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Classification of Wetland Forests and Scrub in the Western Balkans

Dragan Koljanin [1], Jugoslav Brujić [1], Andraž Čarni [2,3], Đorđije Milanović [1], Željko Škvorc [4] and Vladimir Stupar [1,*]

[1] Department of Forest Ecology, Faculty of Forestry, University of Banja Luka, S. Stepanovića 75A, 78000 Banja Luka, Bosnia and Herzegovina
[2] Jovan Hadži Institute of Biology, Research Centre of the Slovenian Academy of Sciences and Arts, Novi trg 2, 1000 Ljubljana, Slovenia
[3] School for Viticulture and Enology, University of Nova Gorica, Vipavska 13, 5000 Nova Gorica, Slovenia
[4] Faculty of Forestry and Wood Technology, University of Zagreb, Svetošimunska 23, 10000 Zagreb, Croatia
* Correspondence: vladimir.stupar@sf.unibl.org

Abstract: Wetland forests and scrub (WFS) are conditioned by the strong impact of water. They consist of various vegetation types, depending on many factors such as type and duration of flooding, water table level and its fluctuation, river current strength, substrate ability to retain water, etc. WFS vegetation has been insufficiently studied in the Balkan Peninsula, especially in Bosnia and Herzegovina. By means of numerical classification, we aimed to classify Western Balkans WFS at the alliance level, and to identify the main underlying ecological gradients driving the variation in species composition. The dataset containing all published and available unpublished relevés from Slovenia, Croatia and Bosnia and Herzegovina was first classified using the EuroVegChecklist Expert System in Juice software in order to assign the corresponding class to each of the relevés. Relevés were subsequently analyzed within each of the four WFS classes (*Alno glutinosae-Populetea albae*, *Salicetea purpureae*, *Alnetea glutinosae* and *Franguletea*). Cluster analysis resulted in eight alliances, *Salicion albae*, *Salicion triandrae*, *Salicion eleagno-daphnoidis*, *Alno-Quercion*, *Alnion incanae*, *Alnion glutinosae*, *Betulion pubescentis* and *Salicion cinereae*, while one cluster could not be assigned with certainty. Edafic factors were found to be the most important factors determining the floristic composition and syntaxa differentiation of WFS in the study area.

Keywords: *Alnetea glutinosae*; *Alno-Populetea*; ecological factors; ecological gradient; floodplain; *Franguletea*; riparian forests; *Salicetea purpureae*; swamp forests; vegetation

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1. Introduction

There are three types of natural vegetation, i.e., zonal, extrazonal and azonal, which generally develop in accordance with the biotic, climatic and soil conditions [1–3]. While zonal vegetation is the large-scale expression of climate dominating a particular area (extrazonal vegetation is found in microclimatically suitable habitats outside of its climatic zone), azonal communities exist in different macroclimatic belts due to the strong influence of specific ecological factors that do not allow zonal vegetation to prevail. Examples of such azonal vegetation are forest and scrub communities developed on sites with periodic/regular flooding and/or high groundwater level. In such sites, zonal vegetation is replaced by azonal, i.e., hygrophilous and mesohygrophilous forest and scrub vegetation. Many terms encompass such plant communities (floodplain, alluvial, riparian, swamp forests); however, none of the terms embrace the entirety of this type of vegetation. Junk and Piedade [4] used the term wetland forests to refer to all types of forests that are subject to irregular, seasonal or long-term flooding, but this definition overlooked scrub vegetation. In this paper, therefore, we refer to forest and scrub communities subjected to irregular, seasonal or long-term flooding as "wetland forests and scrub" (WFS). Based on the type of flooding and spatial position of the community in relation to the river stream, WFS are divided into alluvial and swamp WFS [5].

Alluvial WFS are mostly confined to rivers and other smaller streams. There, plant communities are often under the impact of flooding by flowing water. The floristic composition of these stands reflects the specific habitat conditions, such as flood duration, soil relocation, accumulation of nutrients, physical damage to and uprooting of plants, seed transportation and sometimes intensive changes in soil moisture [6–9]. Such events favor plant species that are able to utilize accessible resources, and tolerate disturbance events as well as competitive relationships [10].

On the other hand, swamp WFS are conditioned by micro-relief depressions that can occur near a river but are often not related to flowing water [11]. Important factors for forming and maintaining swamp habitats are a combination of relief depressions, a substrate capability to retain the water on the surface, and the presence of a water source to fill and maintain a high groundwater table. Such ecosystems often lack oxygen and are thus composed of species tolerant to oxidative stress [11]. It should be pointed out that it is sometimes hard to draw a line between a swamp and alluvial WFS, since both types of flooding might be present at the same sites. Stagnant water may also be present only for a part of the year but still have a huge impact on the floristic composition.

WFS ecosystems encompass the physical environment and biological communities of the inland–freshwater interface and are recognized as highly diverse compared to surrounding areas [12]. Their conservation is crucial for preserving biological diversity, since they contain specialist ecological communities and provide crucial ecosystem services, such as species and gene pool diversity conservation, prevention of riverbank erosion, prevention of floods and water retention, nutrients and contaminant retention, carbon fixation and storage, cultural heritage and ecotourism and many others, while occupying a relatively small landscape area [13,14]. However, they are globally suffering intense anthropogenic pressures (e.g., altered natural water regime, habitat fragmentation, invasive species, to name just a few), which puts them among the most endangered ecosystems of all [7,15,16]. This has led to some of the WFS types (i.e., temperate and boreal hardwood riparian woodland, Mediterranean and Macaronesian riparian woodland, and broad-leaved swamp woodland) being listed as endangered habitats in the Red List of European Habitats [17]. They are also listed in Annex I of the European Union Habitats Directive as habitats of community interest for conservation [18].

We consider that the basic prerequisite for successful legal protection, preservation, monitoring and restoration of habitats is a good understanding of ecological factors and drivers that make and maintain those habitats. This can hardly be achieved without adequate classification. In Europe, WFS communities have to some extent been relatively well studied on the European [11,19] and the national levels [20–25]. However, different communities of WFS are differentiated by subtle differences in the water table, which often leads to mosaics and transitional communities, making them difficult to classify as a complex. Douda et al. [11] thus did not analyze *Salix* dominated communities, while Kalníková et al. [19] treated only gravel-bar scrub vegetation, which is represented by only one alliance in this part of Europe (i.e., *Salicion eleagno-daphnoidis*). Furthermore, in the study of Douda et al. [11], the Balkan Peninsula was heavily underrepresented, which is especially true for Bosnia and Herzegovina (B&H), where there were virtually no relevés included in the study.

Although there have been some reviews of WFS in the Western Balkans [9,26–29], they were not made based on numerical analyses, while syntaxonomic frameworks and concepts are often outdated and non-congruent among themselves. One of the major reasons for the lack of comprehensive analyses has been the insufficient number of published relevés of these communities in part of the research area. For instance, only a few dozen relevés have been published in B&H [30–33].

Another issue is the ambiguous treatment of some alliances listed in Mucina et al. [5]. For example, the *Alno-Quercion* alliance has been a matter of contention from the beginning [9,11,34,35], whereby it has sometimes been considered part of *Alnion incanae*, and sometimes as an alliance of its own. Another example is the alliance *Fraxino-Quercion*, which includes elm–ash and oak riparian forests and was previously considered to be part of *Alnion incanae*, under the suballiance name *Ulmenion* Oberd, 1953. Albeit *Ulmenion* is known to occur in the study area [9], *Fraxino-Quercion* is by definition geographically limited to Central Europe and, consequently, is, a priori, not to be found in the areas south of Austria, Hungary and Romania (i.e., southern Pannonia and the Balkans) [5,36]. Additionally, poplar (*Populus nigra* and *P. alba*)-dominated forests from the region of the Western Balkans do not have a proper syntaxonomic status, with *Populion albae* being by definition a Mediterranean alliance.

This study aimed to provide a comprehensive overview of Western Balkans WFS based on the numerical classification of all available published and unpublished phytosociological relevés from this region. Specifically, we aimed to a) provide a consistent classification of Western Balkans WFS at the alliance level; b) characterize the identified vegetation types by their species composition, ecology and distribution; and c) identify the main underlying gradients driving the variation in species composition of WFS in the Western Balkans.

2. Materials and Methods

2.1. Study Area

The study area encompasses the Western Balkans region, i.e., the southwestern margin of the Pannonian Basin and Dinaric and Julian Alps in Slovenia, Croatia and B&H. Biogeographically, it includes Continental and Alpine biogeographic regions [37]. For the purpose of this study, the Mediterranean biogeographic region was not considered (Figure 1). The area covers approximately 103,000 km^2 (13.3468° E to 19.6534° E and 43.2207° N to 46.8758° N). The northern part of the study area is mostly represented by lowlands with floodplains of large and slow flowing rivers (Sava, Mura, Drava, Krka, Kupa, Danube, Una, Vrbas, Bosna and Drina), depositing finer sediment. The area has been subjected to intensive anthropogenic pressure for a long period of time, with one of the most affected areas being north B&H (Sava River floodplain with its tributaries), which has undergone significant water regime changes, deforestation and conversion of land into intensive agricultural fields in the past few centuries, with the majority of natural forests destroyed [32,38,39]. Lowland forests in Croatia and Slovenia are better preserved but still under great pressure [9,40,41]. The southern and western parts of the research area are represented by the hills and mountains of the Dinaric and Julian Alps. Most of the rivers and streams in this area are smaller and faster, depositing alluvial material of coarser structure. Forest vegetation is usually developed in narrow strips along the streams with the exception of karst poljes, where there is flat terrain and soil conditions similar to those in lowland floodplains.

Figure 1. Location of the study area (in saturated tints). Inset map shows the position of the study area in Europe.

2.2. Data Collection and Preparation

Data (phytosociological relevés; vegetation plots) were obtained from three vegetation databases: Slovenia (EU-00-021), Croatia (EU-HR-002) and B&H (EU-BA-001). Codes refer to the Global Index of Vegetation-Plot Databases (www.givd.info (accessed on 30 January 2023)). Relevés were selected from databases based on their original author assignment to WFS or, in the absence of assignment, indicator species based on various sources [5,11,22,24] were used (i.e., *Acer negundo*, *Alnus glutinosa agg.*, *Alnus incana*, *Betula pendula*, *Betula pubescens*, *Frangula alnus*, *Fraxinus angustifolia*, *Fraxinus excelsior*, *Myricaria germanica*, *Populus alba*, *Populus canadensis*, *Populus canesens*, *Populus nigra*, *Quercus robur*, *Salix alba*, *Salix cinerea*, *Salix eleagnos*, *Salix euxina*, *Salix myrsinifolia*, *Salix purpurea*, *Salix triandra*, *Salix viminalis*, *Salix x rubens*, *Ulmus laevis* and *Ulmus minor*). Indicator species were also used in order the clear the dataset of non-forest/scrub relevés, in which the criterion for keeping a relevé in the dataset was the presence of at least one of the indicator species with a combined cover value greater than 25% in upper layers (shrub layer for scrub and tree layer for forest). All relevés without coordinates or sharing the same coordinates, as well as relevés from studies related to forest dieback, were excluded. After a closer inspection of the dataset, we also omitted several relevés originally assigned to *Salicetum albae* and *Lamio orvalae-Salicetum albae* by Dakskobler [42] and Dakskobler et al. [43] due to their transitional and mixed character. Additionally, around 230 relevés from WFS were recorded in B&H in the last several years and added to the dataset. A total of 1994 relevés was compiled in a Turboveg database [44], and exported to JUICE 7 software [45] for further analysis.

Taxa recorded for more than one layer were merged into one layer because of inconsistent sampling. Records of species determined to the genus level were deleted. Plant nomenclature followed Euro+Med [46]. Species from taxonomically critical groups that were not always identified by the relevé authors were combined into aggregates (agg.), and species that included several subspecies that were not always recorded or recognized by authors were combined and marked with the abbreviation "s.l." (sensu lato) and are also listed in Appendix A. The newly described taxon *Alnus rohlenae* [47] was treated as part of *Alnus glutinosa* agg. We also merged all subspecies of *Fraxinus angustifolia*, since those were not consistently recorded. Although many authors did not record mosses, we kept them in the dataset for the purpose of expert classification.

