Diversity of Ruderal Communities in Urban Environments—A Case Study from Serbia (SE Europe)

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Abstract: The high diversity of ruderal vegetation in urban environments is well known. Although it has been a subject of numerous studies in Serbia, in recent years it has been slightly overlooked, although, due to the dynamics of ruderal habitats, constant research is required. We investigated ruderal vegetation in 20 cities across Serbia during a period of 5 years. Most of the relevés were collected during the summer months, and within 712 relevés, 422 taxa were recorded. Results of the cluster analyses and identified diagnostic species revealed 26 plant communities, of which nine are dominated or co-dominated by aliens. The relevés can be grouped into six ecologically well-differentiated major vegetation groups. Our study revealed the ruderal communities which are the most widespread in urban environments in Serbia. Additionally, some communities were registered for the first time in the country.

Keywords: ruderal vegetation; anthropogenic vegetation; plant communities; phytocoenology; urban habitats; city

1. Introduction

Urban sprawl is a major cause of global landscape change and affects species composition and richness, particularly favoring ruderal and non-native plant species [1]. Ruderal flora and vegetation develop spontaneously in cities and other anthropogenic environments, and their survival depends on human influence.

Ruderal habitats are unstable and highly dynamic, and are characterized by irregular disturbances of varying magnitude that result in patchy vegetation [2,3]. These patches form an extremely heterogeneous mosaic of habitats in cities, where the influence of various abiotic factors, i.e., climatic, geological, pedological, orographic, and other factors, is highly modified [4]. Although urban environmental conditions may change under human influence, some general characteristics of urban climate in comparison with the surroundings are known: increased temperature, higher pollution, lower radiation, higher precipitation, changed water regime, etc. [5]. These unique environmental conditions are reflected in plant communities and lead to high diversity of urban vegetation [4,6–8].

Over a long period of time, a trend of decrease in species richness and diversity has been observed in the ruderal vegetation of Central Europe [9]. Moreover, some studies have shown that the average abundance of neophytes (alien species introduced after 1500 AD) has increased over time [10,11]. According to Rendeková [12], changes in the spectrum of ruderal communities are reflected not only in the emergence of new communities with alien species, but also in many once widespread plant communities that are now rare or have even disappeared.

It is known that disturbed habitats such as ruderal areas are characterized by a higher proportion of alien species compared to other habitats [13–17] but, depending on the degree of disturbance, the proportion of alien species varies in different ruderal habitats [11,18]. Many alien species originate from warmer regions and benefit from the higher temperatures...
in cities [5,19] and often form species-poor or even monophytic plant communities with low species diversity [20]. Compared to Central Europe, ruderal vegetation in Southeast Europe is less studied, especially in Serbia, where floristic studies are more common than vegetation studies [21,22]. Therefore, we analyzed ruderal vegetation of cities across Serbia in order to (1) distinguish and characterize the main vegetation groups, (2) analyze their diversity patterns, and (3) highlight the diagnostic species of the identified communities. Finally, based on the results obtained, we proposed a syntaxonomic scheme for the ruderal communities studied.

2. Materials and Methods

2.1. Study Area and Data Sampling

Serbia has an area of 88,361 km² and is located in Southeast Europe. Most of the territory occupies hilly and mountainous regions of the north-central Balkan Peninsula. The northern part of the country extends into the southern part of the Pannonian Plain. In the country, three basic climate areas can be recognized, with continental climate area being the most widespread. A sector with a moderate continental climate, located south of the previous area, covers the zone from the west and central to south-south-eastern Serbia. The third area, with a modified Mediterranean climate, is located in the south, in Metohija [23].

Ruderal vegetation was studied in 20 cities of various sizes across Serbia. Cities were investigated in the following regions: Bačka (Subotica, Novi Sad); Banat (Kikinda, Banatski Karlovac, Pančevo); Srem (Sremska Mitrovica, Sremski Karlovci); Northwestern Serbia (Šabac, Loznica, Valjevo); Šumadija (Belgrade, Kragujevac, Smederevo); Northeastern Serbia (Kladovo, Negotin); Western Serbia (Užice, Čačak); Eastern Serbia (Niš); Southeastern Serbia (Vladičin Han, Vranje) (Figure 1). During the period 2015–2020, a total of 761 phytosociological relevés were collected. The highest number of relevés was collected in Belgrade (145), the largest city in Serbia. In each other city, at least 20 phytosociological relevés were collected, mostly during the summer months, when the species composition is considered relatively stable. Only a few cities were revisited in spring and early autumn. Relevés were sampled following the Braun-Blanquet method [24], and only vascular plants were recorded within each plot. Plot size was standardized to 10 m². Exceptionally, relevés were sampled in cases when the plot was smaller than 10 m² but larger than 5 m², if the plant communities were representative but physically constrained, e.g., bordered by concrete. A plot size of 10 m² is recommended for herbaceous vegetation [25], and is one of the most commonly used plot sizes for the analysis of anthropogenic vegetation in Europe [26].

2.2. Data Analysis

Using outlier analysis in PC-ORD 6.08 software [27], relevés which deviated more than two standard deviation units from the average Euclidean distance of all plots were detected and removed (14 relevés). The software was also used to perform a cluster analysis. The Bray–Curtis distance measure and group average (UPGMA) linkage method were applied, as ecologically most interpretable. For all identified clusters, diagnostic, dominant, and constant species were defined using the JUICE 7.1 software [28], in order to determine the phytocenological characteristics of the groups. Diagnostic species were identified by calculating the measure of fidelity, phi (Φ) coefficient [29]. Species with the phi coefficient greater than 0.30 were considered diagnostic. Dominant species were determined to be those that were present in at least 5% of the relevés with a cover of ≥35%. Constant species were considered those that occurred in at least 70% of the relevés. These threshold values were chosen subjectively after examining the results with higher and lower thresholds. Clusters were examined in detail and 35 relevés from heterogeneous clusters were removed. Homogeneous clusters with the same combination of diagnostic species were combined into one vegetation group, representing a distinct plant community. A synoptic table with fidelity and frequency values of taxa within each community was prepared using the JUICE 7.1. software (see Table S1 in Supplementary Materials). The same software was used
for calculating the Shannon–Wiener index ($H'$) for expressing diversity, and Shannon’s equitability-evenness ($E_H$).
Using the JUICE software, Ellenberg’s indicator values (EIV) adapted for Italy [30] were obtained for almost all species in the dataset, and average EIV values for light, temperature, continentality, humidity, acidity, and nutrients were calculated for each plot. These ecological values modified for Italy were previously successfully used in different anthropogenic vegetation studies in the Balkans [31,32]. Values missing for some alien species were obtained from Domina et al. [33]. In order to perform a better ecological characterization of the groups, the detrended correspondence analysis (DCA) in the CANOCO 5.03 software [34] was applied, with passively projected ecological indicator values.

