d. *Fraxino-Quercetum roboris*	Pedrotti [27]	5
Continental area		
12. *Querco roboris-Carpinetum*	Glavač [54]	33
13a. *Carpino betuli-Quercetum roboris typicum*	Cestar *et al.* [55]	24
13b. *Carpino betuli-Quercetum roboris typicum*	Rauš [47]	15
13c. *Carpino betuli-Quercetum roboris typicum*	Škvorc *et al.* [51]	21
14a. *Genisto-Quercetum roboris carpinetosum betuli*	Glavač [56]	8
14b. *Genisto-Quercetum roboris carpinetosum betuli*	Baričević [50]	10
15a. *Genisto-Quercetum roboris caricetosum brizoidis*	Rauš [52]	10
15b. *Genisto-Quercetum roboris caricetosum brizoidis*	Baričević [50]	10
16a. *Genisto-Quercetum roboris caricetosum remotae*	Horvat [57]	15
16b. *Genisto-Quercetum roboris caricetosum remotae*	Rauš [46]	5
16c. *Genisto-Quercetum roboris caricetosum remotae*	Rauš [47]	10
16d. *Genisto-Quercetum roboris caricetosum remotae*	Cestar *et al.* [55]	31
16e. *Genisto-Quercetum roboris caricetosum remotae*	Glavač [58]	34
16f. *Genisto-Quercetum roboris caricetosum remotae*	Baričević [50]	10
17. *Pseudostellario europaeae-Carpinetum betuli*	Dakskobler [59]	14
18. *Pseudostellario-Carpinetum betuli leucojetosum aestivi*	Dakskobler [59]	9
19. *Pseudostellario-Quercetum roboris leucojetosum aestivi*	Dakskobler [59]	11
20. *Fraxino-Ulmetum effusae quercetosum roboris*	Košir *et al.* [60]	20
21. *Asparago tenuifolii-Quercetum roboris*	Bertović [2] + this paper	35

TABLE 2. Forests dominated by *Fraxinus angustifolia.*

Number of releve		1	2	3	4	5	6	7	8	9	10	
Number in Figure 1		24	25	27	28	26	29	32	30	33	31	
Altitude in m		14	14	14	14	14	10	14	11	12	12	
Releve area (00 m²)		4	4	4	4	4	5	5	5	5	5	Pres.
Cover in %: tree layer (a)		80	80	85	80	80	60	80	60	70	65	deg.
schrub layer (b)		80	90	40	40	70	50	70	70	40	80	
herb layer (c)		90	70	100	95	100	90	70	100	80	95	
moos layer (d)		1	15	5	1	1	-	-	-	-	-	
Diagnostic species of the association and alliance												
*Fraxinus angustifolia**	a	5	5	5	5	5	3	3	3	4	3	5
Fraxinus angustifolia	b	+	1	1	1	1	2	+	2	2	3	5
*Carex remota**	c	1	3	3	1	2	3	+	2	2	2	5
*Rumex sanguineus**		+	1	+	+	+	2		2	+	2	5
Fraxinus angustifolia		+	+		+		+	+	2	+	+	4
*Ranunculus lanuginosus**		2	+	+			+			+	+	3
Differential species of the subassociation												
Crataegus laevigata	b	2	4	1	1	2	2	+	2	+	2	5
Lysimachia nummularia	c	+	1	2	2	+	+	+	2	2	2	5
Carex riparia		1	2	3	3	3	3	3		2	+	5
Lycopus europaeus		(+)	+	+	+	+	2	2	+	+		5
Cardamine pratensis		+	2	+	+	+			+		+	4
Deschampsia caespitosa		+	+	+	+	+						3
Alisma plantago-aquatica				+	+		+		+	(+)		3
Populetalia albae*												
Ulmus minor	a	2	+	+	+	1			+			3
Populus nigra							2		2			1
Salix alba								2				1
Ulmus minor	b	3	1	+	+	2	3	3	2		3	5
Salix alba										+		1
Carex pendula	c	2	1	1	2	2	2		2	+	2	5
Ulmus minor		+	+				+	2	2		+	3
Salix alba										+		1
Alnetea glutinosae												
Salix cinerea	b							+				1
Valeriana dioica	c		+	1	+							2
Solanum dulcamara								+		+		1
Fagetalia												
Acer campestre	a					+						1
Acer campestre	b	+	+	+	+				+	+	2	4
Lonicera caprifolium		+			+	+						2
Malus sylvestris									+			1
Ranunculus ficaria	c	2	1	+		1			+			3
Circaea lutetiana			+			+			(+)		+	2
Viola reichenbachiana		+		+							+	2
Acer campestre								+		+	+	2
Carex sylvatica								+		+		1

TABLE 2. (continued) - Forests dominated by *Fraxinus angustifolia*.