Although WFS belong to four vegetation classes, they usually share a number of species, and often only the cover ratio of these species makes a difference even between different classes. Furthermore, one class (*Franguletea*) is differentiated more physiognomically (scrub) than floristically, which made it hard to delineate the class from the remaining swamp communities within the original dataset. We thus used the EuroVegChecklist (EVC) expert system of classification of vegetation plots to classes [5] to divide the initial dataset into four vegetation classes of WFS that would be subsequently analyzed separately. It was performed in JUICE software using a sum of powered species cover with no transformation. Since the original EVC expert system species list was missing some important characteristic species required for the proper assignment of relevés to some of the classes (especially *Salicetea purpureae*), we modified it based on species diagnostic for classes according to various authors [11,22,24]. Specifically, *Urtica dioica*, *Echinocystis lobata*, *Humulus lupulus*, *Phalaroides arundinacea*, *Poa trivialis*, *Galium aparine*, *Solidago gigantea* and *Acer negundo* were assigned to *Salicetea purpureae*; *Carex riparia* to *Alno-Populetea; Carex riparia* and *Caltha palustris* to *Alnetea glutinosae*; and *Salix pentandra* to *Franguletea*. Since the EVC expert system outputs a list of classes ordered by the decreasing value of a relevé's affiliation to the given class for each and every relevé, all relevés with initial best scores for non-forest/scrub vegetation class were reassigned to the first scrub or forest class with the next best value. After this, we only kept relevés assigned to *Alnetea glutinosae*, *Franguletea*, *Salicetea purpureae* and *Alno glutinosae-Populetea albae*, while other classes were omitted from the further analyses (mainly *Quercus robur*-dominated plots belonging to *Carpino-Fagetea*). At this point, we removed all mosses from the dataset because of inconsistent sampling. The dataset was then divided into four subdatasets belonging to four WFS classes. Within each subdataset, we performed outlier analysis using PC-ORD 5.0 [48], and relevés whose species composition deviated more than ±2SD from the mean calculated Euclidean distance of all plots within the subdataset were omitted. This resulted in a total of 1086 relevés in all four subdatasets combined (*Salicetea purpureae* subdataset—210 relevés; *Alno-Populetea* subdataset—685 relevés; *Alnetea glutinosae* subdataset—135 relevés; and *Franguletea* subdataset—56 relevés). Prior to the numerical analysis of subdatasets, we deleted species occurring in up to two relevés in a subdataset since the removal of rare species has proven to be useful in minimizing noise of classification.

2.3. Data Analysis

Hierarchical classification was performed on three subdatasets (*Salicetea purpureae*, *Alno-Populetea* and *Alnetea glutinosae*). We did not divide the *Franguletea* subdataset further, since this class is only represented by one alliance in the studied area. Classification was carried out using cluster analysis in PC-ORD 5.0. Data were transformed with an ordinal scale with cut levels: 0 3 5 15 25, as proposed by Tichý et al. [49]. The relative Sørensen index, as the distance measure, and beta flexible set to −0.25 for group linkage, were used. Three clusters were accepted as the optimal level of division for *Salicetea purpureae* and *Alno-Populetea* subdatasets, while two clusters were chosen for the *Alnetea glutinosae* subdataset. As well as being best ecologically and floristically interpretable, cluster numbers for *Alno-Populetea* and *Alnetea glutinosae* were also confirmed by the Crispness of Classification method for identifying the optimum number of clusters [50], which was also performed in JUICE software. The optimum number of clusters for *Salicetea purpureae* was two; however, since the next division resulted in differentiating *Salicion triandrae* from *Salicion albae*, we settled for three clusters in this subdataset, too. After classification at the level of subdatasets (classes), all four subdatasets, with previously removed rare species restored, were unified into the final WFS dataset for further analysis.

To showcase the differences and similarities in species composition among alliances across all four classes of WFS, as well as within each of the classes (except *Franguletea*), an overall synoptic table of alliances within the unified WFS dataset, as well as synoptic tables of alliances within each of the classes *Salicetea purpureae*, *Alno glutinosae-Populetea albae* and *Alnetea glutinosae*, were generated in the JUICE program and the phi coefficient was used as the measure of fidelity. For each combination of clusters, each of the nine, three, three and two groups was virtually adjusted to 1/9, 1/3, 1/3 and 1/2 of the size of the entire dataset, while holding the percentage occurrences of species within and outside the target group the same as in the original dataset [51]. The threshold of the phi value was set at 0.30 for a species to be considered diagnostic. Fisher's exact test was calculated and gave a zero fidelity value to species whose phi values were not statistically significant (p > 0.001).

All 1086 relevés of the unified final WFS dataset, together with the selected ecological variables, were projected onto a DCA plot. Non-transformed percentage covers of species were used, with rare species downweighted. Species ecological indicator values (EIVs) for temperature, light, moisture, soil reaction and nutrients according to Pignatti et al. [52] were used as explanatory ecological variables. Unweighted average EIVs were calculated in JUICE. The significance of their correlation with the DCA relevé scores was tested using the modified permutation test [53]. Other explanatory variables (bioclimatic, elevation, chorotypes, lifeforms, CSR ecological strategies, urbanity type, type of reproduction and origin of taxa) were tested for the strength of correlation with the first and second DCA axis. Bioclimatic variables were obtained from the WorldClim 2 database [54], chorotypes were determined following Pignatti et al. [52] and Gajić [55], life forms according to Raunkiaer [56], while CSR strategies, urbanity type, type of reproduction and origin of taxa were obtained from the BIOLFLOR database [57]. The significances of correlations between these explanatory variables and DCA relevé scores were calculated using the Kendall tau coefficient in Statistica v. 14.0 software (TIBCO Software Inc.). Only three of those variables with the highest explanatory value were selected for further analysis and projected onto a DCA plot.

Syntaxonomical concepts and nomenclature of higher syntaxa followed Mucina et al. [5]. Complete names of associations and subasociations used in text (with author citation) are listed in Appendix B.

3. Results

3.1. Classification and Ordination

Nine ecologically and floristically distinct clusters of relevés of WFS were obtained after expert classification of the initial dataset and numerical classification of the subdatasets (Tables 1 and S1–S4, Appendix C, Figures 2–4). Three out of four subdatasets, each representing an individual class gained during expert classification, were subjected to numerical classification, which resulted in: (a) three clusters within *Salicetea purpureae*; (b) three clusters within *Alno glutinosae-Populetea albae*; and (c) two clusters within *Alnetea glutinosae*. We tried to classify the fourth subdataset, i.e., the class *Franguletea*, but it turned out to be very homogeneous group. Bearing in mind that only one alliance (*Salicion cinereae*) from this class is recognized to be present in the study area [36], we have decided not to further divide it.

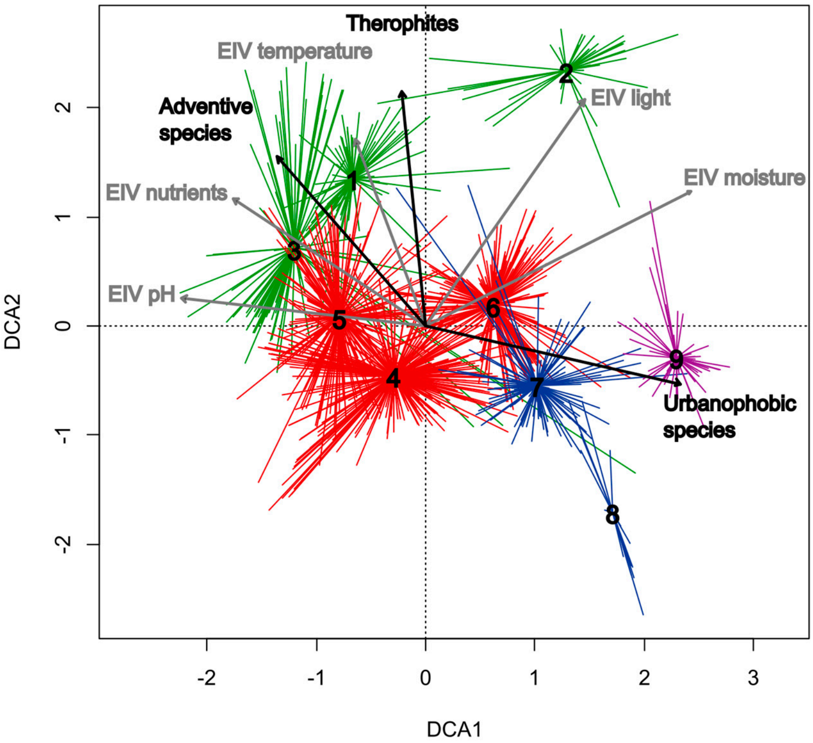

Figure 2. DCA spider plot of the final dataset (1086 relevés). Centroids of clusters are indicated by numbers corresponding to Table 1, Figures 3–4, Tables S1–S4, Appendix C and to those used in the text: 1—*Salicion albae*, 2—*Salicion triandrae*, 3—*Salicion eleagno-daphnoidis*, 4—*Alnion incanae*, 5—*not assigned*, 6—*Alno-Quercion*, 7—*Alnion glutinosae*, 8—*Betulion pubescentis*, 9—*Salicion cinereae*. The colors represent groups of clusters (classes): *Salicetea purpureae* (green), *Alno-Populetea* (red), *Alnetea* (blue) and *Franguletea* (purple).

Table 1. Synoptic table of WFS types in the Western Balkans. Frequencies of species are presented as percentages with phi values multiplied by 100 shown in superscript. Diagnostic species (phi values higher than 0.30) are shaded. Diagnostic species are sorted by decreasing fidelity. Species with a frequency lower than 30% in a cluster for which they are diagnostic are not shown. Only up to 12 species with the highest phi value are presented. Cluster numbers: 1—*Salicion albae*, 2—*Salicion triandrae*, 3—*Salicion eleagno-daphnoidis*, 4—*Alnion incanae*, 5—*not assigned*, 6—*Alno-Quercion*, 7—*Alnion glutinosae*, 8—*Betulion pubescentis*, 9—*Salicion cinereae*. Cluster numbers correspond to Figures 2–4, Tables S1–S4, Appendix C and to those used in the text. The full version of this table is available in Table S1.

Cluster Number	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
No. of Relevés	**90**	**37**	**83**	**281**	**178**	**226**	**121**	**14**	**56**
Salicion albae									
Salix alba	91 $^{58.1}$	8 $^{---}$	23 $^{---}$	21 $^{---}$	47 $^{20.4}$	1 $^{---}$	2 $^{---}$	. $^{---}$	9 $^{---}$
Salix euxina	36 $^{33.3}$	. $^{---}$	13 $^{---}$	14 $^{---}$	10 $^{---}$	. $^{---}$	5 $^{---}$	. $^{---}$	2 $^{---}$
Salicion triandrae									
Salix triandra	19 ^{4}	97 ^{82}	11 $^{---}$	2 $^{---}$	1 $^{---}$	. $^{---}$	. $^{---}$	. $^{---}$	4 $^{---}$
Rorippa sylvestris	6 $^{---}$	49 $^{56.5}$	8 $^{---}$	1 $^{---}$	2 $^{---}$	1 $^{---}$	. $^{---}$	. $^{---}$	. $^{---}$
Echinocystis lobata	39 $^{24.2}$	59 $^{44.7}$	5 $^{---}$	2 $^{---}$	11 $^{---}$	5 $^{---}$	3 $^{---}$	. $^{---}$	7 $^{---}$
Phalaroides arundinacea	56 $^{25.6}$	78 $^{44.3}$	34 $^{7.6}$	7 $^{---}$	15 $^{---}$	4 $^{---}$	19 $^{---}$	. $^{---}$	7 $^{---}$
Agrostis stolonifera agg.	34 $^{10.9}$	70 $^{41.7}$	18 $^{---}$	3 $^{---}$	19 $^{---}$	8 $^{---}$	2 $^{---}$	29 $^{---}$	12 $^{---}$
Calystegia sepium	46 $^{25.1}$	62 $^{40.3}$	14 $^{---}$	5 $^{---}$	11 $^{---}$	7 $^{---}$	4 $^{---}$	. $^{---}$	14 $^{---}$
Persicaria dubia	12 $^{---}$	43 $^{36.7}$	29 $^{20.4}$	6 $^{---}$	2 $^{---}$	1 $^{---}$	2 $^{---}$	. $^{---}$	2 $^{---}$
Rorippa amphibia	10 $^{---}$	30 $^{35.3}$	2 $^{---}$	. $^{---}$	1 $^{---}$	6 $^{---}$	3 $^{---}$	. $^{---}$	2 $^{---}$