The plant nomenclature was harmonized with the Euro+Med [35], except for *Reynoutria × bohemica* and garden plant *Petunia × atkinsiana*. Nomenclature of higher syntaxa was in accordance with Mucina et al. [36]. For nomenclature of associations various sources were consulted.

A map with locations of investigated cities was prepared in the QGIS software version 3.20 [37].

3. Results and Discussion

Ruderal communities occur in a specific environment and the classification of some of them can be rather difficult [8]. The approach used in this paper, i.e., combining homogeneous clusters, and exclusion of heterogeneous, resulted in groups that are very well differentiated. A similar principle was applied for aquatic vegetation in Serbia, thus enabling a classification without fitting the vegetation groups into the existing syntaxonomic scheme [38].

3.1. Results of the Cluster and Ordination Analysis

The final dataset contained 712 relevés and 422 taxa. Based on the results of the classification analyses and identified diagnostic species, 26 clusters or plant communities were distinguished (Figure 2). Additionally, six major vegetation groups can be recognized on the dendrogram (A, B, C, D, E, F). These are well separated, and ecologically well-differentiated, as confirmed by DCA analysis, which showed some general characteristics of the studied vegetation (Figure 3). Group A includes communities that generally occur near rivers and canals, on well-moistened habitats. Stands belonging to this group are characterized by the highest moisture and nutrient levels. They have a negative correlation with light, and tend to prefer shaded habitats compared to the other groups. By comparison, trampled communities belonging to group F occur on dry and insolated habitats, characterized by high light index values, and low nutrient values. Moreover, they are negatively correlated with continentality. Compared to trampled communities of group F, the stands of group E are found on less insolated habitats, that may also be nutrient-poor. Communities of group D are typical summer annuals, characterized by very warm and dry habitats. The largest group C is ecologically diverse, but the majority of its communities are strongly correlated with continentality and soil reaction. Group B, represented solely by the association of *Reynoutrietum japonicae* Görs et Müll 1975, occupies a somewhat transitional position between groups A and C, with lower values for moisture and nutrients than A and higher values for soil reaction (Figure 3).

3.2. General and Floristic Characteristics of Ruderal Communities

The Shannon’s equitability (Eₜ) ranged from 0.49 to 0.78 (Table 1). The Shannon index (H') ranged from 1.13 to 2.4. Four communities of group F occurring on trampled habitats have the lowest average number of species per plot and are among communities with the lowest average Shannon index values. Trampling as a frequent mechanical disturbance prevents plant species from developing, and communities of these habitats are usually low-growing and species-poor. Association of the group F, *Polygonetum avicularis* Gams 1927, has the lowest value for both diversity indices, indicating its unevenness. By comparison, communities of group C are among the communities with the highest average values of Shannon diversity index and equitability. These higher values indicate
more species in the stands or greater evenness. From heterogenous group C, association Convolvulo arvensis-Elytrigietum repentis Felföldy 1943 stands out with the lowest values of Shannon’s index.

Only two communities were registered in all investigated cities, Polygonetum avicularis and Arctietum lappae Felföldy 1942; the latter was one of the most represented communities, having 95 relevés. Association Sambucetum ebuli Felföldy 1942 is also represented with 95 relevés.

Table 1. Floristic parameters of ruderal communities.