Querco-Fagetea												
Quercus robur	a					+						1
Ruscus aculeatus	b								(+)	(+)	(+)	2
Quercus robur								+			(+)	1
Hedera helix	c	2	+	+	+	1			+		2	4
Quercus robur								(+)			(+)	1
Rhamno-Prunetea												
Cornus sanguinea	b	1	+	+	+	+	+	2	2	+	2	5
Prunus spinosa		1		1	2	1		2	+	+	+	4
Crataegus monogyna		1	+		+	+	+		+		+	4
Ligustrum vulgare		+	+			+			+		2	3
Euonymus europaea		+	+						+	(+)	(+)	3
Rhamnus catharticus								+		+		1
Clematis vitalba									(+)		(+)	1
Viburnum opulus								+				1
Molinio-Arrhenatheretea												
Leucojum aestivum	c		+	+	+	+						2
Poa trivialis								+	2	+	+	2
Ajuga reptans				+	+		+					2
Lythrum salicaria				+				+	+			2
Juncus effusus									(+)	+		1
Phragmiti-Caricetea elatae												
Galium palustre	c	+	2	1	1		+		2	+	+	4
Mentha aquatica				1	1			+	+			2
Iris pseudacorus					1	+	(+)			+		2
Lysimachia vulgaris				+		+						1
Galio-Urticetea												
Geum urbanum	c	1				+						1
Agrostietea												
Ranunculus repens	c		1	1	+	+	3	+	2	+	+	5
Agrostis stolonifera				+	+							1
Other spp.												
Rubus caesius	b	2	2	2	2	3	2	2	+	+	+	5
Prunus cerasifera								+		+	+	2
Rosa arvensis					+							1
Sorbus torminalis					+							1
Carex otrubae	c			1			(+)			+	+	2
Potentilla erecta				+	+							1
Taraxacum officinale						+			+			1
Galium aparine								2			+	1
Bryophyta	d											
Brachythecium rutabulum		+		+	+	+		+	+	+	+	4
Anomodon viticulosus		+	+	+			+		+	+	+	3
Neckera complanata			+			+			+	+	+	3
Eurhynchium hians		+	2		+							2
Calliergonella cuspidata				1					+	+		2
Hypnum cupressiforme					+			+			+	2
Campylium stellatum			+				+					1
Fissidens taxifolius							+			+		1
Homalothecium sericeum				+					+			1
Brachythecium salebrosum							+	+				1

TABLE 3. Mixed forests dominated by *Quercus robur, Fraxinus angustifolia, Ulmus minor* and *Carpinus betulus*.

Number of relevé		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	
Number in Figure 1		1	3	5	9	4	6	11	7	8	12	10	2	13	15	17	14	16	22	19	21	18	20	23	
Altitude in m		14	15	15	15	15	16	15	14	14	13	14	14	16	16	16	16	16	17	14	14	16	14	18	
Releve area (00m²)		4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	6	4	6	4	4	5	Pres.
Cover in %: - tree layer (a)		100	80	85	90	85	90	70	95	95	90	80	100	90	100	80	90	100	95	90	80	100	85	75	deg.
- schrub layer (b)		70	70	80	70	30	50	60	60	35	80	60	60	70	70	30	40	70	40	70	70	50	80	50	
- herb layer (c)		50	70	60	70	80	60	80	80	90	70	60	70	90	95	90	100	90	95	85	80	80	90	90	
- moos layer (d)		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
Diagnostic species of the association																									
Ruscus aculeatus	b	1	1	+	+	1	+	1	1	1	+	+	2	4	3	2	3	3	1	4	4	3	4	1	5
Lonicera caprifolium		-	-	-	-	+	+	+	1	+	+	-	+	-	-	-	-	-	+	+	+	+	+	+	3
Carex pendula	c	+	1	1	+	+	3	1	1	3	1	+	2	1	+	1	+	-	1	1	2	1	2	+	5
Primula vulgaris		+	+	1	+	1	+	1	1	1	+	+	1	1	1	1	1	1	2	1	2	+	2	1	5
Lonicera caprifolium		+	-	+	-	-	1	1	1	1	-	-	-	+	-	1	+	-	1	+	+	1	1	1	4
Differential species of the subtypes																									
Prunus spinosa	b	-	-	1	+	+	+	1	2	+	1	1	-	-	+	-	-	-	-	-	-	-	-	-	3
Carex remota	c	+	1	+	2	1	-	2	+	+	1	2	+	-	-	-	-	-	-	-	-	-	+	-	3
Lysimachia nummularia		-	+	-	1	+	+	1	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	2
Deschampsia caespitosa		-	+	+	1	+	+	+	-	+	+	1	+	-	-	-	-	-	-	-	-	-	-	-	3
Vinca minor		-	-	-	-	-	-	-	+	1	-	-	1	3	4	2	3	3	4	1	1	1	3	3	3
Listera ovata		-	-	-	-	-	-	-	-	-	-	-	-	+	1	+	+	+	+	-	+	-	+	+	2
Symphytum tuberosum		-	-	-	-	-	-	-	-	-	-	-	-	+	1	-	1	1	2	+	-	+	-	+	2
Lamium galeobdolon		-	-	-	-	-	-	-	-	-	-	-	-	2	3	-	2	3	-	1	-	-	1	-	2
Euphorbia amygdaloides		-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	+	-	+	-	1	+	2
Polygonatum multiflorum		-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	2	+	2	2	-	2	-	2
Pulmonaria officinalis		-	-	-	-	-	+	-	-	-	-	-	+	-	-	-	-	-	+	-	-	+	-	1	2
Carpinion betuli, Erythronio Carpinion																									
Carpinus betulus	a	1	-	-	-	1	1	1	+	+	-	1	1	2	3	+	3	1	2	1	1	3	2	3	5
Acer campestre		3	2	1	+	2	2	1	-	1	-	+	3	3	2	2	2	2	+	1	3	2	1	2	5
Carpinus betulus	b	+	+	-	-	-	+	-	-	-	-	-	1	-	-	+	-	-	+	+	1	+	+	+	3
Acer campestre		+	+	+	1	1	+	+	+	+	-	+	+	+	+	+	+	+	+	1	+	+	+	+	5
Tilia cordata		-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	1
Carpinus betulus	c	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	1
Acer campestre		+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	1
Helleborus odorus		-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	+	1
Knautia drymeia		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	1
Fagetalia																									
Sambucus nigra	b	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Carex sylvatica	c	+	+	+	+	1	2	+	-	+	+	+	1	+	+	+	1	+	1	1	1	1	1	1	5
Viola reichenbachiana		+	+	+	+	1	+	+	+	-	+	+	+	+	-	+	+	+	+	-	+	+	+	-	5
Circaea lutetiana		+	+	-	+	-	+	+	-	1	+	-	+	+	-	-	-	-	-	-	+	-	-	+	3
Brachypodium sylvaticum		-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	-	-	+	-	-	+	+	+	2
Ranunculus ficaria		-	+	+	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Allium ursinum		-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	2	3	-	-	-	-	-	-	1
Euphorbia dulcis		-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-	-	+	1
Lathyrus vernus		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1
Salvia glutinosa		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1
Mercurialis perennis		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	1
Populetalia albae																									
Fraxinus angustifolia	a	3	4	4	4	3	4	5	3	2	3	4	2	+	2	2	2	+	2	+	+	2	2	+	5
Ulmus minor		-	1	1	3	1	1	-	1	1	1	1	-	+	-	+	-	-	+	2	+	-	1	1	4
Ulmus minor	b	+	1	1	2	1	+	+	+	+	1	1	+	+	-	-	+	-	+	1	+	+	1	1	5
Fraxinus angustifolia		+	-	+	1	-	+	+	-	1	+	+	+	+	-	-	-	+	-	+	+	+	-	+	4
Ranunculus lanuginosus	c	2	2	1	+	1	1	1	-	1	+	+	-	+	+	+	+	-	-	-	-	-	-	-	3
Rumex sanguineus		-	-	-	+	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Fraxinus angustifolia		-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1
Ulmus minor		+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1