Bidens tripartitus	14 ---	43 $^{30.9}$	4 ---	4 ---	4 ---	26 $^{12.7}$	12 ---	. ---	14 ---
Salicion eleagno-daphnoidis									
Salix eleagnos	4 ---	. ---	70 $^{70.4}$	14 ---	2 ---	. ---	. ---	. ---	. ---
Salix purpurea	18 ---	16 ---	84 $^{62.9}$	9 ---	8 ---	. ---	5 ---	. ---	14 ---
Petasites hybridus	1 ---	. ---	53 $^{50.8}$	31 $^{24.4}$	2 ---	. ---	1 ---	. ---	2 ---
Saponaria officinalis	3 ---	. ---	31 $^{46.4}$	2 ---	3 ---	. ---	. ---	. ---	. ---
Clematis vitalba	3 ---	. ---	43 $^{37.8}$	27 $^{19.4}$	17 ---	1 ---	2 ---	. ---	. ---
Taraxacum sect. *Taraxacum*	8 ---	16 ---	42 $^{37.7}$	6 ---	8 ---	4 ---	1 ---	. ---	5 ---
Galium mollugo	8 ---	11 ---	37 $^{35.5}$	6 ---	7 ---	1 ---	4 ---	. ---	5 ---
Chaerophyllum hirsutum	3 ---	. ---	35 $^{30.2}$	30 $^{23.8}$	2 ---	. ---	12 ---	. ---	5 ---
Alnion incanae									
Corylus avellana	2 ---	. ---	27 ---	63 $^{44.8}$	20 ---	19 ---	15 ---	. ---	. ---
Acer pseudoplatanus	. ---	. ---	35 $^{26.1}$	50 $^{42.6}$	3 ---	1 ---	13 ---	. ---	2 ---
Lamium galeobdolon agg.	3 ---	. ---	11 ---	49 $^{42.4}$	24 ---	8 ---	6 ---	. ---	. ---
Sambucus nigra	30 ---	3 ---	12 ---	74 $^{38.9}$	61 $^{28.4}$	21 ---	21 ---	. ---	12 ---
Acer campestre	2 ---	. ---	12 ---	57 $^{38.2}$	21 ---	48 ^{30}	9 ---	. ---	. ---
Fraxinus excelsior	2 ---	. ---	39 $^{25.9}$	47 ^{35}	8 ---	2 ---	20 ---	. ---	4 ---
Brachypodium sylvaticum	13 ---	. ---	53 $^{25.7}$	64 $^{34.8}$	46 $^{19.8}$	8 ---	16 ---	. ---	4 ---
Symphytum tuberosum agg.	3 ---	. ---	4 ---	35 $^{34.2}$	27 $^{24.1}$	1 ---	4 ---	. ---	. ---
Geum urbanum	2 ---	. ---	7 ---	47 $^{33.6}$	30 ---	29 ---	10 ---	. ---	. ---
Lamium orvala	. ---	. ---	23 ---	33 ^{33}	13 ---	. ---	2 ---	. ---	. ---
Carex sylvatica	2 ---	. ---	5 ---	35 $^{31.8}$	17 ---	15 ---	8 ---	. ---	. ---
Aegopodium podagraria	26 ---	11 ---	35 ---	70 $^{31.1}$	57 $^{20.9}$	14 ---	26 ---	21 ---	11 ---
Cluster 5									
Populus alba	7 ---	. ---	. ---	1 ---	38 $^{47.5}$	8 ---	1 ---	. ---	. ---
Ulmus laevis	13 ---	. ---	1 ---	4 ---	54 $^{43.1}$	38 ^{26}	7 ---	. ---	. ---
Populus nigra	22 ---	. ---	33 $^{20.2}$	7 ---	54 $^{42.6}$	2 ---	1 ---	. ---	. ---
Prunus padus	6 ---	. ---	4 ---	5 ---	40 $^{37.9}$	4 ---	21 ---	. ---	4 ---
Arum maculatum	2 ---	. ---	1 ---	17 $^{14.7}$	30 $^{34.2}$	6 ---	. ---	. ---	2 ---
Solidago gigantea	16 ---	. ---	18 ---	14 ---	44 $^{33.9}$	7 ---	11 ---	. ---	2 ---
Acer negundo	23 $^{22.4}$	. ---	2 ---	3 ---	30 $^{32.1}$	4 ---	1 ---	. ---	. ---
Galium aparine	56 $^{26.4}$	14 ---	16 ---	27 ---	62 ^{32}	23 ---	13 ---	. ---	4 ---
Pulmonaria officinalis	1 ---	. ---	10 ---	34 $^{27.5}$	37 $^{30.9}$	8 ---	2 ---	. ---	2 ---
Alno-Quercion									
Fraxinus angustifolia s.lat.	7 ---	. ---	1 ---	9 ---	43 $^{19.9}$	84 $^{55.3}$	37 ---	. ---	4 ---
Ulmus minor	4 ---	. ---	1 ---	10 ---	14 ---	52 $^{47.3}$	15 ---	. ---	. ---
Quercus robur	1 ---	. ---	4 ---	11 ---	37 ---	79 $^{46.5}$	33 ---	36 ---	9 ---
Crataegus laevigata	1 ---	. ---	1 ---	9 ---	3 ---	39 $^{42.6}$	14 ---	. ---	. ---
Acer tataricum	2 ---	. ---	. ---	8 ---	1 ---	31 $^{40.4}$	5 ---	. ---	. ---
Rumex sanguineus	10 ---	. ---	2 ---	12 ---	12 ---	42 $^{37.2}$	8 ---	. ---	5 ---
Carex remota	14 ---	. ---	. ---	33 ---	17 ---	61 $^{35.6}$	26 ---	29 ---	2 ---
Glechoma hederacea	44 ---	11 ---	7 ---	31 ---	37 ---	65 $^{34.5}$	11 ---	. ---	9 ---
Stachys palustris	11 ---	5 ---	1 ---	2 ---	10 ---	46 $^{34.3}$	34 ^{22}	. ---	7 ---
Lysimachia nummularia	24 ---	5 ---	5 ---	23 ---	24 ---	62 $^{30.7}$	27 ---	21 ---	27 ---
Alnion glutinosae									
Carex elongata	. ---	. ---	. ---	1 ---	. ---	20 ^{12}	55 $^{53.1}$	. ---	12 ---
Carex vesicaria	7 ---	. ---	. ---	2 ---	3 ---	11 ---	38 $^{39.3}$	. ---	11 ---
Peucedanum palustre	. ---	. ---	. ---	6 ---	2 ---	23 $^{8.1}$	52 $^{36.2}$	36 ---	18 ---
Carex riparia	3 ---	. ---	. ---	2 ---	3 ---	24 $^{20.8}$	36 ^{36}	. ---	4 ---
Valeriana dioica s.lat.	1 ---	. ---	4 ---	10 ---	5 ---	16 ---	50 $^{35.4}$	21 ---	25 ---
Lycopus europaeus	14 ---	8 ---	6 ---	24 ---	8 ---	46 $^{16.3}$	65 $^{32.3}$	. ---	57 $^{25.7}$

Betulion pubescentis									
Betula pubescens	. ---	. ---	. ---	. ---	. ---	1 ---	. ---	86 91.5	. ---
Molinia caerulea agg.	. ---	5 ---	11 ---	2 ---	. ---	1 ---	7 ---	93 81.8	4 ---
Pinus sylvestris	. ---	. ---	4 ---	. ---	. ---	. ---	. ---	71 80.7	. ---
Sorbus aucuparia	. ---	. ---	. ---	3 ---	. ---	. ---	2 ---	57 70.2	. ---
Betula pendula	. ---	. ---	. ---	1 ---	. ---	1 ---	1 ---	50 66.5	. ---
Salix aurita	. ---	. ---	. ---	1 ---	. ---	1 ---	2 ---	43 61.2	. ---
Knautia sarajevensis	. ---	. ---	. ---	. ---	. ---	. ---	. ---	36 57.5	. ---
Calamagrostis villosa	. ---	. ---	. ---	. ---	. ---	. ---	. ---	36 57.5	. ---
Carex rostrata	. ---	. ---	. ---	. ---	. ---	. ---	. ---	36 57.5	. ---
Frangula alnus	1 ---	. ---	20 ---	21 ---	7 ---	41 7.6	66 26.7	100 52.5	23 ---
Epilobium palustre	. ---	5 ---	. ---	1 ---	1 ---	. ---	2 ---	36 50.3	. ---
Rubus hirtus s.lat.	. ---	. ---	1 ---	14 8.8	. ---	4 ---	1 ---	43 49.1	2 ---
Salicion cinereae									
Salix cinerea	3 ---	8 ---	4 ---	2 ---	. ---	8 ---	28 6.3	36 ---	100 68.8
Filipendula ulmaria	14 ---	. ---	8 ---	26 ---	12 ---	8 ---	45 23.9	. ---	55 32.8
Diagnostic species for more than one cluster									
Alnus glutinosa agg.	12 ---	. ---	11 ---	81 37.6	31 ---	47 ---	94 47.8	. ---	7 ---
Other species with high frequency									
Urtica dioica	82 21	86 24	48 ---	59 ---	66 ---	61 ---	43 ---	. ---	27 ---
Rubus caesius	73 ---	19 ---	58 ---	70 ---	90 29.5	69 ---	46 ---	. ---	12 ---
Solanum dulcamara	38 ---	81 29.6	27 ---	22 ---	13 ---	38 ---	54 9.9	29 ---	59 13.7
Galium palustre agg.	29 ---	49 ---	6 ---	8 ---	10 ---	58 16.1	60 17.3	36 ---	70 24.7
Ranunculus repens	23 ---	35 ---	16 ---	37 ---	16 ---	48 10.6	49 11.3	14 ---	64 23
Cornus sanguinea	43 ---	. ---	43 ---	65 24.7	64 24.2	37 ---	22 ---	. ---	14 ---
Lysimachia vulgaris	28 ---	19 ---	8 ---	16 ---	10 ---	33 ---	67 28	43 ---	50 15
Angelica sylvestris	24 ---	11 ---	46 14.8	37 8.1	12 ---	10 ---	31 ---	29 ---	45 ---
Lythrum salicaria	27 ---	57 23.9	18 ---	6 ---	7 ---	31 3.6	44 13.5	. ---	52 19.9
Iris pseudacorus	43 ---	14 ---	4 ---	6 ---	29 ---	54 22.3	52 20.4	. ---	38 ---
Viburnum opulus	10 ---	. ---	13 ---	43 13.1	35 ---	25 ---	53 21	36 ---	25 ---
Euonymus europaeus	32 ---	3 ---	12 ---	55 25.2	47 18.9	31 ---	26 ---	. ---	12 ---
Persicaria hydropiper	28 ---	57 28.9	5 ---	15 ---	10 ---	50 22.8	31 ---	. ---	9 ---
Caltha palustris	7 ---	. ---	11 ---	30 ---	8 ---	31 ---	48 21.5	36 ---	34 ---
Humulus lupulus	43 17.4	27 ---	6 ---	32 ---	39 13.6	10 ---	26 ---	. ---	21 ---
Poa trivialis	43 19.8	14 ---	22 ---	20 ---	38 14.8	21 ---	11 ---	. ---	18 ---
Deschampsia cespitosa	4 ---	. ---	40 17.1	29 7.5	13 ---	22 ---	29 ---	36 ---	11 ---
Crataegus monogyna	7 ---	. ---	22 ---	48 26.1	34 ---	46 24.4	14 ---	. ---	2 ---
Myosotis palustris agg.	12 ---	30 ---	4 ---	10 ---	2 ---	35 15.8	40 20.4	7 ---	23 ---
Circaea lutetiana	9 ---	. ---	. ---	44 25.7	35 ---	38 20.3	22 ---	. ---	2 ---

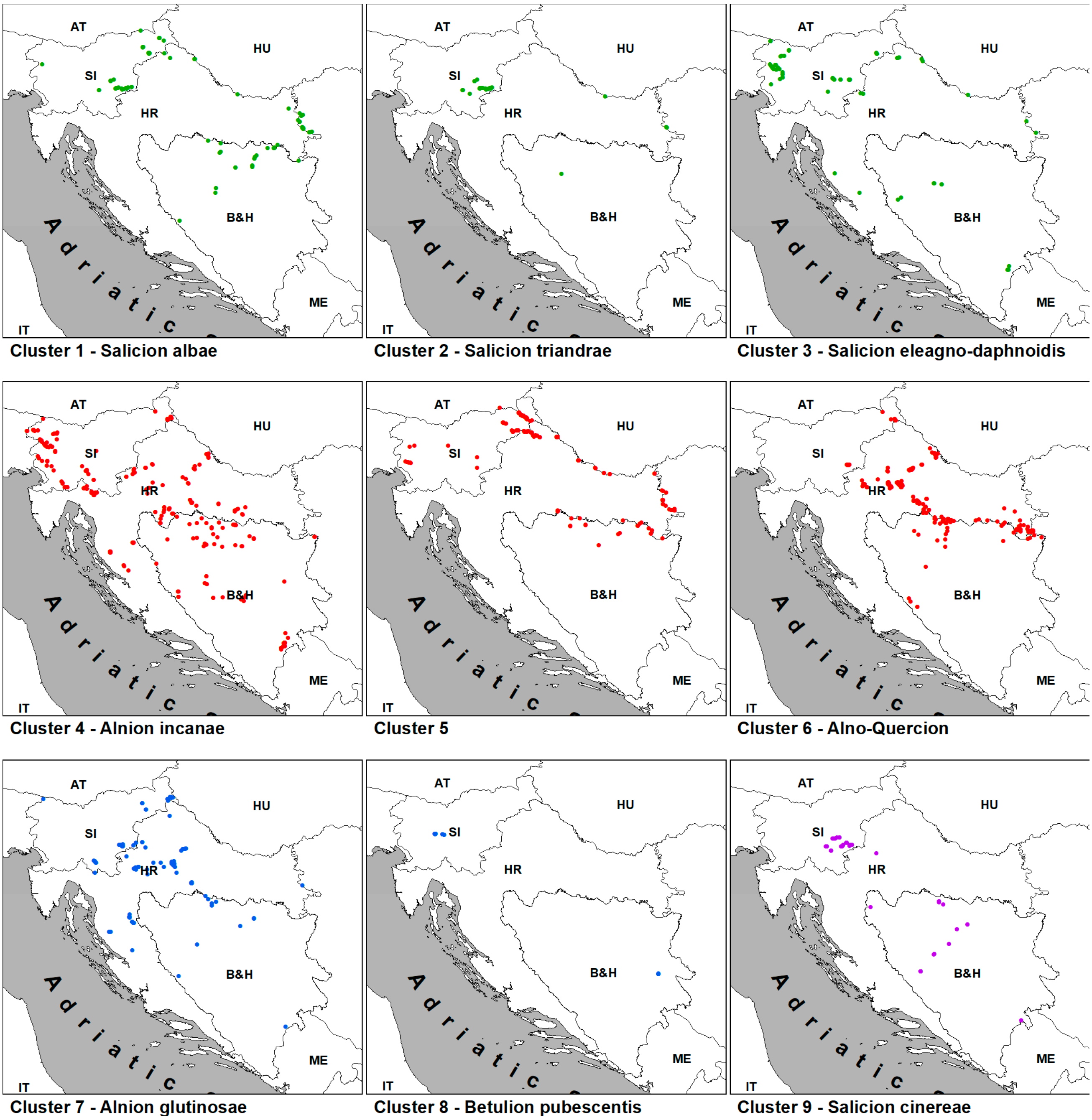

Figure 3. Distribution of relevés classified into the particular cluster. Cluster numbers correspond to Table 1, Figures 2 and 4, Tables S1–S4, Appendix C and to those used in the text. The colors represent groups of clusters (classes): *Salicetea purpureae* (green), *Alno-Populetea* (red), *Alnetea* (blue) and *Franguletea* (purple).