| Cl. No. | Gr. | Association | No. of Rel. | No. of Cities | Avg. No. Sp./Plot | Total No. of sp. | Shannon’s Equitability (E_H) | Shannon-Wiener Index (H') |
|---------|-----|-------------|-------------|---------------|------------------|------------------|-----------------------------|--------------------------|
| 1       | A   | Amaranthus tuberculatus (Bidention tripartitae) Bidens frondosus-Persicaria lapathifolia (Bidention tripartitae) | 3 | 1 | 18.67 | 37 | 0.64 | 1.88 |
| 2       | A   | Amorpha fruticosa (Rubo caesi-Amorphion fruticosae) | 17 | 6 | 21.12 | 117 | 0.65 | 1.98 |
| 3       | A   | Asteretum lanceolati | 21 | 7 | 17.19 | 116 | 0.58 | 1.65 |
| 4       | A   | Artemision lanceolati | 9 | 3 | 15 | 77 | 0.53 | 1.41 |
| 5       | B   | Reynoutrietum japonicae | 21 | 4 | 14.19 | 92 | 0.56 | 1.48 |
| 6       | C   | Arctietum lappae Tanacetum vulgaris-Artemisietum vulgaris | 95 | 20 | 19.66 | 221 | 0.67 | 1.97 |
| 7       | C   | Cichorieetum intybi Carduo acanthoidis-Onopordetum acanthii | 5 | 4 | 22 | 71 | 0.78 | 2.40 |
| 8       | C   | Cichorieetum intybi Carduo | 48 | 18 | 18.38 | 169 | 0.66 | 1.93 |
| 9       | C   | Cichorieetum intybi Carduo acanthoidis-Onopordetum acanthii | 15 | 9 | 19.4 | 107 | 0.67 | 1.98 |
| 10      | C   | Asclepiadetum syriacae Erigeron sumatrensis (Eragrostietalia) Sorghum halepense (Eragrostietalia) | 7 | 2 | 21.86 | 78 | 0.67 | 2.08 |
| 11      | C   | Asclepiadetum syriacae Erigeron sumatrensis (Eragrostietalia) Sorghum halepense (Eragrostietalia) | 4 | 3 | 23.25 | 57 | 0.69 | 2.17 |
| 12      | C   | Cichorieetum intybi Carduo acanthoidis-Onopordetum acanthii | 7 | 2 | 15.86 | 57 | 0.59 | 1.61 |
| 13      | C   | Calystegio-Equisetetum tenebricetum Convexula arvensis-Elytrigietum repentis | 4 | 2 | 16.25 | 43 | 0.62 | 1.72 |
| 14      | C   | Cichorieetum intybi Carduo acanthoidis-Onopordetum acanthii | 8 | 7 | 12.5 | 59 | 0.55 | 1.37 |
| 15      | C   | Sambucetum ebuli Poo compressae-Tussilaginetum farfarae Cynodonto dactyl-Atriplicotum tataricetum | 95 | 17 | 13.75 | 178 | 0.59 | 1.51 |
| 16      | C   | Cichorieetum intybi Carduo acanthoidis-Onopordetum acanthii | 2 | 2 | 18 | 31 | 0.52 | 1.51 |
| 17      | D   | Chenopodiadum stricti | 3 | 3 | 16.67 | 32 | 0.61 | 1.73 |
| 18      | D   | Ambrosietaetum artemisiifolii | 65 | 18 | 17.68 | 179 | 0.66 | 1.88 |
| 19      | D   | Ambrosietaetum artemisiifolii | 60 | 17 | 18.05 | 188 | 0.65 | 1.88 |
| 20      | E   | Hordeum murinum | 52 | 3 | 15.58 | 121 | 0.60 | 1.64 |
| 21      | E   | Plantago lanceolata (Cynosurion cristati) Malva sylvestris (Sisymbriion officinalis) | 6 | 2 | 16.83 | 49 | 0.66 | 1.85 |
| 22      | E   | Plantago lanceolata (Cynosurion cristati) Malva sylvestris (Sisymbriion officinalis) | 10 | 2 | 19 | 72 | 0.66 | 1.94 |
| 23      | F   | Cynodontetum dactyl Diplotaxis stricta | 14 | 5 | 9.79 | 35 | 0.51 | 1.16 |
| 24      | F   | Lolietum perennis | 51 | 17 | 10.51 | 82 | 0.62 | 1.43 |
| 25      | F   | Lolietum perennis | 5 | 2 | 9.4 | 20 | 0.62 | 1.39 |
| 26      | F   | Lolietum perennis | 85 | 20 | 10.21 | 106 | 0.49 | 1.13 |
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3.3. Characteristics of Plant Communities

Group A includes four communities dominated or co-dominated by alien herb or shrub species. The least represented from this group is the community where *Amaranthus tuberculatus* dominates, recorded only on the riverbanks in the city of Šabac, in
western Serbia. In these stands, the alien species *A. tuberculatus* has cover values ≥50%. To date, no stands dominated by *A. tuberculatus* have been observed in Serbia, but similar communities have been reported in Italy: *Amaranthus tuberculatus*-phytocoenon Bolpagni 2013, assigned to the class *Bidentetum* Tx. et al. ex von Rochow 1951 [39]. In the author’s opinion, the size of this alien species and its invasiveness make it difficult to identify a distinct combination of constant species in this community, as it outcompetes other species in the stand. Diagnostic species of *Amaranthus tuberculatus* community: *Amaranthus tuberculatus* (85.1), *Bidens frondosus* (31.6), *Panicum barbipulvinatum* (44.6), *P. maculosa* (39.4); Constant species: *Amaranthus tuberculatus*, *Rorippa sylvestris*, *Echinochloa crus-galli*, *Symphyotrichum lanceolatum*, *Calystegia sepium*, *Bidens frondosus*; Dominant species: *Amaranthus tuberculatus*, *Panicum barbipulvinatum*, *P. maculosa*, *Urtica dioica*.

More common were dense stands of *Bidens frondosus*-Persicaria lapathifolia community, recorded in six cities (Loznica, Vladičin Han, Niš, Šabac, Sremska Mitrovica, and Valjevo). In most of them, *Persicaria lapathifolia* is dominant, except for a few relevés in which other species diagnostic of the class *Bidentetum* are distinguished as dominant, such as *Bidens frondosus*, and *Echinochloa crus-galli* [36]. In Serbia, several associations of the class *Bidentetum* have been registered [40]. Our stands are floristically very similar to the relevés of the ass. *Bidentetum tripartitae* Miljan 1933, which were recorded in Serbia by several authors [41–43]. The main difference is that, in our stands, *B. tripartitus* has lower cover values, and is replaced with the alien *B. frondosus*, which reaches cover values ≥50% in two relevés. In the Czech Republic, ass. *Bidentetum tripartitae* is dominated by *P. lapathifolia* or *B. tripartitus* (cover values >50%), whereas stands dominated by *B. frondosus* (cover values >50%) are classified as ass. *Polygonetum hydropiperis* Passarge 1965 [44]. A few communities dominated or co-dominated by this alien are also registered in Italy [17]. Diagnostic species of *Bidens frondosus*-Persicaria lapathifolia community: *Persicaria lapathifolia* (63.6), *Bidens frondosus* (41.3), *Echinochloa crus-galli* (30.9); Constant species: *Bidens frondosus*, *Persicaria lapathifolia*, *Echinochloa crus-galli*, *Xanthium orientale* subsp. *italicum*; Dominant species: *Bidens frondosus*, *Chenopodium album*, *Echinochloa crus-galli*, *Persicaria lapathifolia*, *Persicaria maculosa*.