TABLE 3. (continued) - Mixed forests dominated by *Quercus robur, Fraxinus angustifolia, Ulmus minor* and *Carpinus betulus*.

Alnetalia glutinosae																									
Lycopus europaeus	c	-	-	-	-	-	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	1
Cardamine pratensis		+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Querco-Fagetae																									
Quercus robur	a	4	1	1	1	1	+	1	2	3	3	2	4	3	3	3	2	4	3	4	4	3	3	+	5
Pyrus communis		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	-	1
Corylus avellana		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	1
Corylus avellana	b	-	+	1	+	1	+	-	-	+	+	+	+	1	1	1	1	1	1	1	2	2	1	+	5
Quercus robur		1	+	-	+	-	+	-	-	+	+	-	+	-	+	-	+	+	-	+	+	-	-	-	3
Pyrus communis		-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Hedera helix	c	3	3	3	2	3	2	3	4	4	3	+	3	1	2	3	1	1	3	3	4	3	3	4	5
Quercus robur		+	+	+	+	-	+	-	-	-	-	-	+	+	+	1	-	+	+	-	1	+	+	+	4
Arum italicum		-	-	-	-	+	-	-	+	-	-	-	-	+	+	+	-	-	+	-	-	-	-	-	2
Tamus communis		-	-	-	-	-	-	-	+	+	-	-	-	-	+	-	-	-	-	+	1	-	+	-	2
Anemone nemorosa		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	2	-	-	-	-	-	-	1
Rhamno-Prunetea																									
Crataegus oxyacantha	b	3	2	4	2	1	2	1	+	1	4	3	3	+	1	+	-	+	1	1	2	1	1	3	5
Crataegus monogyna		-	1	+	+	+	+	+	+	+	-	+	+	+	+	+	1	+	+	+	+	-	+	+	5
Cornus sanguinea		-	1	-	+	+	+	-	+	+	+	+	+	+	-	+	+	+	2	+	+	-	1	1	4
Ligustrum vulgare		1	+	+	-	1	1	1	2	2	-	-	1	-	-	+	+	+	1	1	1	+	+	1	4
Viburnum opulus		+	+	+	-	-	+	-	+	1	1	+	+	-	-	+	-	+	+	+	+	+	+	-	4
Euonymus europaea		+	+	+	+	-	-	-	+	+	+	-	-	+	+	+	-	-	-	+	-	-	-	-	3
Rhamnus cathartica		-	+	-	-	+	-	-	+	+	-	-	-	-	+	+	-	-	-	-	-	-	+	-	2
Prunus ceracifera		-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	1
Ligustrum vulgare	c	-	+	-	-	-	-	-	1	-	+	-	-	-	-	-	-	-	+	-	-	+	-	-	1
Rubus plicatus		-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Molinio-Arrhenatheretea																									
Ajuga reptans	c	-	+	-	-	-	1	+	-	-	+	+	1	-	-	+	+	-	+	+	+	+	+	1	3
Lythrum salicaria		-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-		1
Prunella vulgaris		-	-	-	-	-	+	-	-	-	+	+	-	-	-	-	-	-	+	-	-	-	-		1
Other species																									
Rosa arvensis	b	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	1
Cornus mas		-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	1
Eupatorium cannabinum		-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	1
Laurus nobilis		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	1
Rubus caesius	c	-	-	-	+	-	-	+	1	+	+	1	+	-	-	-	+	-	+	+	-	1	+	+	3
Aegopodium podagraria		-	-	+	-	-	+	-	+	1	+	+	+	-	+	-	+	1	+	-	-	+	-	-	3
Ranunculus repens		-	-	-	1	-	-	1	-	-	1	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Potentilla erecta		-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Galium palustre		-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
Vicia dumetorum		-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	1
Glechoma hederacea		-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	1
Fragaria vesca		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1
Ophioglossum vulgatum		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1
Viola hirta		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	1
Polypodium vulgare		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	1
Erigeron annuus		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	1
Plantago major		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	1
Stellaria nemorum		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	1
Equisetum telmateia		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	1
Bryophyta																									
Anomodon viticulosus		+	+	+	-	+	-	+	+	+	+	+	-	+	+	+	+	+	+	+	+	-	-	+	4
Brachythecium rutabulum		-	+	+	+	+	+	+	+	+	+	-	+	+	-	+	-	-	-	+	+	+	+	-	4
Fissidens taxifolius		-	+	-	-	-	-	+	+	+	+	+	+	-	+	-	+	-	-	+	+	+	+	+	3
Neckera complanata		+	+	+	-	-	-	+	-	-	-	+	-	-	-	+	-	+	-	+	+	+	+	+	3
Eurhynchium hians		-	+	-	-	-	-	+	-	-	+	-	+	-	-	+	-	-	+	-	-	+	+	-	2
Homalothecium sericeum		-	-	+	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	1
Brachythecium salebrosum		-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	+	-	+	-	1
Calliergonella cuspidata		+	-	-	-	-	-	+	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	1
Hypnum cupressiforme		-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	1
Leucodon sciuroides		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	1
Campylium stellatum		-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Hygroamblystegium tenax		-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	1