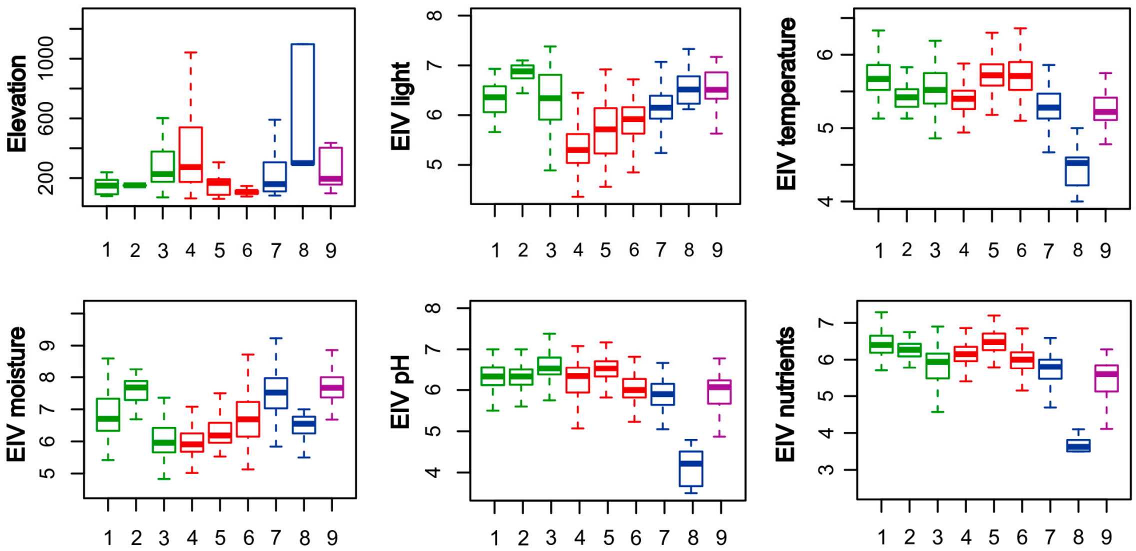

Figure 4. Comparison of the selected EIVs and elevation among clusters. Boxes indicate the 25–75% interquartile range with their median (bold line). Cluster numbers correspond to Table 1, Figures 2 and 3, Tables S1–S4, Appendix C and to those used in the text. The colors represent groups of clusters (classes): *Salicetea purpureae* (green), *Alno-Populetea* (red), *Alnetea* (blue) and *Franguletea* (purple).

Comparing these results with the accepted definitions of the syntaxa at the alliance level, we found for the most part a good correspondence. The syntaxonomic interpretation of the clusters of the presented classification was as follows: cluster 1—*Salicion albae*; cluster 2—*Salicion triandrae*; cluster 3—*Salicion eleagno-daphnoidis*; cluster 4—*Alnion incanae*; cluster 6—*Alno-Quercion roboris*; cluster 7—*Alnion glutinosae*; cluster 8—*Betulion pubescentis*; cluster 9—*Salicion cinereae*. Cluster 5 is mainly made of relevés traditionally classified as *Ulmenion* (without *Alno-Quercion*), but it does not fit into the current concept of geographical differentiation of European hardwood riparian forests, whereas *Fraxino-Quercion roboris* is limited to Central Europe, and *Alno-Quercion* is the only alliance to appear in the Balkans. Nevertheless, we decided to keep this cluster as it is, because it is ecologically and floristically very well differentiated from the rest of the dataset.

Classification is backed by the DCA ordination plot (Figure 2), in which EIVs for moisture, soil reaction, nutrients, temperature, and light are significantly related to the first two DCA axes ($p < 0.05$). The percentages of therophytes, urbanophobic, and adventive species were selected among the other explanatory variables having the highest score of statistically significant correlation with the first two DCA axes ($p < 0.001$). The main ecological factors influencing the variation in the floristic composition along the first axis are EIVs for moisture (positively correlated with the first axis), soil reaction and nutrients (negatively correlated with the first axis), suggesting that the main gradient in species composition is the gradient of site moisture, productivity and soil reaction, running from the driest, nutrient-rich and basophilous *Salicion eleagno-daphnoidis*, *Alnion incanae* and cluster 5 (left side of the diagram), to the wettest, nutrient-poor, and acidophilous *Betulion pubescentis* and *Salicion cinereae*. The first axis is also correlated with the type of urbanity, where the most urbanophobic species are found on the right side of the DCA plot. The second DCA axis is most strongly correlated with EIVs for light and temperature (both positively), differentiating the coldest and darkest communities (*Betulion pubescentis* and *Alnion incanae*) from the most temperature- and light-demanding *Salicion triandrae*, *Salicion albae* and *Salicion eleagno-daphnoidis*. The second axis is also positively correlated with the percentage of annual and adventive species, indicating that *Salicetea purpureae* communities are the most disturbed and most endangered by invasive species.

3.2. Overview of the Classified Communities

3.2.1. *Salicetea purpureae* Group of Clusters (Clusters 1–3; Table 1, Columns 1–3; Table A1)

This group of clusters consists of willow scrub and woodland communities that are found near stream banks or on regularly flooded floodplain sites. This class is represented by three alliances in the researched area, which was confirmed by the results of unsupervised classification of the first subdataset.

Cluster 1 (Table 1, column 1; Table A1, column 1)
Syntaxonomy: ***Salicion albae***

This cluster is mostly comprised of relevés of tall *Salix alba*-dominated communities. *Salix euxina* and *Populus nigra* are also sometimes present in the tree layer. Invasive species such as *Acer negundo* and *Amorpha fruticose* can often be important.

Diagnostic (bold) and constant species within the WFS: ***Salix alba***, ***Salix euxina***, *Rubus caesius*, *Galium aparine*, *Phalaroides arundinacea*, *Urtica dioica*.

Diagnostic (bold) and constant species within the *Salicetea purpureae* group of clusters: ***Acer negundo***, ***Amorpha fruticosa***, ***Euonymus europaeus***, ***Rubus caesius***, ***Salix alba***, ***Salix euxina***, ***Carex remota***, ***Galium aparine***, ***Glechoma hederacea***, ***Iris pseudacorus***, *Rubus caesius*, *Phalaroides arundinacea*, *Urtica dioica*.

Ecology and distribution: These communities are usually located on the lower part of river terraces or in regularly flooded micro-depressions formed outside of the main riverbanks. In both cases, floodings with flowing water are regular and relatively long-lasting events. Soils are nutrient-rich fluvisols with a fine granulometric composition capable of retaining water for a long period of the year, although topsoil layers can dry out during summer. They are found in the floodplains of large lowland rivers throughout the whole area of research: Drava, Sava, Danube, Mura, Krka, Una, Vrbas, Bosna and Drina.

Published relevés from this cluster were mainly referred to as *Salicetum albae*, *Galio-Salicetum albae* and *Salici-Populetum*. *Populus nigra* dominated or co-dominated communities were not classified within this cluster or even this group of clusters. Additionally, 24 new and unpublished relevés from B&H were classified within this cluster.

Cluster 2 (Table 1, column 2; Table A1, column 2)
Syntaxonomy: ***Salicion triandrae***

This cluster consists of *Salix triandra*-dominated scrub, with *Salix viminalis* sometimes present. The tree layer is absent, while the height of stands is up to 5 m.

Diagnostic (bold) and constant species within the WFS: ***Salix triandra***, ***Agrostis stolonifera* agg.**, ***Bidens tripartitus***, ***Calystegia sepium***, ***Echinocystis lobata***, ***Persicaria dubia***, ***Phalaroides arundinacea***, ***Rorippa amphibia***, ***Rorippa sylvestris***, ***Rumex crispus***, *Solanum dulcamara*, *Lythrum salicaria*, *Persicaria hydropiper*, *Urtica dioica*.

Diagnostic (bold) and constant species within the *Salicetea purpureae* group of clusters: ***Salix triandra***, ***Solanum dulcamara; Agrostis stolonifera* agg.**, ***Alisma plantago-aquatica***, ***Bidens tripartitus***, ***Calystegia sepium***, ***Echinocystis lobata***, ***Galium palustre* agg.**, ***Lythrum salicaria***, ***Persicaria hydropiper***, ***Phalaroides arundinacea***, ***Rorippa amphibia***, ***Rorippa sylvestris***, *Urtica dioica*.

Ecology and distribution: These communities are usually located on the lowest part of river terraces along the slower downstream of large rivers. They form narrow vegetation strips along riverbanks and on sandbars, where they are under constant accumulation of new sandy and loamy sediment brought by the river current for as many as 100 days a year. With new material accumulating the ground gets higher, and the flood dynamics changes towards fewer days under flood. Hence, these short-lived pioneer communities, after no more than ten years, give away to the next stages in the succession. Although there is a lack of relevés from these communities, they are present in all three countries: Drava, Danube, Vrbas and Drina.

All published relevés from this cluster were originally assigned the name *Salicetum triandrae*. Only one new and unpublished relevé from B&H was classified within this cluster.

Cluster 3 (Table 1, column 3; Table A1, column 3)

Syntaxonomy: ***Salicion eleagno-daphnoidis***

This cluster comprises relevés of *Salix eleagnos* and/or *Salix purpurea*-dominated scrub. Diagnostic species are light-demanding species with moisture requirements varying from moisture-demanding to mesophilic species.

Diagnostic (bold) and constant species within the WFS: ***Clematis vitalba***, ***Salix eleagnos***, ***Salix purpurea***, ***Centaurea nigrescens* ssp. *vochinensis***, ***Chaerophyllum hirsutum***, ***Galium mollugo***, ***Helianthus tuberosus***, ***Knautia drymeia* s.lat.**, ***Lathyrus sylvestris***, ***Melilotus albus***, ***Mentha longifolia***, ***Pastinaca sativa***, ***Petasites hybridus***, ***Petasites paradoxus***, ***Peucedanum altissimum***, ***Pimpinella major***, ***Plantago lanceolata***, ***Saponaria officinalis***, ***Silene vulgaris***, ***Taraxacum* sect. *Taraxacum***, ***Tussilago farfara***, ***Vicia cracca* s.lat.**, *Rubus caesius*, *Brachypodium sylvaticum*.

Diagnostic (bold) and constant species within the *Salicetea purpureae* group of clusters: ***Acer pseudoplatanus***, ***Alnus incana***, ***Carpinus betulus***, ***Clematis vitalba***, ***Corylus avellana***, ***Frangula alnus***, ***Fraxinus excelsior***, ***Hedera helix***, ***Salix eleagnos***, ***Salix purpurea***, ***Salvia glutinosa***, ***Ulmus glabra***, ***Brachypodium sylvaticum***, ***Chaerophyllum hirsutum***, ***Cirsium oleraceum***, ***Deschampsia cespitosa***, ***Equisetum arvense***, ***Erigeron annuus***, ***Eupatorium cannabinum***, ***Festuca gigantea***, ***Galium mollugo***, ***Geranium robertianum***, ***Helianthus tuberosus***, ***Heracleum sphondylium***, ***Knautia drymeia s.lat.***, ***Lamium orvala***, ***Lunaria rediviva***, ***Melilotus albus***, ***Mentha longifolia***, ***Mycelis muralis***, ***Pastinaca sativa***, ***Petasites hybridus***, ***Petasites paradoxus***, ***Peucedanum altissimum***, ***Pimpinella major***, ***Ranunculus lanuginosus***, ***Saponaria officinalis***, ***Silene vulgaris***, ***Stachys sylvatica***, ***Taraxacum sect. Taraxacum***, ***Tussilago farfara***, ***Vicia cracca* s.lat.**, *Rubus caesius*.