Dense stands of the *Amorpha fruticosa* community, up to 2–2.5 m high, were registered in seven cities (Belgrade, Kladovo, Vladičin Han, Šabac, Novi Sad, Smederevo, Sremska Mitrovica). In Serbia, communities dominated by *A. fruticosa* from different habitats are classified into different vegetation classes. Association *Amorheto-Typhaetum* Jarić et al. 2011, with edificator species *A. fruticosa* and *Typha latifolia*, was described in the zone of drainage canals in the unbuilt wider area of the city of Belgrade [45]. This association was described as ruderal and originally assigned by the author in the class *Phragmito-Magnocaricetea* Klika in Klika et Novak 1941. In our stands, other species are not clearly characterized, and excluding *A. fruticosa* which forms the upper layer, other constant species occurring in more than 50% of relevés are *Elytrigia repens*, *Symphyotrichum lanceolatum*, *Calystegia sepium*, *Aristolochia clematitis*, *Taraxacum sect. Taraxacum*, and *Bidens frondosus*, of which only *C. sepium* is noted in the ass. *Amorheto-Typhaetum*. Most of the constant species are listed as diagnostic of the class *Epilobietea angustifolii* Tx. et Preising ex von Rochow 1951 [36]. *A. fruticosa* dominating communities in wetland areas of Serbia are classified to the class *Salicetea purpureae* Moor 1958 [46]. This classification scheme was also recommended for different *A. fruticosa* communities in Ukraine [47,48]. In Italy, stands dominated by this shrub have been assigned into different classes [17]. Diagnostic species of *Amorpha fruticosa* community: *Amorpha fruticosa* (87.5); Constant species: *Amorpha fruticosa*; Dominant species: *Amorpha fruticosa*, *Elytrigia repens*, *Symphyotrichum lanceolatum*.

*Asteretum lanceolati* Holzner et al. 1978 is the only community from group A that was also registered in somewhat drier habitats. The stands dominated by neophyte *Symphyotrichum lanceolatum* were found along riversides, roadsides, unmown areas along fences in residential areas, and in forest fringes, in Belgrade, Sremska Mitrovica, and Šabac. This herbaceous association is well known in ruderal habitats of Central Europe [49,50]. In Serbia, ass. *Asteretum lanceolati* was observed on wet and degraded habitats along river-
sides in the city of Belgrade [51]. These stands occur in sporadically shady habitats and are characterized by higher cover values of phanerophytes, compared to our results. Diagnostic species of Asteretum lanceolati: Symphyotrichum lanceolatum (67.8); Constant species: Symphyotrichum lanceolatum; Dominant species: Symphyotrichum lanceolatum, Clematis vitalba, Elytrigia repens, Rubus caesius.

Group B is represented by association Reynoutrietum japonicae. Compact stands dominated by Reynoutria × bohemica were registered in four cities (Užice, Čačak, Beograd, and Pančevo) from May to August. The thick canopy of this broad-leaved tall alien herb significantly reduced the abundance of other species. Genus Reynoutria has extensively been researched in Serbia, and the hybrid Reynoutria × bohemica is the most widespread taxon of the genus [52]. In this study the focus was mainly on distribution patterns, and to date, Reynoutria-dominated communities have not been reported in Serbia in ruderal habitats. Species-poor association Reynoutrietum japonicae, dominated by Reynoutria taxa (R. japonica and R. sachalinensis, and their hybrid R. × bohemica), occurs in ruderal habitats in Czech Republic [50]. This association is also reported in other countries of Central Europe [20,49,53], and the region [54]. Diagnostic species of Reynoutrietum japonicae: Reynoutria × bohemica (89.2); Constant species: Reynoutria × bohemica; Dominant species: Reynoutria × bohemica, Galium aparine.

The largest and most heterogeneous group C includes 11 communities registered in various habitats, which are dominated mostly by biennial and perennial species. One of the most common and the most widespread from this group is Arctietum lappae, recorded in all investigated cities. These stands characterized by A. vulgaris were found in various soils, from dry to moderately humid habitats, along roadsides, railroads, fences, and sidewalks, abandoned lots and yards, sites with construction and communal waste present, on forest edges, with weak or moderate anthropogenic pressure. Association Arctietum lappae is characterized by two species Artemisia vulgaris, and Arctium lappa. Comparing our results with the published relevés of this association from Serbia [4,41,55], A. lappa also has mostly low cover values in previously published data, but it is constantly present as opposed to in our stands. In the formal definition of this association in Central Europe A. lappa has cover values >25% [56]. Diagnostic species of Arctietum lappae: Artemisia vulgaris (54); Constant species: Artemisia vulgaris; Dominant species: Arctium lappa, Artemisia vulgaris, Elytrigia repens.

Another frequently occurring community from this group is Sambucetum ebuli, found in all except three cities in Vojvodina (Kikinda, Sremski Karlovci, Subotica), where lesser representation of this community was generally observed. This community is particularly common in the eastern and western parts of the country, where it forms large dense stands mainly along roadsides and railways, but also forest edges and abandoned lots, from early summer to early fall. This association is well known in Serbia, and has been recorded by several authors [4,41,42,57,58]. Because only a few species can develop in the shade of S. ebulus, this is generally a species-poor community. Diagnostic species of Sambucetum ebuli: Sambucus ebulus (87.4); Constant species: Sambucus ebulus, Elytrigia repens, Convolvulus arvensis; Dominant species: Sambucus ebulus, Clematis vitalba, Elytrigia repens, Rubus caesius.

Tanaceteto vulgaris-Artemisietum vulgaris Sissingh 1950 was registered in four cities (Loznica, Užice, Vranje, Vladičin Han), along roadsides, abandoned lots with construction waste, and the unknown margin of grasslands. Two associations dominated by T. vulgare have been registered in Serbia, Tanaceteto vulgaris-Artemisietum vulgaris originally assigned to Arction lappae Tx. 1937 [4,42,59], and another, floristically different ass. Tanaceteto-Epilobietum lamyii Laban 1975, of the alliance Onopordion acanthii Br.-Bl. et al. 1936 [60]. Diagnostic species of Tanaceteto vulgaris-Artemisietum vulgaris: Tanacetum vulgare (74.7), Agrostis stolonifera (32.8); Constant species: Tanacetum vulgare, Achillea millefolium, Artemisia vulgaris; Dominant species: Tanacetum vulgare, Rubus ulmifolius.