TABLE 4. Differential species (marked grey) with frequency (≥30%) and fidelity (*phi* coefficient×100, ≥35) values for the compared mixed hardwood syntaxa: (1) *Genisto eletae-Quercetum roboris*, [57, 46, 47, 58, 50], N-Croatia; (2) *Carpino betuli-Quercetum roboris*, [54, 47, 51, 56, 50], N-Croatia; (3) 23 relevés in the present study + 12 relevés Bertović [2], (4) *Fraxino pannonicae-Quercetum roboris*, [31, 32], Italy.

Group No.	1	2	3	4
No. of relevés	74	87	35	20
Diagnostic species				
Iris pseudacorus	**75**$^{76.5}$	9^{---}	.$^{---}$	.$^{---}$
Genista tinctoria	**70**$^{72.7}$	9^{---}	.$^{---}$	.$^{---}$
Stachys palustris	**58**$^{67.1}$	5^{---}	.$^{---}$	.$^{---}$
Caltha palustris	**52**$^{66.9}$	.$^{---}$	.$^{---}$	.$^{---}$
Carex strigosa	**62**$^{66.8}$	9^{---}	.$^{---}$	.$^{---}$
Lycopus europaeus	**82**$^{64.0}$	19^{---}	22^{---}	.$^{---}$
Mentha aquatica	**52**$^{62.3}$	.$^{---}$	.$^{---}$	5^{---}
Glechoma hederacea	**83**$^{59.5}$	51$^{20.5}$	3^{---}	.$^{---}$
Leucojum aestivum	**43**$^{58.9}$	1^{---}	.$^{---}$	.$^{---}$
Carex vesicaria	**39**$^{56.9}$	.$^{---}$	.$^{---}$	.$^{---}$
Carex elongata	**43**$^{56.8}$	3^{---}	.$^{---}$	.$^{---}$
Galium palustre	**88**$^{54.5}$	18^{---}	11^{---}	50$^{9.6}$
Lysimachia vulgaris	**61**$^{54.4}$	3^{---}	14^{---}	10^{---}
Carex vulpina	**38**$^{52.8}$	.$^{---}$	3^{---}	.$^{---}$
Lythrum salicaria	**49**$^{52.0}$	2^{---}	8^{---}	5^{---}
Euphorbia palustris	**32**$^{51.5}$	.$^{---}$	.$^{---}$	.$^{---}$
Ranunculus repens	**82**$^{50.0}$	16^{---}	31^{---}	30^{---}
Solanum dulcamara	**39**$^{49.5}$	7^{---}	.$^{---}$	.$^{---}$
Lychnis flos-cuculi	**52**$^{49.1}$	3^{---}	.$^{---}$	20$^{1.8}$
Mentha verticillata agg.	**30**$^{45.4}$	3^{---}	.$^{---}$	.$^{---}$
Peucedanum palustre	**30**$^{45.4}$	3^{---}	.$^{---}$	.$^{---}$
Myosotis palustris agg.	**36**$^{45.2}$	9^{---}	.$^{---}$	.$^{---}$
Lysimachia nummularia	**74**$^{40.4}$	41$^{1.0}$	44$^{5.5}$	.$^{---}$
Cardamine pratensis	**44**$^{38.1}$	9^{---}	6^{---}	15^{---}
Cerastium sylvaticum	**43**$^{36.4}$	28$^{14.4}$	3^{---}	.$^{---}$
Oxalis acetosella	.$^{---}$	**48**$^{63.9}$	.$^{---}$	.$^{---}$
Galium odoratum	.$^{---}$	**42**$^{59.1}$	.$^{---}$	.$^{---}$
Dryopteris filix-mas	3^{---}	**42**$^{56.3}$	.$^{---}$	.$^{---}$
Athyrium filix-femina	21$^{2.6}$	**55**$^{53.3}$	.$^{---}$	.$^{---}$
Tilia cordata	.$^{---}$	**38**$^{52.6}$	3^{---}	.$^{---}$
Veronica montana	12^{---}	**68**$^{52.3}$	.$^{---}$	30$^{3.4}$
Galeobdolon luteum	1^{---}	**50**$^{48.9}$	19$^{2.7}$	.$^{---}$
Geum urbanum	19$^{4.9}$	**46**$^{46.1}$	.$^{---}$	.$^{---}$
Carex brizoides	6^{---}	**32**$^{44.1}$	.$^{---}$	.$^{---}$
Anemone nemorosa	.$^{---}$	**33**$^{43.3}$	8^{---}	.$^{---}$
Veronica chamaedrys	6^{---}	**35**$^{42.0}$	6^{---}	.$^{---}$
Primula vulgaris	.$^{---}$	11^{---}	**97**$^{90.9}$	.$^{---}$
Lonicera caprifolium	.$^{---}$	3^{---}	**81**$^{69.3}$	25^{---}
Carex pendula	4^{---}	17^{---}	**97**$^{68.3}$	40^{---}
Vinca minor	.$^{---}$	4^{---}	**53**$^{63.7}$	.$^{---}$
Ranunculus lanuginosus	.$^{---}$	5^{---}	**53**$^{55.0}$	10^{---}