Ecology and distribution: These communities are usually developed on gravel or sandy beds of small and medium rivers with fast-flowing water and with regular and intense short floods. Fluctuations are intensified by pronounced drought periods that occur in summer caused by a significant drop in the water table, which is intensified by the inability of gravel and sand to retain water. Relevés are primarily concentrated in Slovenia, while scattered over only a couple of localities in Croatia and Bosnia and Herzegovina at different altitudes.

Published relevés from this cluster were originally assigned the following names: *Salici-Myricarietum*, *Salicetum incano-purpureae*, *Lamio orvalae-Salicetum eleagni*, *Lamio orvalae-Salicetum purpureae*, *Carici-Salicetum myrsinifoliae*, *Salicetum purpureae*, *Salicetum cinereo-purpureae*, *Saponario-Salicetum*. Additionally, nine new and unpublished relevés from B&H were classified within this cluster.

3.2.2. *Alno glutinosae-Populetea albae* Group of Clusters (Clusters 4–6; Table 1, Columns 4–6; Table A2)

The *Alno glutinosae-Populetea albae* group of clusters contains floodplain riparian alder–ash, elm–ash and oak forests on nutrient-rich soils and characterized by inter- and intra-annual fluctuations in the water level. This class is represented by three alliances in the researched area, which was confirmed by the results of unsupervised classification of the second subdataset.

Cluster 4 (Table 1, column 4; Table A2, column 1)

Syntaxonomy: ***Alnion incanae* s. str.**

This cluster consists of forests dominated by *Alnus incana* and/or *A. glutinosa*, as well as *Salix eleagnos*, and sometimes also *S. alba* and/or *S. euxina*. Trees related to mesophilous and ravine forests, such as *Acer pseudoplatanus*, *Fagus sylvatica*, *Fraxinus excelsior* and *Ulmus glabra*, are also frequent. The understory is also a mixture of hygrophilous, mesophilous and nitrophilous species.

Diagnostic (bold) and constant species within the WFS: ***Acer campestre***, ***Acer pseudoplatanus***, ***Alnus glutinosa* agg.**, ***Corylus avellana***, ***Fraxinus excelsior***, ***Sambucus nigra***, ***Aegopodium podagraria***, ***Brachypodium sylvaticum***, ***Cardamine bulbifera***, ***Carex pendula***, ***Carex sylvatica***, ***Geum urbanum***, ***Lamium galeobdolon* agg.**, ***Lamium orvala***, ***Lunaria rediviva***, ***Mercurialis perennis***, ***Oxalis acetosella***, ***Primula acaulis***, ***Symphytum tuberosum* agg.**, *Cornus sanguinea*, *Euonymus europaeus*, *Rubus caesius*, *Urtica dioica*.

Diagnostic (bold) and constant species within the *Alno glutinosae-Populetea albae* group of clusters: ***Acer pseudoplatanus***, ***Alnus glutinosa* agg.**, ***Corylus avellana***, ***Fagus sylvatica***, ***Fraxinus excelsior***, ***Salvia glutinosa***, ***Sambucus nigra***, ***Ulmus glabra***, ***Aegopodium podagraria***, ***Angelica sylvestris***, ***Brachypodium sylvaticum***, ***Cardamine bulbifera***, ***Chaerophyllum hirsutum***, ***Cirsium oleraceum***, ***Equisetum arvense***, ***Knautia drymeia* s.lat.**, ***Lamium galeobdolon* agg.**, ***Lamium orvala***, ***Lunaria rediviva***, ***Mercurialis perennis***, ***Petasites hybridus***, ***Primula acaulis***, ***Ranunculus lanuginosus***, *Acer campestre*, *Cornus sanguinea*, *Euonymus europaeus*, *Rubus caesius*, *Urtica dioica*.

Ecology and distribution: Stands classified in this cluster occur on stream banks and at headwater seepages, which are usually flooded in spring for several days or weeks and usually dry out during the summer. Stands dominated by *Alnus incana* and/or *A. glutinosa*, and sometimes *Salix eleagnos*, *S. alba* and *S. euxina*, together with *Acer pseudoplatanus*, *Fagus sylvatica*, *Fraxinus excelsior* and *Ulmus glabra*, usually occupy banks of small to medium-sized streams of the colline to montane belt, on stony to sandy, nutrient rich colluvial soil. On the other hand, stands dominated by *Alnus glutinosa* are mainly confined to lower and mid-elevations along smaller streams or at headwater seepages with sandy to loamy, slightly acidic and moderately rich soil. They are common in suitable habitats throughout the study area.

Published relevés from this cluster were referred to as: *Alnetum incanae*, *Lamio orvalae-Alnetum incanae*, *Carici acutiformis-Alnetum glutinosae*, *Carici brizoidis-Alnetum glutinosae* p.p., *Carici elongatae-Alnetum* p.p., *Frangulo-Alnetum glutinosae*, *Lamio orvalae-Alnetum glutinosae*, *Pruno padi-Fraxinetum*, *Stellario-Alnetum glutinosae*, *Lamio orvalae-Salicetum eleagni*, *Lamio orvalae-Salicetum albae ranunculetosum lanuginosae*. Additionally, 87 new and unpublished relevés from B&H were classified within this cluster.

Cluster 5 (Table 1, column 5; Table A2, column 2)

Syntaxonomy: *not assigned*

This cluster contains floodplain hardwood (*Ulmus laevis*, *Fraxinus angustifolia* and sometimes *Quercus robur*) and/or poplar (*Populus alba* and *P. nigra*) forests. The shrub layer is well developed, with *Cornus sanguinea*, *Sambucus nigra*, *Prunus padus*, *Euonymus europaeus* and *Prunus padus*, among others, while the herb layer is typically made of nemoral mesophilous and hygromesophilous species. Invasive alien species such as *Acer negundo*, *Solidago gigantea*, *Impatiens glandulifera* and *Robinia pseudoacacia* can be common.

Diagnostic (bold) and constant species within the WFS: ***Acer negundo***, ***Populus alba***, ***Populus nigra***, ***Prunus padus***, ***Ulmus laevis***, ***Anemone ranunculoides***, ***Arum maculatum***, ***Galium aparine***, ***Leucojum vernum***, ***Pulmonaria officinalis* agg.**, ***Solidago gigantea***, ***Veronica hederifolia***, *Cornus sanguinea*, *Rubus caesius*, *Sambucus nigra*, *Aegopodium podagraria*, *Urtica dioica*.

Diagnostic (bold) and constant species within the *Alno glutinosae-Populetea albae* group of clusters: ***Acer negundo***, ***Populus alba***, ***Populus nigra***, ***Prunus padus***, ***Robinia pseudoacacia***, ***Salix alba***, ***Ulmus laevis***, ***Galium aparine***, ***Impatiens glandulifera***, ***Solidago***

gigantea, ***Veronica hederifolia***, *Cornus sanguinea*, *Rubus caesius*, *Sambucus nigra*, *Aegopodium podagraria*, *Urtica dioica*.

Ecology and distribution: These forests are developed on floodplains of the middle and lower reaches of the largest rivers in the study area (Sava, Drava, Danube, Una, Vrbas, Bosna and Drina). They form on alluvial deposits on the highest terraces within the floodplain, which are only under water during the highest, mainly spring floods. The soil is mainly sandy and, due to the pronounced water regime dynamics, it can become very dry during the summer months.

Published relevés from this cluster were referred to as: *Equiseto-Alnetum incanae*, *Fraxino-Ulmetum effusae*, *Salicetum albae* p.p. (polidominant communities), *Lamio orvalae-Salicetum albae caricetosum pendulae*, *Populetum nigro-albae*, *Salici-Populetum* and *Carduo crispi-Populetum nigrae*. Additionally, 22 new and unpublished relevés from B&H were classified within this cluster.

Cluster 6 (Table 1, column 6; Table A2, column 3)

Syntaxonomy: ***Alno-Quercion roboris***

The cluster encompasses floodplain hardwood forests dominated by *Quercus robur* and/or *Fraxinus angustifolia* s.lat. with *Ulmus minor*, *Alnus glutinosa* and *Acer campestre*, frequently admixed. In some cases, *Alnus glutinosa* has the role of edifier (probably in secondary succession stages). The shrub layer is not as developed as in Cluster 5, with *Crataegus* sp., *Frangula alnus* and *Cornus sanguinea* being the most important, with a frequency of around 40%. The herb layer is represented mainly by hygrophilous and hygromesophilous forest species.

Diagnostic (bold) and constant species within the WFS: ***Acer tataricum***, ***Crataegus laevigata***, ***Fraxinus angustifolia* s.lat.**, ***Quercus robur***, ***Ulmus minor***, ***Carex remota***, ***Carex strigosa***, ***Glechoma hederacea***, ***Lysimachia nummularia***, ***Rumex sanguineus***, ***Stachys palustris***, *Rubus caesius*, *Galium palustre* agg., *Iris pseudacorus*, *Urtica dioica*.

Diagnostic (bold) and constant species within the *Alno glutinosae-Populetea albae* group of clusters: ***Acer tataricum***, ***Crataegus laevigata***, ***Fraxinus angustifolia* s.lat.**, ***Quercus robur***, ***Ulmus minor***, ***Bidens tripartitus***, ***Carex elongata***, ***Carex remota***, ***Carex riparia***, ***Galium palustre* agg.**, ***Glechoma hederacea***, ***Iris pseudacorus***, ***Leucojum aestivum***, ***Lycopus europaeus***, ***Lysimachia nummularia***, ***Lythrum salicaria***, ***Myosotis palustris* agg.**, ***Persicaria hydropiper***, ***Rumex sanguineus***, ***Stachys palustris***, *Rubus caesius*, *Urtica dioica*.

Ecology and distribution: These communities are mostly distributed in lowlands but are not confined to floodplains, since they can be quite distant from a river. The commonality of these forests is the presence of stagnant water at the surface during a longer or shorter time during the year (mostly in spring and autumn), which is influenced by the flat relief and clayey soil. When within a floodplain, they develop in a transitional zone between the highest river terraces (Cluster 5) and depressions with stagnant water (Cluster 7). The fluctuation of water level in the soil can vary greatly and is often a key factor determining the type of community to develop. In the period between floods, the soil may be dry or wet, depending on the flood duration and groundwater table. In the research area, these communities are widespread within alluvia of large rivers, but also on flat, periodically waterlogged, terrains outside the alluvium, such as karst poljes (e.g., Livanjsko polje in B&H).

Published relevés from this cluster were referred to as: *Genisto elatae-Quercetum*, *Leucojo-Fraxinetum*, *Frangulo-Alnetum glutinosae*, *Carici elongatae-Alnetum* p.p. (less swampy relevés), *Carici brizoidis-Alnetum glutinosae* p.p. (only two relevés from original description [34]). Additionally, 53 new and unpublished relevés from B&H were classified within this cluster.

3.2.3. *Alnetea glutinosae* Group of Clusters (Clusters 7–8; Table 1, Columns 7–8; Table A3)

The *Alnetea glutinosae* group of clusters consists of swamp alder forests and birch wooded mires on gleic soils of permanently waterlogged sites. Swamp species tolerant of oxidative stress at permanently waterlogged sites dominate in the herb layer. This class is represented in the researched area by two alliances, which was confirmed by the results of unsupervised classification of the third subdataset.

Cluster 7 (Table 1, column 7; Table A3, column 1)

Syntaxonomy: ***Alnion glutinosae***

Cluster 7 encompasses relevés of mesotrophic regularly flooded alder carr dominated by *Alnus glutinosa* and sometimes accompanied by *Quercus robur* and/or *Fraxinus angustifolia*. The understory is mainly represented by tall sedges (*Carex elongate*, *C. acutiformis* and *C. riparia*) and other wetland plant species.

Diagnostic (bold) and constant species within the WFS: ***Alnus glutinosa* agg.**, ***Carex elongata***, ***Carex riparia***, ***Carex vesicaria***, ***Lycopus europaeus***, ***Peucedanum palustre***, ***Valeriana dioica* s.lat.**, *Frangula alnus*, *Solanum dulcamara*, *Viburnum opulus*, *Dryopteris carthusiana*, *Galium palustre* agg., *Iris pseudacorus*, *Lysimachia vulgaris*.

Diagnostic (bold) and constant species within the *Alnetea glutinosae* group of clusters: ***Alnus glutinosa* agg.**, ***Rubus caesius***, ***Carex elongata***, ***Filipendula ulmaria***, ***Iris pseudacorus***, ***Lycopus europaeus***, ***Lythrum salicaria***, ***Urtica dioica***, *Frangula alnus*, *Solanum dulcamara*, *Viburnum opulus*, *Dryopteris carthusiana*, *Galium palustre* agg., *Lysimachia vulgaris*, *Peucedanum palustre*.

Ecology and distribution: In the study area, these forests develop in shallow waterlogged depressions usually inundated by groundwater for considerable parts of the growing season. Soils lack well-aerated horizons and are often characterized by a significant accumulation of undecomposed organic matter. Although this habitat often occurs on sites not related to rivers, they can also be found along oxbows of large rivers (Sava, Vrbas, Bosna, Drina).