Cichorietum intybi (Tüxen 1942) Sissingh 1969 was registered in all investigated cities, except Čačak and Kikinda. C. intybus dominated stands reach their optimum during
summer, and were observed along roadsides, railways, and previously mowed overgrown green areas. To date in ruderal habitats in Serbia, similar communities have not been reported. Association Cichorietum intybi is found on various habitats in Europe, and in accordance is assigned to different syntaxa [8]. Diagnostic species of Cichorietum intybi: Cichorium intybus (55.4); Constant species: Cichorium intybus, Convolvulus arvensis; Dominant species: Cichorium intybus, Trifolium repens.

Association Carduo acanthoidis-Onopordetum acanthii Soó ex Jarolímek et al. 1997 (syn. Onopordetum acanthi Br.-Bl. 1926) occurs during spring and summer, usually on dry soils, abandoned lots, along roads and railroads, and often adjacent to waste deposits. These tall stands dominated by O. acanthium were registered in nine cities (Šabac, Loznica, Novi Sad, Banatski Karlovci, Vladičin Han, Kladovo, Subotica, Beograd, Pančevo). In Serbia this association was registered by a few authors [4,41,59]. Ass. Carduo acanthoidis-Onopordetum acanthii is characterized by another thistle species Carduus acanthoides, which is also the case with our stands. In the neighboring Hungary, two associations dominated by O. acanthium have been reported Onopordetum acanthi, and more mesophilous Carduo-Onopordetum acanthi Soó 1947 [61]. By comparison, in Bulgaria, stands dominated by O. acanthium, or C. acanthoides are considered as one association [62]. Diagnostic species of Carduo acanthoidis-Onopordetum acanthii: Onopordum acanthium (78.7); Constant species: Onopordum acanthium, Convolvulus arvensis, Elytrigia repens, Ballota nigra, Carduus acanthoides; Dominant species: Carduus acanthoides, Conium maculatum, Elytrigia repens, Lactuca serriola, Onopordum acanthium, Sisymbrium loeselii.

Compact stands of associations. Calystegio-Quisitetum telmateiae S. Jov. 1993. were registered in two cities, Beograd and Negotin, on forest edges and along roadsides in relatively humid soils. Jovanović [63] described this association characterized by the dominant Equisetum telmateia on ruderal habitats in Belgrade and assigned it to the alliance Senection floviatilis Tx. ex Moor 1958, class Epilobieta angustifolii. It is stated that this association is structurally and physiognomically determined by E. telmateia, and develops on moderately humid and higher positions along streams and canals or in larger and humid depressions along roadsides. Diagnostic species of Calystegio-Equisetum telmateiae: Equisetum telmateia (92.4); Constant species: Equisetum telmateia, Elytrigia repens, Rubus caesius, Urtica dioica, Galium aparine, Artemisia vulgaris; Dominant species: Clematis vitalba, Equisetum telmateia.

Convolvulo arvensis-Elytrigietum repentis was registered in seven cities (Vranje, Šabac, Pančevo, Beograd, Smederevo, Kragujevac, Kikinda), during spring and summer, mostly along roadsides. This association, characterized by Elytrigia repens was thus far registered only in Belgrade and its surroundings [4,64]. It develops in the form of compact grass zones, partially to a completely closed structure, with a pronounced meadow physiognomy. Diagnostic species of Convolvulo arvensis-Elytrigietum repentis: Elytrigia repens (48.4); Constant species: Elytrigia repens; Convolvulus arvensis; Dominant species: Elytrigia repens, Convolvulus arvensis, Lepidium draba.

Poo compressae-Tussilaginetum farfarae Tüxen 1931 (syn. Tussilaginetum farfarae Oberd. 1949) was registered only in the city of Užice, western Serbia, in two plots in which T. farfara has cover values ≥50%. These low-growing stands were observed on humid, bare sites, next to a construction site and one along the river. In Serbia, this association was registered by Jovanović [4] in the city of Belgrade, and classified within the alliance Convolvulo arvensis-Agropyriion repentis Gös 1967. According to Jovanović, this is a pioneer community, that develops on bare, disturbed soils, which are usually insolated and dry. In Czech Republic, this community develops in similar habitats from lowlands up to mountain areas, from dry to humid and skeletal to loamy soils [65]. Diagnostic species of Poo compressae-Tussilaginetum farfarae: Tussilago farfara (92.6); Constant species: Tussilago farfara, Convolvulus arvensis, Plantago lanceolata, Taraxacum sect. Taraxacum, Elytrigia repens; Dominant species: Tussilago farfara.

The remaining three communities of group C are dominated by alien species. Asclepiadetum syriaceae Lániková in Chytrý 2009, dominated by A. syriaca was observed along paths near canals, abandoned lots, and neglected sports fields in the province of Vojvodina (Subotica and Novi Sad). Several authors have registered A. syriaca character-
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ized stands in Serbia. They were first observed in Belgrade by Kojić et al. [66], when the submesophilous association was described on the slopes of river embankments. Their presence was later confirmed by Jarić et al. [45], who differentiated two subassociations based on the level of moisture. High cover values of *A. syriaca* were registered within ass. *Convolvulo arvensis-Elytrigietum repens*, which as a dominant species participates in forming a clearly differentiated subassociation *asclepietosum syriaci* [64]. A recent study has shown that in Backa, Vojvodina Province, weedy-ruderal ass. *Asclepiadetum syriacae* develops on slightly dry habitats [67]. Diagnostic species of *Asclepiadetum syriacae*: *Asclepias syriaca* (83.7), *Galium verum* (35); Constant species: *Asclepias syriaca*, *Silene latifolia*, *Dactylis glomerata*, *Erigeron annuus*; Dominant species: *Asclepias syriaca*, *Galium verum*.