TABLE 4. (continued) - Differential species (marked grey) with frequency (≥30%) and fidelity (*phi* coefficient×100, ≥35) values for the compared mixed hardwood syntaxa: (1) *Genisto eletae-Quercetum roboris*, [57, 46, 47, 58, 50], N-Croatia; (2) *Carpino betuli-Quercetum roboris*, [54, 47, 51, 56, 50], N-Croatia; (3) 23 relevés in the present study + 12 relevés Bertović [2], (4) *Fraxino pannonicae-Quercetum roboris*, [31, 32], Italy.

Group No.	1	2	3	4
No. of relevés	74	87	35	20
Diagnostic species				
Ligustrum vulgare	1^{---}	17^{---}	**89**$^{68.7}$	25^{---}
Corylus avellana	4^{---}	31$^{2.1}$	**83**$^{67.9}$	.$^{---}$
Ruscus aculeatus	.$^{---}$	27^{---}	**97**$^{64.1}$	45$^{3.1}$
Viburnum opulus	22^{---}	19^{---}	**78**$^{60.8}$	.$^{---}$
Aegopodium podagraria	16^{---}	17^{---}	**64**$^{53.8}$	.$^{---}$
Listera ovata	.$^{---}$	16^{---}	**47**$^{50.0}$	.$^{---}$
Cornus sanguinea	14^{---}	33^{---}	**81**$^{46.7}$	35^{---}
Symphytum tuberosum agg.	.$^{---}$	12^{---}	**36**$^{42.3}$	.$^{---}$
Arum italicum	.$^{---}$	.$^{---}$	**28**$^{41.2}$	5^{---}
Iris foetidissima	.$^{---}$	.$^{---}$	.$^{---}$	**65**$^{76.3}$
Rubus ulmifolius	.$^{---}$	.$^{---}$	.$^{---}$	**60**$^{72.8}$
Luzula forsteri	.$^{---}$	2^{---}	.$^{---}$	**60**$^{70.9}$
Moehringia trinervia	8^{---}	18^{---}	.$^{---}$	**65**$^{58.5}$
Myosotis sylvatica	.$^{---}$	.$^{---}$	.$^{---}$	**40**$^{57.7}$
Quercus ilex	.$^{---}$	.$^{---}$	.$^{---}$	**40**$^{57.7}$
Holcus lanatus	.$^{---}$	.$^{---}$	.$^{---}$	**35**$^{53.6}$
Brachypodium sylvaticum	3^{---}	39$^{6.5}$	17^{---}	**75**$^{51.2}$
Cyclamen repandum	.$^{---}$	.$^{---}$	.$^{---}$	**30**$^{49.3}$
Hypericum androsaemum	.$^{---}$	.$^{---}$	.$^{---}$	**30**$^{49.3}$
Populus alba	4^{---}	.$^{---}$	.$^{---}$	**35**$^{49.3}$
Pteridium aquilinum	.$^{---}$	2^{---}	3^{---}	**30**$^{43.6}$
Veronica officinalis	4^{---}	3^{---}	.$^{---}$	**30**$^{41.3}$
Diagnostic species for more syntaxa				
Persicaria hydropiper	**31**$^{28.5}$	**25**$^{18.2}$	.$^{---}$	.$^{---}$
Frangula alnus	**34**$^{26.6}$	**19**$^{3.3}$	14^{---}	.$^{---}$
Agrostis stolonifera	**44**$^{28.9}$	3^{---}	.$^{---}$	**45**$^{30.1}$
Poa trivialis	**44**$^{28.0}$	5^{---}	.$^{---}$	**45**$^{29.1}$
Juncus effusus	**48**$^{25.2}$	18^{---}	3^{---}	**45**$^{21.3}$
Urtica dioica	**43**$^{16.5}$	31$^{1.9}$	.$^{---}$	**45**$^{19.2}$
Carpinus betulus	17^{---}	**100**$^{47.0}$	**89**$^{33.8}$	35^{---}
Euphorbia amygdaloides	.$^{---}$	**28**$^{14.2}$	**36**$^{26.1}$	10^{---}
Polygonatum multiflorum	.$^{---}$	**34**$^{26.9}$	**33**$^{25.3}$	.$^{---}$
Pyrus pyraster	18^{---}	**25**$^{8.6}$	**33**$^{20.9}$	.$^{---}$
Pulmonaria officinalis	1^{---}	**15**$^{5.4}$	**31**$^{34.1}$	.$^{---}$
Crataegus monogyna	36^{---}	**60**$^{4.0}$	**86**$^{34.0}$	45^{---}
Crataegus laevigata	35^{---}	**70**$^{23.9}$	**92**$^{49.1}$	.$^{---}$
Acer campestre	29^{---}	**89**$^{23.5}$	**97**$^{34.5}$	65^{---}
Viola reichenbachiana	12^{---}	**70**$^{15.0}$	**86**$^{34.1}$	60$^{3.6}$
Carex sylvatica	9^{---}	**68**$^{7.9}$	**97**$^{42.9}$	**70**$^{10.6}$
Euonymus europaeus	10^{---}	**62**$^{22.5}$	**50**$^{7.9}$	**50**$^{7.9}$
Hedera helix	9^{---}	49^{---}	**100**$^{44.0}$	**95**$^{38.0}$
Carex flacca	.$^{---}$	.$^{---}$	**28**$^{28.2}$	**20**$^{14.3}$