Published relevés from this cluster were referred to as: *Carici elongatae-Alnetum*, *Carici acutiformis-Alnetum glutinosae*, *Carici brizoidis-Alnetum glutinosae* p.p., *Leucojo-Fraxinetum* p.p., *Genisto elatae-Quercetum roboris* p.p. and *Pseudostellario-Quercetum roboris* p.p. (the last four names are related only to several relevés with a pronounced swamp character and dominated by *Alnus glutinosa* (besides *Q. robur* and *F. angustifolia*)). Additionally, nine new and unpublished relevés from B&H were classified within this cluster.

Cluster 8 (Table 1, column 8; Table A3, column 2)

Syntaxonomy: ***Betulion pubescentis***

Cluster 8 contains acidophilous and poor in nutrients forests on bog, dominated by *Betula pubescens* and sometimes accompanied by *Pinus sylvestris* or *Betula pendula*. The herb layer is represented by acidophilous species and species of nutrient-poor soils. The moss layer is well developed and with a significant participation of various *Sphagnum* species.

Diagnostic (bold) and constant species within the WFS: ***Betula pendula***, ***Betula pubescens***, ***Frangula alnus***, ***Picea abies***, ***Pinus sylvestris***, ***Populus tremula***, ***Rubus hirtus* s.lat.**, ***Salix caprea***, ***Salix pentandra***, ***Sorbus aucuparia***, ***Vaccinium myrtillus***, ***Salix aurita***, ***Lonicera nigra***, ***Vaccinium vitis-idaea***, ***Agrostis canina***, ***Aruncus dioicus***, ***Calamagrostis villosa***, ***Calluna vulgaris***, ***Carex echinata***, ***Carex pallescens***, ***Carex paniculata***, ***Carex rostrata***, ***Carex spicata***, ***Cirsium palustre***, ***Danthonia decumbens***, ***Dryopteris carthusiana***, ***Eleocharis palustris***, ***Epilobium palustre***, ***Equisetum palustre***, ***Equisetum sylvaticum***, ***Gentiana pneumonanthe***, ***Knautia sarajevensis***, ***Molinia caerulea* agg.**, ***Orthilia secunda***, ***Parnassia palustris***, ***Persicaria bistorta***, ***Pyrola media***, ***Viola canina***.

Diagnostic (bold) and constant species within the *Alnetea glutinosae* group of clusters: ***Betula pendula***, ***Betula pubescens***, ***Pinus sylvestris***, ***Populus tremula***, ***Rubus hirtus* s.lat.**,

Salix pentandra, ***Sorbus aucuparia***, ***Salix aurita***, ***Lonicera nigra***, ***Agrostis canina***, ***Aruncus dioicus***, ***Calamagrostis villosa***, ***Calluna vulgaris***, ***Carex echinata***, ***Carex rostrata***, ***Carex spicata***, ***Cirsium palustre***, ***Danthonia decumbens***, ***Epilobium palustre***, ***Equisetum palustre***, ***Equisetum sylvaticum***, ***Knautia sarajevensis***, ***Molinia caerulea* agg.**, ***Parnassia palustris***, ***Pyrola media***, ***Viola canina***, *Frangula alnus*, *Dryopteris carthusiana*.

Ecology and distribution: These communities are far to the south of the center of their distribution, and there are only a few relict sites with this habitat type in the research area (Slovenia and Bosnia and Herzegovina). The stands occur on acidic and nutrient poor waterlogged habitats with *Sphagnum* peat.

Published relevés from this cluster were referred to as: *Pineto-Betuletum pubescentis*, *Sphagno nemorei-Betuletum pubescentis* and *Betulo-Quercetum roboris*.

3.2.4. *Franguletea* Group of Clusters (Cluster 9; Table 1, Column 9)

There is only one cluster in this group of willow swamp scrub.

Cluster 9 (Table 1, column 9)

Syntaxonomy: ***Salicion cinereae***

Cluster 9 encompasses willow carr dominated by *Salix cinerea*, sometimes accompanied by *S. pentandra*. The herb layer is heterogeneous, represented by hygrophilous species of wet meadows and swamps.

Diagnostic (bold) and constant species within the WFS: ***Salix cinerea***, ***Carex nigra***, ***Carex panicea***, ***Filipendula ulmaria***, ***Rhinanthus rumelicus***, ***Succisella inflexa***, *Solanum dulcamara*, *Galium palustre* agg., *Lycopus europaeus*, *Lythrum salicaria*, *Ranunculus repens*.

Ecology and distribution: This scrub can be found in river alluviums, wet meadows, fens and lake shores throughout the research area. They are a stage in the natural succession of lakes and fens, as well as the secondary succession following the abandonment of wet meadows or the removal of alder carrs.

Published relevés from this cluster were referred to as *Salicetum cinereae.* Additionally, 23 new and unpublished relevés from B&H were classified within this cluster.

4. Discussion

The application of different methods of unsupervised classification often results in different, incompatible classification results, often calling for compromise when choosing the final classification system [58]. Moreover, when dealing with broad-scale datasets of different but similar vegetation types, the practice of manual re-arrangement of the numerical classification results indicates that formalization of the traditional expert-based classification by cluster analysis is difficult to achieve on large datasets [59,60]. The expert classification of our initial dataset into classes enabled the preservation of the previously defined syntaxonomic system of alliances at the class level, while at the same time we were able to analyze species variation within each of the classes of WFS. We were thus able to recognize all of the eight already considered alliances for the study area [7,28,36], while another one which is ecologically and floristically well distinguished from the remainder of the dataset (cluster 5) emerged. Apart from the cluster 5, the obtained syntaxonomic scheme of alliances within WFS is in accordance with the broadly accepted syntaxonomic scheme [5].

The alliance *Salicion albae* encompasses only forest communities and is distributed in the majority of Europe [36]. This alliance is relatively well documented in Slovenia [43,61–64] and Croatia [65–67]. In Bosnia and Herzegovina, only a couple of relevés transitional between *Salicion albae* and *Alnion incanae* have been published as a part of a synoptic table [68]. Here, *Salix alba* and/or *S. fragilis* stands along faster streams are subjected to shorter, stronger and irregular flooding, making them dryer for longer periods in the season, allowing forest mesophytes to prevail. Although some authors have considered poplar-dominated communities to be a part of *Salicion albae* [9,21,65,67], our results suggest that dryer sites on higher parts of alluvial plains with a shorter period of flooding and lower groundwater level, that are occupied by poplar-dominated communities, should be classified within *Alno-Populetea*. The soil is more stable and shows the first signs of pedogenetic evolution. As a result, the shrub layer is relatively abundant with mesophilous and hygro-mesophyllous species, while the herb layer comes with more forest mesophytes, which makes these communities similar to elm–ash communities of what was formerly known as the *Ulmenion* suballiance of *Alnion incanae.* This is in line with the fact that *Fraxino excelsioris-Populetum albae* Jurko 1958, i.e., poplar floodplain forests dominated by *Populus alba* and *P. nigra* distributed along large rivers in lowland areas of the nemoral zone of Europe, was classified within *Alnion incanae* [11]. Since poplars (especially *P. nigra*) require flooding when young but dryer conditions afterwards, natural communities with *P. nigra* are becoming scarcer, since the river dynamics are not as pronounced as before due to flow regulations [69].

Salicion triandrae encompasses scrub communities and forest mantle of *Salix alba* communities if the natural vegetation is preserved, and hence has a similar distribution to *Salicion albae*. However, some authors do not consider *Salicion triandrae* to be a separate alliance but rather a part of *Salicion albae* [64,67]. It is well documented only in Slovenia [64], while it potentially has a much bigger distribution area along large rivers in Croatia and B&H, although there are only a couple of relevés published from Croatia [9,65,67], and no published relevés from B&H. Large areas of its potential habitat along the Sava river in B&H are mine contaminated and impossible to sample.

Salicion eleagno-daphnoidis is a scrub occupying gravelly stream beds or bars in submontane to subalpine belts in different parts of Europe. Since these are under the strong impact of flowing water, they are also often in close contact with early-successional vegetation from the class *Epilobietalia fleischeri* [19]. Dominant willows in these alliances are *Salix eleagnos* on coarser gravelly sediment in upper elevations, while *Salix purpureae* occupies finer gravelly sediments of the lower parts of the river course. It should be noted that *Salix eleagnos* can also be an important species in forest communities of *Alnion incanae*, in which it is found in the tree layer. This difference in physiognomy between scrub and forest communities dominated by *Salix eleagnos* is the determining factor for their syntaxonomical differentiation (*Salicetea purpureae* or *Alno-Populetea*). Furthermore, dynamic and fast successional changes also make these communities challenging to classify. Thus, although the association *Lamio orvalae-Salicetum eleagni* is considered to be a part of *Alnion incanae* [43,62,63], our results suggest that some relevés from the Idrijca Valley belong to *Salicion eleagno-daphnoidis*. Although these relevés of *Salix eleagnos* are tall communities, they have high percentages of stoniness [62], which probably favors species that are characteristic of the alliance *Salicion eleagno-daphnoidis* and eliminates species of more developed soils that are characteristic of *Alnion incanae*. High *Salix eleagnos* communities have been recorded and analyzed in Bosnia and Herzegovina, from the Sutjeska river [68]. Those relevés were not included in further analyses because they were classified as *Quercetea pubescentis* because of the thermophilous character they displayed. The association *Salici eleagni-Juniperetum communis* has been described from Italy and placed into the alliance *Berberidion vulgaris* [70], indicating a much wider ecological amplitude of *Salix eleagnos* in terms of soil humidity, which can be especially pronounced in later life stages. The association *Petterio-Salicetum eleagni* has been described from the southern part of Bosnia and Herzegovina, from the Neretva river catchment [71], but it was not analyzed due to its geographical position in the Mediterranean biogeographic region. Comprehensive analyses of *Salix eleagnos* tall communities with special attention given to Mediterranean communities should be performed to determine their syntaxonomical position and the number of alliances to which they are related.

The alliance *Alnion incanae* is present in almost all European countries [36]. In Slovenia and Croatia, sites in the upper parts of stream catchments are often dominated by *Alnus incana* while in the lower parts *Alnus glutinosa* is adjoined and often prevails [9,42,43,63,72–75]. On the other hand, in Bosnia and Herzegovina, *Alnus glutinosa* is much more often in the upper courses, while *Alnus incana* is rarely found at lower and middle altitudes. In a recently published paper from Sutjeska National Park [68], all records of *Alnus glutinosa* from this habitat type refer to newly described species from the *Alnus glutinosa* complex, i.e., *Alnus rohlenae*, and sometimes *Salix eleagnos*, *S. alba* and *S. fragilis* also form the tree layer. Our results indicate that most of the lowland meso-hygrophilous *Alnus glutinosa*-dominated forests along small streams classified in *Alno-Populetea* belong to this alliance, which is not in line with several authors who have placed it in *Alno-Quercion* [27,72,76,77] or even *Carpinion betuli*/*Erythronio-Carpinion* [35,61]. It should also be noted that some authors put *Lamio orvalae-Alnetum glutinosae* (originally described from south-western Slovenia [42]) from north-eastern Italy into *Ligustro vulgaris-Alnion glutinosae*, the alliance encompassing riparian forests of the sub-Mediterranean regions of the northern and central Apennine Peninsula [78]. This, however, was not supported by Poldini and Sburlino [79] who placed it within the *Alnion incanae*.

Lowland hardwood riparian forests dominated by *Quercus robur* and *Fraxinus angustifolia* in the study area have usually been assigned to the alliance *Alno-Quercion roboris* [34,35,72,80–84]. However, it has sometimes been considered to be part of *Ulmenion* [9,15], or more often to be part of *Alnion incanae* [11,85]. In general, this type of forest is well-documented for most of the study area. While in Croatia these forests have a long history of research and are very well documented [34,65,80–82,84,86], since they are among the economically most important forests in the country, in Slovenia they have only been reported in a few papers [41,61]. In contrast, in Bosnia and Herzegovina, where these forests have largely been removed in the last 200 years, there is a significant lack of published relevés. Fukarek [32] published only six relevés of degraded *Q. robur* stands from northern B&H, which are to date the only published relevés of these forests in B&H. Although these forests are mostly distributed in lowlands, they can be quite distant from a river. On the other hand, they are rarely present in the Dinaric mountains or Alps. These communities require stagnant water on the surface during a longer or shorter part of the year [9,61,77], which is influenced by the flat relief. The fluctuation of the water level throughout the year can be very great and is often the key factor that determines which type of vegetation will develop [87]. *Fraxinus angustifolia* is present in southern Europe and parts of Central Europe [88]. In Austria, the Czech Republic and Slovakia, this species is usually confined to meso-hygrophillous forests and is absent from swamp microdepressions, in which *Alnus glutinosa* prevails [22,24,25,89]. However, in the southern part of its distribution, this species is often present in swamp habitats [9,21,35,90,91] where it replaces/adjoins *Alnus glutinosa*. *Fraxinus angustifolia* swamp communities are prone to drying out in the summer [21,92] and therefore can contain significantly less peat than *Alnus glutinosa* swamps. Nevertheless, Douda et al. [11] classified *F. angustifolia* dominated communities (*Leucojo-Fraxinetum*) within *Alnetea glutinosae.* However, since *Fraxinus angustifolia* was listed in the expert system as a characteristic species of *Alno-Populetea*, most of our *F. angustifolia* transitional relevés between *Alno-Populetea* and *Alnetea glutinosae* were classified into the class *Alno-Populetea* and, consequently, into *Alno-Quercion*.