*Sorghum halepense* community was recorded during summer months in two cities, Negotin and Valjevo, on unmown green paths near rivers, abandoned lots and yards, along fences and roadsides, and in warm and often sandy habitats. This type of community has to date not been recorded in ruderal habitats in Serbia. In Romania [54], the weed community *Setario pumilae-Sorghetum halepensis* Štefan et Oprea 1997, dominated by *S. halepense* has been observed in different crops, often accompanied with typical ruderal species. Although *S. halepense* dominated stands are common for agricultural areas, they can be potentially urban [6]. Of the same opinion is Fanelli [68], who reported compact, dense, and species-poor stands of *S. halepense* in the city of Rome, which differ from those in agricultural areas. Diagnostic species of *Sorghum halepense* community: *Sorghum halepense* (72.1); Constant species: *Sorghum halepense*, *Convolvulus arvensis*, *Daucus carota*; Dominant species: *Sorghum halepense*, *Convolvulus arvensis*, *Cynodon dactylon*, *Erigeron annuus*, *Medicago sativa*.

Another summer community, *Erigeron sumatrensis*, was registered in three cities (Novi Sad, Valjevo, Belgrade). These stands were found below an overpass, along sidewalks, and on abandoned lots. Similar communities dominated by annual *E. sumatrensis* have not been reported in Serbia. In Spain, ass. *Chenopodia albi-Conyzetum sumatrensis* has been described by Carretero [69], in which *Erigeron sumatrensis* dominates, sometimes almost exclusively. It has been originally classified by the author into the Mediterranean class *Chenopodietea* Br.-Bl. in Br.-Bl. et al. 1952. According to Mucina et al. [36], *E. sumatrensis* is considered diagnostic of classes *Chenopodietea* and *Digitario sanguinalis-Eragrostietea minoris* Mucina, Lososova et Šilc 2016. Diagnostic species of *Erigeron sumatrensis* community: *Erigeron sumatrensis* (81.2); Constant species: *Erigeron annuus*, *Erigeron sumatrensis*, *Convolvulus arvensis*, *Medicago lupulina*, *Crepis foetida* subsp. *rhoeadifolia*, *Plantago lanceolata*, *Carduus acanthoides*, *Taraxacum sect. Taraxacum*, *Symphyotrichum lanceolatum*; Dominant species: *Cynodon dactylon*, *Erigeron annuus*, *Erigeron sumatrensis*.

Group D includes three communities dominated by summer annuals, developing on warm, well-drained, often sandy soils. The least common association from this group is *Cynodonton dactylis-Atriplicitum tataricae* Morariu 1943. These rare stands dominated by *Atriplex tatarica* were registered during summer, on warm sandy soils in Vojvodina province, by a single plot per city (Sremski Karlovci, Pančevo, Banatski Karlovci). This association has been reported in few countries in Europe [54,70,71]. In Serbia, low-growing ass. *Atriplicitum nitentis* Slavnić 1951 was registered in moderately humid habitats in Banat, Vojvodina [59], but is considered by Mucina [70] as a synonym to the ass. *Cynodonton dactylis-Atriplicitum tataricae*. Diagnostic species of *Cynodonton dactylis-Atriplicitum tataricae*: *Atriplex tatarica* (83.6), *Bassia scoparia* (42.4); Constant species: *Atriplex taraica*, *Chenopodium album*, *Amaranthus retroflexus*, *Solanaeum nigrum*, *Lolium perene*; Dominant species: *Atriplex tatarica*, *Bassia scoparia*, *Chenopodium album*.

By comparison, the other two communities from group D are common and widespread in urban habitats across Serbia. *Chenopodietum stricti* (Oberdorfer 1957) Passarge 1964 was registered during summer months on various soils, but usually on dry and warm habitats, in all investigated cities, except Loznica and Valjevo. Often monodominant stands of *Chenopodium album* are found in yards, next to abandoned houses, construction sites, along roads and railroads, and waste places. Ass. *Chenopodietum stricti*, defined by the dominance of taxa from *Chenopodium album* aggregate, is common in Central Europe [70,71].
According to Fanelli [68], stands dominated by *C. album* usually occur in strongly urbanized areas in Rome, and considered an impoverished aspect of *Amarantho-Chenopodietum ambrosioidis* O. Bolós 1967, probably due to *C. album* being more competitive for light, and having prolonged germination compared to other summer annuals. In Serbia, ass. *Chenopodi–Ambrosietum artemisiifoliae* Jarić et al. 2011 was described in abandoned fields and edges of roads, with ediphicator species *C. album* and *Ambrosia artemisiifolia* [45]. This association additionally includes 11 constant species, which are also characterized by high levels of abundance and cover, which is not the case with our stands. Moreover, our results show that stands dominated by *C. album* and *A. artemisiifolia* clearly form two separate communities-clusters, and are often monodominant, enabling other species to thrive. Diagnostic species of *Chenopodietum stricti*: *Chenopodium album* (48.9); Constant species: *Chenopodium album, Polygonum aviculare; Dominant species: Chenopodium album, Polygonum aviculare.*

*Ambrosietum artemisiifoliae* Višnarić 1973 was registered in 17 cities, only absent from Užice, Niš, and Vranje. These stands represent pioneer ruderal community dominated by *A. artemisiifolia* on dry and warm soils, bare places along roads, railroads, and construction sites. *A. artemisiifolia* forms the upper herb layer, alone or sometimes accompanying by *Chenopodium album.* Ass. *Ambrosietum artemisiifoliae* was recorded in Romania [54], while in Slovenia and other countries of Central Europe ass. *Odontito-Ambrosietum Jarolímek et al. 1997* [72]. Diagnostic species of *Ambrosietum artemisiifoliae: Ambrosia artemisiifolia* (58.1); Constant species: *Ambrosia artemisiifolia, Chenopodium album; Dominant species: Ambrosia artemisiifolia, Chenopodium album.*