were classified in the alliance *Erythronio-Carpinion*, and more precisely, according to the latest phytogeographical differentiation of oak-hornbeam forests of southeast Europe [19], they are classified in the sub-alliance *Lonicero caprifoliae-Carpinenion betuli* group *Quercus robur*, within the alliance *Erythronio-Carpinion*. In the studied mixed hardwood forests, of the species characteristic of the alliance abundantly present were *Primula vulgaris* and *Lonicera caprifolium*, while of the differential species of the sub-alliance these are *Anemone nemorosa*, *Vinca minor*, *Euphorbia dulcis*, *Knautia drymeia* and *Lamium galeobdolon*, and of the differential species of the group *Quercus robur* these are *Quercus robur*, *Carex remota* and *Circaea lutetiana* (cf. Košir *et al.* [19], Table 1).

Although in the dendrogram on Figure 3, the continental oak-hornbeam forests and the studied stands in Istria are separated at a relatively low level, they cannot be considered as belonging to the same association. The mixed hardwood forests of the Mediterranean area contain a certain number of species from the warmer climate, but also a higher presence of the narrow-leaved ash, European white elm, and some species associated with a high level of ground waters. They lack a part of continental species that do not penetrate wet habitats of the Mediterranean area, and are frequent in the continental forests of the common oak and common hornbeam (for example, *Galium odoratum*, *Oxalis acetosella*, *Dryopteris filix-mas*, *Tilia cordata* and others). In addition, continental stands are described in the association *Lonicero caprifoliae-Quercetum roboris* [45], which is broadly understood and of heterogeneous composition. This was also confirmed by Douda *et al.* [10], when they divided it into associations *Fraxino panonnicae-Ulmetum glabrae* and *Ficario vernae-Ulmetum campestris*, within the alliance *Alnion incanae*. However, the majority of stands of the association *Lonicero caprifoliae-Quercetum roboris* belong to the snytaxa within the *Carpinion* alliance: stands with the species of Illyrian floristic geo-element will be classified within the alliance *Erythronio-Carpinion*, and those in which these species are lacking in the alliance *Carpinion betuli*. The center of distribution and the largest areas of this association are located in Pannonian Croatia, where they are known under the name *Carpino betuli-Quercetum roboris* [46, 47], whereas in Hungary similar forests have been described as association *Circaeo lutetianae-Quercetum roboris* and others [48].

On the basis of previous vegetation research and this analysis, we have classified mixed forests of hardwood broadleaved trees along the Mirna River in the association *Asparago-tenuifolii-Quercetum roboris*. Its area is in the Mediterranean region of the north-western part of Slovenia and Croatia, and in the eastern part of Venezia Giulia. The diagnostic species of the association are *Ruscus aculeatus*, *Lonicera caprifolium*, *Carex pendula*, *Primula vulgaris* and *Arum italicum*. Although it is of extrazonal character, the cover of the species of the Illyrian floral geoelement is high. The sub-Mediterranean climate benefits their relatively thermophilic character.

The species *Asparagus tenuifolius* is absent from our phytocenological relevés, but is abundantly present in the surrounding zonal forests of the downy oak and the European hop-hornbeam. It does not respond well to wet and occasionally flooded habitats.

Future research of forests in the river valleys of the North Adriatic littoral will show the justifiability of classifying the studied forest stands of hardwood broadleaved trees into the association *Asparago tenuifoli-Quercetum roboris* and the alliance *Erythronio-Carpinion* betuli. Based on our analyses and recent phytocenological trends, their separation into new syntaxa is for now unfounded.

The association *Asparago tenuifolii-Quercetum roboris* was studied in two larger localities, hence its analysis in the hierarchical phytocoenological system is not yet warranted. The study of the stand along the Mirna River can be divided into two subtypes (Table 3): the first subtype of 12 relevés (subtype *Carex remota*, relevés 1-12 in Table 3) is distributed on wetter habitat, shallow depressions and very mild slopes, and according to the drier subtype, the prominent differential species are *Carex remota*, *Deschampsia cespitosa*, *Prunus spinosa*, *Lysimachia nummularia*, *Ranunculus lanuginosus*. In addition to them, there is also an increased presence of other hygrophilous species, especially *Ulmus minor*.