Cluster 5 is close to *Alnion incanae* and *Alno-Quercion* but ecologically and floristically well distinguished (Tables 1 and A2; Figure 2). A large number of the relevés from this cluster were originally assigned to the association *Fraxino-Ulmetum effusae*. In general, this elm–ash dominated community is developed on well-drained sandy alluvial soils on elevated river terraces [41,84]. The poplar-dominated communities *Populetum nigro-albae* and *Salici-Populetum nigrae*, which are developed on sandy fluvisols on middle and high-positioned terraces along rivers banks of large rivers, show a similar ecological pattern [65]. A pioneer community of *Alnus incana* is known from the lowland floodplain of the Drava river in Croatia under the name *Equiseto hyemali-Alnetum incanae*, where it occupies gravelly and sandy fluvisols with a developed humus layer [9]. Although these are *Alnus incana*-dominated communities, Vukelić et al. [75] noted that the tree layer is rich in species typical of lowland hardwood riparian forests (*Ulmus laevis*, *Ulmus minor*, *Quercus ro-*

bur, *Fraxinus angustifolia* and *Populus alba*). The syntaxon *Lamio orvalae-Salicetum albae caricetosum pendulae* was described from the Vipava Valley in Slovenia and encompasses mostly polydominant communities of *Populus nigra* and *Salix alba*, also growing on elevated fluvisols [42]. These communities are well differentiated from other analyzed alliances since they develop on well-aerated water-permeable soils in lowlands. Although this cluster is a combination of relevés originally classified into different alliances (*Alnion incanae*, *Salicion albae* and *Alno-Quercion*), it always occupies similar positions and soil types along a river. This cluster best corresponds to the description and floristic composition of the suballiance *Ulmenion* provided by Petrášová-Šibíková et al. [93]. For a long time, and by many authors, *Ulmenion* was considered to be part of *Alnion incanae* [9,21,22,25,94]. However, Mucina et al. [5] considered *Ulmenion* to be a corresponding name of the alliance *Fraxino-Quercion roboris*, i.e., elm–ash and oak riparian floodplain forests on nutrient-rich brown soils in the nemoral zone of Europe, which is geographically constrained to Central Europe [36]. On the other hand, *Populion albae* which was formerly known as an alliance that encompassed poplar-dominated communities of the nemoral zone [29], is now biogeographically constrained to the Mediterranean region [5,36]. The ambiguous position of this vegetation type is supported by the recently described alliance *Dioscoreo communis-Populion nigrae* from Italy, which shows similar ecological and floristic traits to our cluster 5 [95]. This implies that the syntaxonomical position of cluster 5, although closest to the concept of *Fraxino-Quercion*, is still unclear and should be further investigated on a larger geographical scale.

The alliance *Alnion gutinosae* has a wide distribution and is present in almost the whole of Europe [36]. These communities are well documented in Croatia [73,80,96,97] and Slovenia [61,72], but there have been no published relevés from B&H. Although this alliance mainly encompasses communities dominated by *Alnus glutinosa*, some authors also include monodominant wet forests of other species such as *Fraxinus angustifolia* (*Leucojo-Fraxinetum*) [11,83], *Salix alba* (*Galio-Salicetum albae*) [70] and *Quercus robur* (*Cardamini parviflorae-Quercetum roboris* and *Carici elongatae-Quercetum roboris*) [21,98]. However, our results suggest that hardwood forests with a pronounced swamp character, even though ecologically transitional, are dry for a significant time during the vegetation season, and thus harbor a significant number of mesophitic species, which makes them closer to *Alno-Quercion*. Moreover, the whole original table with the type relevé [34] was classified into *Alno-Quercion*. Another alliance from *Alnetea* glutinosae that could enter into the consideration is *Frangulo alni-Fraxinion oxycarpae*, which encompasses interdunal or karstic swamps developed on hydromorphic soils with large amounts of slightly decomposed organic matter that are dominated by *Fraxinus angustifolia* [90]. This alliance has a narrow distribution (Italy, Croatia and Albania) and, although it is reported for Croatia [36], we did not recognize it in our dataset. The reason may be that it is confined to the Mediterranean region, which we omitted in our analysis. Furthermore, since it is a relatively recently described alliance, its exact distribution is not known and, moreover, it is noted that the distinction between the alliances *Alnion glutinosae* and *Frangulo-Fraxinion* is sometimes not clear [91].

Forests from the alliance *Betulion pubescentis* are widespread in Europe, except for the southern parts of the continent. In the study area, they have been recorded only at two localities, i.e., Ljubljansko Barje in Slovenia [99] and Han Kram in B&H [33]. Bearing in mind their marginal position in the distribution area of the alliance [36] and small number of recorded relevés, these might show some peculiarities in comparison with typical stands from Central and Northern Europe.

The alliance *Salicion cinereae* is distributed in most European countries, except for the southernmost parts [36]. Many authors have considered these communities to be part of the class *Alnetea glutinosae* [9,21,22]. However, Mucina et al. [5] proposed relocating this alliance into the scrub class *Franguletea*, based on the principle of distinction between forest and scrub communities in different classes. Nevertheless, it should be noted that, without expert classification, relevés from *Salicion cinereae* could not be distinguished from *Alnion glutinosae*. This alliance has been well documented and analyzed in Slovenia [100]. On the other hand, only one relevé of this alliance has been published in Croatia [9], while in Bosnia and Herzegovina no relevés have been published to date, although Milanović and Stupar [101] reported the class *Franguletea* in the checklist of vegetation classes of B&H.

Soil moisture, soil reaction and nutrient availability were found to be the most important factors determining the floristic composition and, consequently, the alliance differentiation of WFS in the study area (Figure 2). On the other hand, the correlation with climatic variables was not found to be statistically significant. Few smaller-scale studies within WFS consider soil moisture and nutrient-related variables to be dominant drivers of variation in species composition [41,102], while Douda et al. [11] reported only site moisture as an important driver. On the other hand, the differentiation of the Iberian floodplain forest at the alliance level was mainly influenced by climatic drivers (i.e., continentality and precipitation) [20]. Our ordination results suggest that Western Balkans WFS are azonal vegetation influenced by edaphic factors and physiological stresses that floodplain plants share, regardless of climatic differences.

5. Conclusions

Our study supported the division of WFS of the Western Balkans into nine clusters that corresponded well with accepted syntaxa at the alliance level. Additionally, the classification of around 230 new and unpublished relevés from B&H contributed to the knowledge of WFS in this part of Europe, since only a few dozen relevés had been published from B&H to date.

The main ecological factors influencing the variation of the floristic composition are soil moisture, soil reaction, and nutrients, while there is a weak correlation with macroclimatic variables, implying that WFS represent azonal plant communities, with no significant geographical patterns.

However, further research is needed to determine the syntaxonomic position of cluster 5. Although this cluster is floristically and ecologically similar to *Fraxino-Quercion*, it does not fit into its current geographical concept, which is limited to Central Europe.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/d15030370/s1, Table S1: Full synoptic table of the of WFS types in the Western Balkans; Table S2: Full synoptic table for the cluster group Salicetea purpureae; Table S3: Full synoptic table for the cluster group Alno-Populetea; Table S4: Full synoptic table for the cluster group Alnetea glutinosae.

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Appendix A

List of species merged to aggregates (agg.) and broadly defined taxa (s.l.).

Alnus glutinosa agg. (*A. glutinosa* and *A. rohlenae*)
Aquilegia vulgaris agg. (*A. nigricans* and *A. vulgaris*)
Aconitum variegatum agg. (*A. variegatum* and *A. degenii*)
Agrostis stolonifera agg. (*A. gigantea* and *A. stolonifera*)
Galium palustre agg. (*G. palustre* and *G. elongatum*)
Lamium galeobdolon agg. (*L. galeobdolon* ssp. *argentatum, L. galeobdolon* ssp. *flavidum, L. galeobdolon* ssp. *galeobdolon* and *L. galeobdolon* ssp. *montanum*)
Molinia caerulea agg. (*M. caerulea* and *M. arundinacea*)
Myosotis palustris agg. (*M. scorpioides* and *Myosotis palustris*)
Rubus fruticosus agg. (*R. plicatus, R. silvaticus* and *Rubus fruticosus*)
Crocus vernus agg. (*Crocus vernus* and *C. vernus* ssp. *albiflorus*)
Malus sylvestris agg. (*M. sylvestris* and *M. pumila*)
Ranunculus auricomus agg. (*R. cassubicus*. and *R. auricomus*)
Stellaria media agg. (*S. media* and *S. neglecta*)
Rosa canina (all species from *Rosa canina* group sensu Tutin et al. [103])
Aconitum lycoctonum s.lat. (*A. lycoctonum* ssp. *lycoctonum* and *A. lycoctonum* ssp. vulparia)
Asarum europaeum s.lat. (*A. europaeum* ssp. *caucasicum* and *A. europaeum* ssp. *europaeum*)
Centaurea scabiosa s.lat (*C. scabiosa* ssp. *scabiosa* and *Centaurea scabiosa* ssp. *fritschii*)
Dactylis glomerata s.lat. (*D. glomerata* ssp. *glomerata* and *D. glomerata* ssp. *lobata*)
Fraxinus angustifolia s.lat. (*F. angustifolia* ssp. *angustifolia* and *Fraxinus angustifolia* ssp. *oxycarpa*)
Hesperis matronalis s.lat. (*H. matronalis* ssp. *matronalis* and *H. matronalis* ssp. *candida*)
Knautia drymeia s.lat. (*K. drymeia* ssp. *drymeia* and *K. drymeia* ssp. *intermedia*)
Phyteuma spicatum s.lat. (*P. spicatum* ssp. s*picatum* and *P. spicatum* ssp. *coeruleum*)
Plantago major s.lat (*P. major* ssp. *major* and *P. major* ssp. *intermedia*)
Prunus domestica s.lat. (*P. domestica* ssp. d*omestica* and *P. domestica* ssp. *insititia*)
Solanum nigrum s.lat. (*S. nigrum* ssp. *nigrum* and *S. nigrum* ssp. *schultesii*)
Arabidopsis halleri s.lat. (*A. halleri* ssp. *halleri* and *A. halleri* ssp. *ovirensis*)
Carex divulsa s.lat. (*C. divulsa* ssp. *divulsa* and C. d*ivulsa* ssp. *leersii*)
Euphorbia esula s.lat (*E. esula* ssp. *esula* and *E. esula* ssp. *tommasiniana*)
Leucanthemum ircutianum s.lat. (*L. ircutianum* ssp. *ircutianum* and *L. ircutianum* ssp. *leucolepis*)
Pyrus communis s.lat. (*P. communis* ssp. *communis* and *P. communis* ssp. *pyraster*)
Rhamnus alpina s.lat. (*R. alpina* ssp. a*lpina* and *Rhamnus alpina* ssp. *fallax*)
Helleborus dumetorum s.lat. (*H. dumetorum* ssp. *dumetorum* and *H. dumetorum* ssp. *atrorubens*)

Appendix B

List of associations used throughout the text with authorship indicated

Alnetum incanae Lüdi 1921
Betulo-Quercetum roboris Martinčič 1987
Cardamini parviflorae-Quercetum roboris Molnár Zs. 2010
Carduo crispi–Populetum nigrae Kevey in Borhidi and Kevey 1996
Carici acutiformis-Alnetum glutinosae Scamoni 1935
Carici brizoides-Alnetum glutinosae Horvat 1938
Carici elongatae-Alnetum glutinosae Koch 1926

Carici elongatae-Quercetum Sokołowski 1972
Carici paniculatae-Salicetum myrsinifoliae Dakskobler in Vreš, Seliškar et Dakskobler 2012
*Equiseto hyemali-Alnetum incana*e Moor 1958
Frangulo-Alnetum glutinosae Rauš 1971 (1973)
Fraxino excelsioris-Populetum albae Jurko 1958
Fraxino angustifoliae-Ulmetum effusae Slavnić 1952
Galio palustri–Salicetum albae Rauš 1973
Genisto elatae-Quercetum roboris Horvat 1938
Lamio orvalae-Alnetum glutinosae Dakskobler 2016
*Lamio orvalae-Alnetum incana*e Dakskobler 2010
Lamio orvalae-Salicetum albae Dakskobler 2016
Lamio orvalae-Salicetum albae caricetosum pendulae Dakskobler 2016
Lamio orvalae-Salicetum albae ranunculetosum lanuginosae Dakskobler 2016
Lamio orvalae-Salicetum eleagni Dakskobler, Šilc and Čušin ex Dakskobler 2007
Lamio orvalae-Salicetum purpureae nom. prov. (Dakskobler, 2016)
Leucojo aestivi-Fraxinetum angustifoliae Glavač 1959
Petterio-Salicetum eleagni Redžić, Muratspahić and Lakušić 1992
Pino-Betuletum pubescentis Stefanović 1961
Populetum nigro-albae Slavnić 1952
Pruno padi-Fraxinetum angustifoliae Čarni et al. 2008
Pseudostellario europaeae-Quercetum roboris Accetto 1974
Salicetum albae Issler 1926
Salicetum cinereae Zólyomi 1931
Salicetum cinereo-purpureae Pelcer 1975 prov.
Salicetum purpureae Wendelberger-Zelinka 1952
Salicetum incano-purpureae Sillinger 1933
Salicetum triandrae Malcuit ex Noirfalise in Lebrun et al. 1955
Salici eleagni-Juniperetum communis Poldini, Francescato, Vidali and Castello 2020
Salici purpureae-Myricarietum germanicae Moor 1958
Salici-Populetum nigrae (R. Tx. 1931) Meyer Drees 1936
Saponario officinalis-Salicetum purpureae Tchou 1948
Sphagno nemorei-Betuletum pubescentis (Libbert 1933) Passarge 1968
Stellario nemorum-Alnetum glutinosae Lohmeyer 1957

Appendix C

Table A1. Synoptic table for the cluster group *Salicetea purpureae*. Frequencies of species are presented as percentages with phi values multiplied by 100 shown in superscript. Diagnostic species (phi values higher than 0.30) are shaded. Species with frequency lower than 30% in a cluster for which they are diagnostic are not shown. Only up to 15 species with the highest phi value are presented. Cluster numbers: 1—*Salicion albae*, 2—*Salicion triandrae*, 3—*Salicion eleagno-daphnoidis*. Cluster numbers correspond to Table 1, Figures 2–4 and to those used in the text. The full version of this table is available in Table S2.