Communities of group E were registered in May and early June, in sunny habitats. Dense stands of ass. *Hordeetum murini* Libbert 1932 were registered in three cities (Šabac, Pančevo, Belgrade), along sidewalks and roads, which are occasionally moved. Several authors have reported *Hordeetum murini* in Serbia [4,41,42,57,59,73]. In Czech Republic, two associations have been recognized, ass. *Hordeetum murini* absolutely dominated by *H. murinum* and, ass. *Hordeo murini-Brometum sterilis* Lohmeyer ex von Rochow 1951, dominated by *Anisantha sterilis,* and *H. murinum* [71]. In our results, four stands with higher cover values of *A. sterilis* differ from other relevés of the same cluster, but due to a small number of relevés and high similarity with the rest of the cluster, we treated all relevés as one group. Diagnostic species of *Hordeetum murini: Hordeum murinum* (53.7); Constant species: *Hordeum murinum, Convolvulus arvensis, Taraxacum sect. Taraxacum, Polygonum aviculare, Lolium perenne; Dominant species: Anisantha sterilis, Convolvulus arvensis, Hordeum murinum, Lolium perenne.*

Similar to the previous, *Plantago lanceolata* community develops during May and June, on occasionally mowed habitats, along fences, roads, and sidewalks, and was registered in the cities of Šabac and Belgrade. *Plantago lanceolata,* and in addition to the second diagnostic species of the community, *Crepis biennis,* are considered diagnostic for a few syntaxa of the mesic meadows [74]. Diagnostic species of *Plantago lanceolata* community: *Plantago lanceolata* (48.4), *Crepis biennis* (30.4); Constant species: *Plantago lanceolata, Lolium perenne, Convolvulus arvensis, Hordeum murinum; Dominant species: Crepis biennis, Crepis foetida subsp. *rheudifolia, Hordeum murinum, Lolium perenne, Plantago lanceolata, Trifolium repens.*

*Malva sylvestris* community was recorded in Belgrade and Pančevo in early June. Stands develop in light areas, along sidewalks, roads, parks, neglected, and unmown green surfaces in residential areas. To date, similar communities have not been recorded in Serbia, but in the neighboring Romania and Hungary, stands with the dominance of *M. sylvestris* are described as *Balloto-Malvetum sylvestris* Gutte 1966, assigned to *Artemisietea vulgaris* [54,61]. As opposed to ours, this association develops on nutrient-rich soil and is additionally characterized by the species *Ballota nigra,* which was not registered in a single plot in our stands. Stands from Serbia are more floristically similar to phyto-coenoses from Hungary. According to Mucina [75], this association in Central Europe, with dominant *M. sylvestris,* and subdominant species *B. nigra,* also forms on soils rich
in nutrients, which are skeletal and permeable. Our stands clearly develop on different habitats, and are mostly characterized by diagnostic species of the class *Sisymbrietea* Gütte et Hilbig 1975. Diagnostic species of *Malva sylvestris* community: *Malva sylvestris* (65); Constant species: *Malva sylvestris*, *Convulvulus arvensis*, *Plantago lanceolata*, *Hordeum murinum*, *Polygonum aviculare*, *Lolium perenne*; Dominant species: *Malva sylvestris*, *Anisantha tectorum*, *Convulvulus arvensis*, *Hordeum murinum*, *Lolium perenne*, *Sisymbrium orientale*.

Group F includes plant communities developing on various trampled habitats. The intensively trampled *Ochlopoa annua* community was registered in the cities of Pančevo and Belgrade during May. In addition to *O. annua*, *Sclerochloa dura* is also identified as diagnostic of this community. All collected relevés are floristically very similar, except for species *S. dura*, which is absent in three relevés (of five total). Ass. *Poetum annuae* (Gams 1927) Knapp 1945, characterized by *Ochlopoa annua*, and ass. *Sclerochloa-Polygonetum avicularis* (Gams 1927) Soó 1940, characterized by *Sclerochloa dura* have to date been reported in Serbia [4,41,57]. Comparing with the floristic composition of the published data from Serbia, our stands have a somewhat transitional position between these two associations, and would be assigned into two associations following the formal definitions proposed by Simonová [76]. Due to high similarity and a small number of plots, we treated all relevés as one group. Diagnostic species of *Ochlopoa annua* community: *Sclerochloa dura* (50.8); *Ochlopoa annua* (49.6); Constant species: *Ochlopoa annua*, *Taraxacum sect.* *Taraxacum*, *Polygonum aviculare*, *Trifolium repens*, *Lolium perenne*, *Plantago major*; Dominant species: *Ochlopoa annua*, *Sclerochloa dura*, *Taraxacum sect.* *Taraxacum*.

During spring and summer, on highly insolated habitats in Pančevo, Beograd, Valjevo, Sremu Mitrovica, and Negotin, *Cynodontetum dactyli* Gams 1927 was registered. To date, this association has not been reported in Serbia. In addition to the dominant *C. dactylon*, in Romania, *Hordeum murinum* also stands out as dominant of ass. *Cynodontetum dactyli* [54], which is not the case with stands from Serbia and Central Europe [7,70,71]. In Central Europe, this association is classified in different trampled alliances of the class *Digitario sanguinalis*-Eragrostietea minoris. It occurs in warm, dry, sunny, disturbed habitats on sandy soils. Additionally, among other species, it is accompanied by other species adapted to trampling, but in our stands, species of the class *Polygono-Poetea annuae* Rivas-Mart. 1975 are more predominant. Diagnostic species of *Cynodontetum dactyli*: *Cynodon dactylon* (51.2); Constant species: *Cynodon dactylon*, *Polygonum aviculare*, *Trifolium repens*, *Lolium perenne*; Dominant species: *Cynodon dactylon*, *Ochlopoa annua*.