Relevés 13-23 in Table 3 represents a drier subtype (subtype *Vinca minor*) of mixed hardwood stands especially distributed on highest terrains along the Mirna River. The differential species according to the first subtype are *Vinca minor*, *Listera ovata*, *Symphytum tuberosum*, *Galeobdolon luteum*, *Euphorbia amygdaloides*, *Polygonatum multiflorum* and *Pulmonaria officinalis*. To a lesser extent, other species of less humid habitats also have diagnostic significance, and in relation to the previous subtype there is a higher presence of the common oak and common hornbeam.

It should be emphasized that the studied hardwood forests along the Mirna River represent a permanent vegetation stage conditioned by the hydrological regime, primarily by groundwater. For that reason, the presence of the species *Ulmus minor* and *Fraxinus angustifolia* is higher than in other *Carpinetum* communities of southeast Europe.

CONCLUSIONS

The phytocoenological study of periodically flooded and wet forests along the Mirna River in Istria and their comparisons with related syntaxa resulted in defining two associations. *Fraxinus angustifolia* forests with numerous hygrophilous species are classified in the association *Carici remotae-Fraxinetum oxycarpae* with the new sub-association *crataegetosum laevigatae*. The mixed hardwood forests belong to the association *Asparago tenuifolii-Quercetum roboris* distributed in the planar zone in broader river lowlands of the central part of the northern Mediterranean area. Both associations in the studied area lack numerous termophilous species from related syntaxa of southern Europe, as well as many hygrophilous species from related continental flooded and wet forests. The reasons primarily lie in the biogeographical position, ecological conditions and anthropogenic influences in the studied area. It is located at the northern most part of the Mediterranean, deeply retracted into the European continent. It is also marked by Mediterranean and continental climate impacts, especially modified by the 15 km distant Dinaric mountains with numerous species of the Illyrian floristic geo-element. These reasons have caused a certain isolation and transitional character of the area, which, in turn, has reflected on the floristic composition of the studied forests.

Syntaxonomical scheme:
Class: *Querco roboris-Fagetea sylvaticae* Br.-Bl. et Vlieger in Vlieger 1937
Order: *Populetalia albae* Br.-Bl. ex Tchou 1949
Alliance: *Carici remotae-Fraxinion oyycarpae* Pedrotti ex Pedrotti, Biondi, Allegrezza & Casavecchia in Biondi et al. 2014
Ass: *Carici-Fraxinetum oxycarpae* Pedrotti 1970 ex 1992
crataegetosum laevigatae subass. nova hoc. loco
Order: *Fagetalia* Pawlowski in Pawlowski *et al.* 1928
Alliance: *Erythronio-Carpinion betuli* (Horvat 1938) Marinček in Wallnöfer *et al.* 1993
Suballiance: *Lonicero caprifoliae-Carpinenion betuli* Vukelić in Marinček 1994 group *Quercus robur*
Ass: *Asparago tenuifolii-Quercetum roboris* (Lausi 1967) Marinček 1994
Carex remota subtype
Vinca minor subtype

The study results add to the knowledge of the composition and character of flooded and wet forests in this part of Europe, and will also serve to resolve the issues with their syntaxonomy. In addition, they are important in the preservation of these rare and endangered habitat types.

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APPENDIX

Appendix 1.

Table 2. (1) - N 45° 22' 16,5" - E 13° 52' 25,0"; (2) - N 45° 22' 11,9" - E 13° 52' 18,9"; (3) - N 45° 22' 11,3" - E 15° 52' 03,3"; (4) - N 45° 22' 05,6" - E 13° 52' 08,7"; (5) - N 45° 22' 01,9" - E 13° 52' 15,3"; (6) - N 45° 20' 45,4" - E 13° 47' 48,9"; (7) - N 45° 21' 10,8" - E 13° 51' 22,4"; (8) - N 45° 21' 10,8" - E 13° 48' 04,5"; (9) - N 45° 21' 12,3" - E 13° 50' 01,7"; (10) - N 45° 20' 55,9" - E 13° 49' 50,4".

Table 3. (1) - N 45° 22' 16,5'' - E 13° 52' 25,8''; (2) - N 45° 22' 11,9'' - E 13° 52' 18,9''; (3) - N 45° 22' 11,3'' - E 15° 52' 03,3''; (4) - N 45° 22' 05,6'' - E 13° 52' 08,7''; (5) - N 45° 22' 01,9'' - E 13° 52' 15,3''; (6) - N 45° 22' 23,9'' - E 13° 52' 45,7''; (7) - N 45° 22' 17,9'' - E 13° 52' 36,4''; (8) - N 45° 21' 49,4'' - E 13° 51' 15,1''; (9) - N 45° 21' 47,4'' - E 13° 51' 21,8''; (10) - N 45° 21' 53,5'' - E 13° 51' 43,8''; (11) - N 45° 22' 10,2'' - E 13° 52' 51,1''; (12) - N 45° 22' 05,0'' - E 13° 51 48,3''; (13) - N 45° 22' 01,4'' - E 13° 52' 17,8''; (14) - N 45° 22' 03,0'' - E 13° 52' 27,5''; (15) - N 45° 22' 08,0'' - E 13° 52' 36,7''; (16) - N 45° 22' 10,5'' - E 13° 52' 39,1''; (17) - N 45° 22' 12,3'' - E 13° 52' 43,6''; (18) - N 45° 22' 25,6'' - E 13° 53' 14,9''; (19) - N 45° 21' 50,2'' - E 13° 51' 47,3''; (20) - N 45° 21' 55,5'' - E 13° 51' 57,4''; (21) - N 45° 22' 26,0'' - E 13° 53' 01,9''; (22) - N 45° 21' 48,9'' - E 13° 51' 47,5''; (23) - N 45° 22' 36,8'' - E 13° 53' 11,7''.