Cluster Number	**1**	**2**	**3**
Number of Relevés	**90**	**37**	**83**
Salicion albae			
Salix alba	91 $^{72.6}$	8 $^{---}$	23 $^{---}$
Galium aparine	56 $^{42.9}$	14 $^{---}$	16 $^{---}$
Glechoma hederacea	44 $^{41.1}$	11 $^{---}$	7 $^{---}$
Iris pseudacorus	43 $^{40.9}$	14 $^{---}$	4 $^{---}$
Salix euxina	36 $^{36.9}$	. $^{---}$	13 $^{---}$
Rubus caesius	73 ^{33}	19 $^{---}$	58 $^{---}$

Euonymus europaeus	32 $^{32.2}$	3 $^{---}$	12 $^{---}$
Salicion triandrae			
Salix triandra	19 $^{---}$	97 $^{78.6}$	11 $^{---}$
Alisma plantago-aquatica	1 $^{---}$	38 $^{50.8}$	1 $^{---}$
Rorippa sylvestris	6 $^{---}$	49 $^{48.3}$	8 $^{---}$
Solanum dulcamara	38 $^{---}$	81 $^{46.2}$	27 $^{---}$
Agrostis stolonifera agg.	34 $^{---}$	70 $^{42.2}$	18 $^{---}$
Persicaria hydropiper	28 $^{---}$	57 $^{41.7}$	5 $^{---}$
Bidens tripartitus	14 $^{---}$	43 ^{40}	4 $^{---}$
Echinocystis lobata	39 $^{---}$	59 $^{37.3}$	5 $^{---}$
Lythrum salicaria	27 $^{---}$	57 $^{34.3}$	18 $^{---}$
Galium palustre agg.	29 $^{---}$	49 $^{32.8}$	6 $^{---}$
Phalaroides arundinacea	56 $^{---}$	78 ^{32}	34 $^{---}$
Rorippa amphibia	10 $^{---}$	30 $^{31.9}$	2 $^{---}$
Calystegia sepium	46 $^{---}$	62 $^{30.9}$	14 $^{---}$
Salicion eleagno-daphnoidis			
Salix eleagnos	4 $^{---}$	. $^{---}$	70 $^{73.9}$
Salix purpurea	18 $^{---}$	16 $^{---}$	84 ^{65}
Petasites hybridus	1 $^{---}$	. $^{---}$	53 $^{64.3}$
Clematis vitalba	3 $^{---}$	. $^{---}$	43 $^{54.2}$
Brachypodium sylvaticum	13 $^{---}$	. $^{---}$	53 $^{52.6}$
Fraxinus excelsior	2 $^{---}$	. $^{---}$	39 $^{51.5}$
Acer pseudoplatanus	. $^{---}$	. $^{---}$	35 $^{51.3}$
Deschampsia cespitosa	4 $^{---}$	. $^{---}$	40 $^{49.9}$
Eupatorium cannabinum	7 $^{---}$	. $^{---}$	42 $^{49.6}$
Salvia glutinosa	. $^{---}$	. $^{---}$	31 $^{48.3}$
Chaerophyllum hirsutum	3 $^{---}$	. $^{---}$	35 ^{47}
Equisetum arvense	6 $^{---}$	. $^{---}$	37 $^{46.6}$
Ranunculus lanuginosus	1 $^{---}$	. $^{---}$	30 $^{45.6}$
Saponaria officinalis	3 $^{---}$	. $^{---}$	31 $^{43.7}$
Cirsium oleraceum	11 $^{---}$	3 $^{---}$	39 $^{39.3}$
Other species with high frequency			
Urtica dioica	82 $^{15.7}$	86 $^{---}$	48 $^{---}$
Cornus sanguinea	43 $^{---}$	. $^{---}$	43 $^{---}$
Persicaria dubia	12 $^{---}$	43 $^{---}$	29 $^{---}$
Angelica sylvestris	24 $^{---}$	11 $^{---}$	46 $^{29.9}$
Poa trivialis	43 $^{27.6}$	14 $^{---}$	22 $^{---}$
Lamium maculatum	29 $^{---}$	24 $^{---}$	24 $^{---}$
Humulus lupulus	43 ^{29}	27 $^{---}$	6 $^{---}$
Alliaria petiolata	34 $^{---}$	14 $^{---}$	27 $^{---}$
Ranunculus repens	23 $^{---}$	35 $^{---}$	16 $^{---}$
Aegopodium podagraria	26 $^{---}$	11 $^{---}$	35 $^{---}$

Table A2. Synoptic table for the cluster group *Alno-Populetea*. Frequencies of species are presented as percentages, with phi values multiplied by 100 shown in superscript. Diagnostic species (phi values higher than 0.30) are shaded. Species with frequency lower than 30% in a cluster for which they are diagnostic are not shown. Only up to 15 species with the highest phi value are presented. Cluster numbers: 4—*Alnion incanae*, 5—*not assigned*, 6—*Alno-Quercion*. Cluster numbers correspond to Table 1, Figures 2–4 and to those used in the text. The full version of this table is available in Table S3.

Cluster Number	**4**	**5**	**6**
Number of Relevés	**281**	**178**	**226**

Alnion incanae			
Acer pseudoplatanus	50 [59.5]	3 ---	1 ---
Fraxinus excelsior	47 [50.7]	8 ---	2 ---
Ranunculus lanuginosus	32 [45.7]	2 ---	1 ---
Petasites hybridus	31 [44.5]	2 ---	. ---
Chaerophyllum hirsutum	30 [43.5]	2 ---	. ---
Equisetum arvense	39 [43.2]	9 ---	1 ---
Corylus avellana	63 [42.9]	20 ---	19 ---
Alnus glutinosa agg.	81 [39.6]	31 ---	47 ---
Brachypodium sylvaticum	64 [35.4]	46 ---	8 ---
Lamium galeobdolon agg.	49 [35.1]	24 ---	8 ---
Lamium orvala	33 [34.3]	13 ---	. ---
Aegopodium podagraria	70 [33]	57 ---	14 ---
Sambucus nigra	74 [31.5]	61 ---	21 ---
Angelica sylvestris	37 [31.1]	12 ---	10 ---
Cluster 5			
Populus nigra	7 ---	54 [57]	2 ---
Prunus padus	5 ---	40 [45.7]	4 ---
Populus alba	1 ---	38 [43.9]	8 ---
Salix alba	21 ---	47 [39.8]	1 ---
Acer negundo	3 ---	30 [38.5]	4 ---
Solidago gigantea	14 ---	44 [38.3]	7 ---
Impatiens glandulifera	8 ---	30 [37]	. ---
Galium aparine	27 ---	62 [36.2]	23 ---
Ulmus laevis	4 ---	54 [33.6]	38 [8.7]
Alno-Quercion			
Fraxinus angustifolia s.lat.	9 ---	43 ---	84 [54.5]
Galium palustre agg.	8 ---	10 ---	58 [53.1]
Quercus robur	11 ---	37 ---	79 [52.5]
Stachys palustris	2 ---	10 ---	46 [46.8]
Ulmus minor	10 ---	14 ---	52 [43.5]
Crataegus laevigata	9 ---	3 ---	39 [42]
Persicaria hydropiper	15 ---	10 ---	50 [40.6]
Iris pseudacorus	6 ---	29 ---	54 [38.5]
Myosotis palustris agg.	10 ---	2 ---	35 [38.1]
Lysimachia nummularia	23 ---	24 ---	62 [37.2]
Leucojum aestivum	2 ---	9 ---	33 [36.3]
Acer tataricum	8 ---	1 ---	31 [36.3]
Rumex sanguineus	12 ---	12 ---	42 [34.5]
Carex remota	33 ---	17 ---	61 [34.5]
Lythrum salicaria	6 ---	7 ---	31 [32.9]
Other species with high frequency			
Rubus caesius	70 ---	90 [23.4]	69 ---
Urtica dioica	59 ---	66 ---	61 ---
Cornus sanguinea	65 [13.6]	64 ---	37 ---
Euonymus europaeus	55 [14.7]	47 ---	31 ---
Crataegus monogyna	48 ---	34 ---	46 ---
Acer campestre	57 [21.1]	21 ---	48 ---
Geum urbanum	47 [16.9]	30 ---	29 ---
Ranunculus repens	37 ---	16 ---	48 [21.1]
Hedera helix	41 [19.5]	22 ---	23 ---

Ligustrum vulgare	34 $^{13.9}$	30 $^{---}$	13 $^{---}$

Table A3. Synoptic table for the cluster group *Alnetea glutinosae*. Frequencies of species are presented as percentages with phi values multiplied by 100 shown in superscript. Diagnostic species (phi values higher than 0.30) are shaded. Species with frequency lower than 30% in a cluster for which they are diagnostic are not shown. Only up to 15 species with the highest phi value are presented. Cluster numbers: 7—*Alnion glutinosae*, 8—*Betulion pubescentis.* Cluster numbers correspond to Table 1, Figures 2–4 and to those used in the text. The full version of this table is available in Table S4.

Cluster Number	**7**	**8**
Number of Relevés	**121**	**14**
Alnion glutinosae		
Alnus glutinosa agg.	94 $^{94.4}$	. $^{---}$
Lycopus europaeus	65 $^{69.6}$	. $^{---}$
Carex elongata	55 $^{61.2}$	. $^{---}$
Iris pseudacorus	52 $^{59.3}$	. $^{---}$
Rubus caesius	46 $^{54.9}$	. $^{---}$
Filipendula ulmaria	45 $^{54.2}$	. $^{---}$
Lythrum salicaria	44 ^{53}	. $^{---}$
Urtica dioica	43 $^{52.3}$	. $^{---}$
Betulion pubsecentis		
Betula pubescens	. $^{---}$	86 $^{86.6}$
Molinia caerulea agg.	7 $^{---}$	93 $^{86.2}$
Pinus sylvestris	. $^{---}$	71 $^{74.5}$
Sorbus aucuparia	2 $^{---}$	57 $^{60.9}$
Betula pendula	1 $^{---}$	50 $^{56.5}$
Rubus hirtus s.lat.	1 $^{---}$	43 $^{50.9}$
Salix aurita	2 $^{---}$	43 $^{49.5}$
Calamagrostis villosa	. $^{---}$	36 $^{46.6}$
Lonicera nigra	. $^{---}$	36 $^{46.6}$
Cirsium palustre	. $^{---}$	36 $^{46.6}$
Parnassia palustris	. $^{---}$	36 $^{46.6}$
Knautia sarajevensis	. $^{---}$	36 $^{46.6}$
Carex rostrata	. $^{---}$	36 $^{46.6}$
Salix pentandra	1 $^{---}$	36 $^{45.1}$
Equisetum sylvaticum	1 $^{---}$	36 $^{45.1}$
Other species with high frequency		
Frangula alnus	66 $^{---}$	100 $^{---}$
Dryopteris carthusiana	53 $^{---}$	71 $^{---}$
Lysimachia vulgaris	67 $^{---}$	43 $^{---}$
Galium palustre agg.	60 $^{---}$	36 $^{---}$
Viburnum opulus	53 $^{---}$	36 $^{---}$
Peucedanum palustre	52 $^{---}$	36 $^{---}$
Caltha palustris	48 $^{---}$	36 $^{---}$
Solanum dulcamara	54 $^{---}$	29 $^{---}$
Valeriana dioica s.lat.	50 $^{---}$	21 $^{---}$
Quercus robur	33 $^{---}$	36 $^{---}$

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