The most common vegetation type of trampled habitats, registered in all investigated cities is *Polygonetum avicularis*. This low-growing and species-poor association has been observed on dry and insolated trampled sites, on which the species *P. aviculare* often forms monodominant stands, which is confirmed with the lowest Evenness value. *Polygonetum avicularis* was recorded in Serbia by Stanković-Kalezić [57], Šajinović [41] and Jovanović [4], and compared to the latter two authors, *P. aviculare* has much higher cover values in our stands. Diagnostic species of *Polygonetum avicularis*: *Polygonum aviculare* (47); Constant species: *Polygonum aviculare*, *Plantago major*, *Lolium perenne*, *Taraxacum sect.* *Taraxacum*; Dominant species: *Polygonum aviculare*.

Association *Lolietum perennis* Gams 1927 was registered mostly during spring and summer in all investigated cities, except for Niš, Čačak and Kikinda. It develops on trampled habitats along roads, sidewalks, in yards, trampled paths in residential areas, next to playgrounds, etc. This association with edificator species such as *Lolium perenne* and *Plantago major*, is considered as one of the most widespread ruderal communities in Serbia [77]. Conditions in these stands, are somewhat more favorable compared to other trampled communities [57]. In Serbia and Romania, it has traditionally been classified within the vegetation of trampled habitats *Polygono-Poetea annuae* [54,77], a scheme which we follow in this study. In other European countries, this association has been assigned to the vegetation class of meadows and mesic pastures, *Molinio-Arrhenatheretalia* Tüxen 1937 [7,68,74]. Diagnostic species of *Lolietum perennis*: *Plantago major* (39.7), *Lolium perenne* (32.3); Constant species: *Lolium perenne*, *Plantago major*, *Polygonum aviculare*, *Tarax-
acum sect. Taraxacum, Trifolium repens; Dominant species: Lolium perenne, Plantago major, Trifolium repens.

3.4. Syntaxonomical Scheme

On the basis of the results obtained, we propose a syntaxonomic overview of the recorded communities, which can be represented by the following scheme:

- **Bidentetea** Tx. et al. ex von Rochow 1951
- **Bidentetalia** Br.-Bl. et Tx. ex Klika et Hadač 1944
- **Bidention tripartitae** Nordhagen ex Klika et Hadač 1944
- Comm. *Amaranthus tuberculatus* (Bidention tripartitae)
- Comm. *Bidens frondosus-Persicaria lapathifolia* (Bidention tripartitae)
- Comm. *Epilobietea angustifolii* Tx. et Preising ex von Rochow 1951
- *Circaeo lutetianae-Stachyetalia sylvaticae* Passarge 1967
- **Aegopodion podagrariae** Tx. 1967
- **Asteretum lanceolati** Holzner et al. 1978
- **Reynoutrietum japonicae** Görs et Müller in Görs 1975
- **Epilobietea angustifolii** Tx. et Preising ex von Rochow 1951
- **Artemisietea vulgaris** Lohmeyer et al. in Tx. ex von Rochow 1951
- **Onopordetalia acanthii** Br.-Bl. et al. 1936
- **Rubo caesii-Amorphion fruticosae** Shevchyk et V. Solomakha in Shevchyk et al. 1996
- **Atriplicion** Passarge 1978
- **Chenopodietum stricti** (Oberdorfer 1957) Passarge 1964
- **Ambrosietum artemisiifoliae** Vitalariu 1973
- **Sisymbrietalia sophiae** J. Tx. et Görs 1966
- **Atriplicetum tataricae** Morariu 1943
- **Cynodonto dactyli-Atriplicetum tataricae** Morariu 1943
- **Chenopodietum stricti** (Oberdorfer 1957) Passarge 1964
- **Ambrosietum artemisiifoliae** Vitalariu 1973
- **Sisymbrient officinalis** Tx. et al. ex von Rochow 1951
- **Molinio-Arrhenatheretalia** Tx. 1937
- **Arrhenatheretalia elatioris** Tx. 1931
Cynosurion cristati Tx. 1947
Comm. Plantago lanceolata (Cynosurion cristati)
Polygono-Poëtea annuae Rivas-Mart. 1975
Polygono arenstri-Poëtalia annuae Tx. in Géhu et al. 1972 corr. Rivas-Mart. et al. 1991
Polygono-Coronopodion Sissingh 1969
Comm. Ochlopoa annua (Polygono-Coronopodion)
Polygonetum avicularis Gams 1927
Cynodontetum dactyli Gams 1927
Lolietum perennis Gams 1927

* According to Mucina et al. [36] alliance Arction lappae has a transitional position between Artemisietea and Epilobietea angustifolii, and classification within both classes is possible.

4. Conclusions
The occurrence of many ruderal associations that have been registered to date in Serbia [40,77] was not confirmed with our study. As the relevés for this research were exclusively taken in settlements and mostly during the summer months, we cannot claim that some known associations have disappeared from the territory of Serbia. Conversely, many new communities have emerged in urban environments, whose presence was until now not recorded. From the seven most widespread associations, i.e., Arctietum lappae, Sambucetum ebuli, Lolietum perennis, Polygonetum avicularis, Ambrosietum artenisiifolii, Chenopodietum stricti, and Cichorietum intybi, the latter three have not been reported from ruderal habitats in Serbia, at least not in this form. Some of the newly emerged communities are dominated by alien plants. In general, a total of nine communities are dominated or co-dominated by aliens. This paper is the first insight into ruderal communities of various cities across Serbia, as the previous studies from the country were very unevenly distributed [78]. A more detailed syntaxonomic revision of the analyzed vegetation, in addition to a final judgement on all the associations currently included in it, can only be made after further, more comprehensive analyses, in which all the registered ruderal syntaxa from Serbia will be included.

Supplementary Materials: The following table is available online at https://www.mdpi.com/article/10.3390/d13120638/s1, Table S1: Synoptic table of ruderal communities.

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