Appendix 2.

Alnion incanae Pawlowski in Pawlowski *et al.* 1928; *Alno glutinosae-Fraxinetum angustifoliae* Br.-Bl. ex Tchou 1948; *Alno-Quercion roboris* I. Horvat 1938; *Alno-Ulmion* Br.-Bl. et Tüxen ex Tchou 1948; *Aro italici-Ulmetum minoris* Rivas-Martínez in G. López 1976; *Asparago tenuifolii-Quercetum roboris* (Lausi 1967) Marinček 1994; *Carici pendulae-Quercetum roboris* Trinajstić 2008; *Carici remotae-Fraxinetum oxycarpae* Pedrotti 1970 corr. Pedrotti 1992; *Carici remotae-Fraxinion oxycarpae* Pedrotti ex Pedrotti et al. in Biondi et al. 2014; *Carici remotae-Fraxinetum oxycarpae alnetosum glutinosae* Gelini et al. 1986; *Carici remotae-Fraxinetum oxycarpae caricetosum cuprinae* Mercadal *et* Vilar 2013; *Carici remotae-Fraxinetum oxycarpae iridetosum foetidissimae* Conti *et* Pirone 1992; *Carici remotae-Fraxinetum oxycarpae populetosum albae* Mercadal *et* Vilar 2013; *Carici remotae-Fraxinetum oxycarpae quercetosum pubescentis* Mercadal *et* Vilar 2013; *Carici remotae-Fraxinetum oxycarpae quercetosum roboris* Mercadal *et* Vilar 2013; *Carici remotae-Fraxinetum oxycarpae crataegetosum laevigatae* subass. nova hoc loco; *Carpinion betuli* Issler 1926; *Carpino betuli-Quercetum roboris* (Anić 1959) Rauš 1971; *Carpino betuli-Quercetum roboris typicum* Rauš 1975; *Circaeo lutetianae-Quercetum roboris* Borhidi 2003; *Corno sanguineae-Fraxinetum angustifoliae* Lara et Garilleti 1996; *Erythronio-Carpinion betuli* Marinček in Wallnöfer *et al.* 1993; *Fagetalia* Pawlowski in Pawlowski *et al.* 1928; *Ficario ranunculoidis-Fraxinetum angustifoliae* Rivas-Martínez et Costa in Rivas-Martínez *et al.* 1980; *Ficario vernae-Ulmetum campestris* Knapp ex Medwecka-Kornaś 1952; *Fraxino-Quercetum roboris* Gellini *et al.* 1986; *Fraxino-Ulmetum laevis* Slavnić 1952; *Fraxino-Ulmetum effusae quercetosum roboris* Košir *et al.* 2013; *Fraxino pannonicae-Carpinion betuli* Accetto 2006; *Fraxino pannonicae-Ulmetum glabrae* Aszód 1935 corr. Soó 1963; *Genisto elatae-Quercetum roboris* I. Horvat 1938; *Genisto-Quercetum roboris caricetosum brizoidis* I. Horvat 1938; *Genisto-Quercetum roboris caricetosum remotae* I. Horvat 1938; *Genisto-Quercetum roboris carpinetosum betuli* Glavač 1961; *Junco-Fraxinetum oxycarpae* Kárpáti *et* Kárpáti 1961; *Lauro nobilis-Fraxinion angustifoliae* Kárpáti *et* Kárpáti 1961; *Leucojo-Fraxinetum angustifoliae* Glavač 1959; *Leucojo-Fraxinetum angustifoliae typicum* Glavač 1959; *Leucojo-Fraxinetum angustifoliae alnetosum glutinosae* Glavač 1959; *Lithospermo purpureocaerulei-Ulmetum minoris* Bolòs 1956; *Lonicero caprifoliae-Carpinenion betuli* Vukelić in Marinček 1994; *Lonicero caprifoliae-Quercetum roboris* (Rauš) Marinček 1994; *Populetalia albae* Br.-Bl. ex Tchou 1949; *Populion albae* Braun-Blanquet ex Tchou 1948; *Pseudostellario-Carpinetum betuli leucojetosum aestivi* Dakskobler 2016; *Pseudostellario-Quercetum roboris* Accetto 1974; *Querco roboris-Carpinetum betuli* (Soó ex Balacs 1943) I. Horvat et al. 1974; *Querco roboris-Carpinetum* Soó *et* Pócs 1957; *Querco roboris-Carpinetum betuli „submediterraneum"* Bertović 1975; *Querco pubescenti-Carpinetum orientalis* Horvatić 1939; *Querco roboris-Fagetea sylvaticae* Br.-Bl. *et* Vlieger in Vlieger 1937; *Rusco-Fraxinetum angustifoliae* Gesti *et al.* 2003; *Viburno lantane-Ulmetum minoris* Biurrun *et* García-Mijangos in Rivas-Martínez *et al*. 2002.