

1 **Classification of mesic and semi-dry grasslands in Hungary**

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16 *In memoriam Eszter Illyés (1979–2012)*

17

18 **Abstract**

19 Mesic and semi-dry grasslands are among the most valuable and species-rich anthropogeneous  
20 habitat types in Hungary. In contrast with their high respect in nature conservation, their vegetation  
21 diversity and syntaxonomy were neglected for a long time. In this paper we present their first

1 country-level synthesis and syntaxonomical review based on numerical classification of the  
2 *Arrhenatheretalia* order, and an update on *Brometalia erecti*.

3 After careful data selection and resampling, we classified 1204 relevés to 60 clusters. Clusters  
4 representing the same association were merged on the basis of a minimum spanning tree and expert  
5 assessment of their species composition. Species composition, geographical distribution, and  
6 environmental background of each mesic and semi-dry grassland association are discussed. The  
7 relationships of associations were also examined by ordination. Evaluation of clusters and  
8 associations were based only on those relevés which were unambiguously classified.

9 We recognized 11 associations in the *Arrhenatheretalia* order in two alliances. In the  
10 *Arrhenatherion* alliance, several new association names are adopted from the literature of foreign  
11 countries, as well as a new one is proposed. According to our concept, *Arrhenatherion* includes  
12 *Ranunculo-Alopecuretum*, a meso-hygrophilous type; *Filipendulo-Arrhenatheretum* and  
13 *Anthoxantho-Festucetum pratensis*, which are typical for meadows of changing soil water level but  
14 have different geographic distribution; *Pastinaco-Arrhenatheretum*, that is a widespread mesic  
15 meadow with many generalist species; *Ranunculo bulbosi-Arrhenatheretum* containing drought-  
16 tolerant and less nutrient-demanding species; *Tanaceto-Arrhenatheretum*, a semi-ruderal type; and  
17 *Diantho-Arrhenatheretum*, that harbours many species of montane meadows. In the *Cynosurion*,  
18 four associations are distinguished. *Cynosuro-Lolietum* is an intensively grazed type on nutrient-  
19 rich, mesic or moist soil in humid climate; *Alopecuro-Festucetum pseudovinae* is also a heavily  
20 grazed type, but in more continental climate and on packed soil. *Anthoxantho-Festucetum*  
21 *pseudovinae* and *Colchico-Festucetum rupicolae* are lowland mesic pastures that contain some  
22 xerophilous species, however, they differ in grazing intensity and regional species pool. Two  
23 transitional associations of *Cirsio-Brachypodion* towards more mesic types are detected for the first  
24 time in Hungary: *Filipendulo-Brometum* with sub-Atlantic distribution and *Brachypodio-*  
25 *Molinietum* with more montane and Carpathian distribution. We also recognized *Sanguisorbo-*

1 *Brometum*, that is a common semi-dry grassland type of rocky soils in Transdanubia; *Polygalo-*  
2 *Brachypodietum*, a colline type with many Pontic species; *Trifolio-Brachypodietum*, an association  
3 of more forested and montane landscapes, and *Euphorbio-Brachypodietum*, the semi-dry grassland  
4 type of Pannonian loess regions. We rejected the presence of *Phyteumo-Trisetion* and *Bromion*  
5 *erecti* in Hungary.

6

## 7 **Keywords**

8 *Arrhenatheretalia*, *Brometalia erecti*, Carpathian Basin, classification, clustering, meadow,  
9 Hungary, phytosociology, syntaxonomy

10

## 11 **Introduction**

12 Mesic and semi-dry grasslands are among the most valuable and species-rich anthropogeneous  
13 habitat types in Hungary. They are typically located on formerly forested sites, and they are  
14 maintained by mowing and grazing, while after abandonment they can easily transform into other  
15 vegetation types following the colonization of shrubs, trees or tall forbs. Factors influencing the  
16 dynamics and richness of semi-natural grasslands are subject of numerous studies in Europe, and  
17 most of them agree that the continuous, low-intensity management as well as spatial and temporal  
18 heterogeneity of the environment are essential for sustaining their diversity (Linusson et al. 1998,  
19 Huhta et al. 2001, Aavik et al. 2008, Marini et al. 2008, Bernhardt-Römermann et al. 2011,  
20 Burrascano et al. 2013, Fajmonová et al. 2013, Janeček et al. 2013, Michalcová et al. 2014, Mathar  
21 et al. 2015). As traditional, extensive management declines in Hungary, natural and economic  
22 values posed by semi-natural grasslands are also under threat (Molnár et al. 2008a, b); therefore  
23 documenting their diversity is an urgent task.

1 Due to the intensive research of Central European grasslands since the earliest decades of  
2 phytosociology (Braun-Blanquet 1930), when many of the currently known and widely applied  
3 syntaxon names were established, by the end of the 1990s or the first years of the 21<sup>st</sup> century,  
4 comprehensive, national monographs of these vegetation types were published in some countries  
5 (e.g. Austria: Ellmauer & Mucina 1993, Czech Republic: Chytrý 2007, Slovakia: Janišová et al.  
6 2007, Hegedúšová Vantarová & Škodová 2014). On the contrary, diversity and syntaxonomy of  
7 secondary vegetation in Hungary received relatively little attention in comparison with other  
8 vegetation types, besides investigations with economic and agricultural purposes (e.g. Jeanplong  
9 1987, Vinczeffy 2006) and restoration studies (Török et al. 2011, 2012). Most studies in the 20<sup>th</sup>  
10 century present qualitative descriptions of associations of narrow geographical areas (e.g. Juhász-  
11 Nagy 1959, Máthé & Kovács 1960, Kovács 1994, Varga 1997, Lájér 2002). Not surprisingly, to  
12 date country-level summaries relied on generalizations of such local observations, adoptions of  
13 results from foreign literature and subjective experiences of field botanists (Soó 1971, 1973,  
14 Borhidi & Sánta 1999, Borhidi 2003). Quantitative studies appeared only in the 21<sup>st</sup> century, when  
15 Horváth (2002, 2010) thoroughly studied the loess forest-steppe vegetation of the Mezőföld region  
16 and described the unique, xeromesic grassland of the Pannonian, loess-covered lowland and colline  
17 areas as a new association, *Euphorbio-Brachypodietum*. Illyés et al. (2007) studied the geographical  
18 variation of semi-dry grasslands in Central Europe along a continentality gradient, and then revised  
19 their syntaxonomy in Hungary (Illyés et al. 2009). Bauer (2012, 2014) presented the classification  
20 of dry and semi-dry grasslands (*Festuco-Brometea*) of the Bakony Mts and its adjacent regions. In  
21 contrast to these recent contributions to the knowledge of semi-dry grasslands, the mesic meadows  
22 and pastures remained rather neglected by the Hungarian phytosociologists. Apart from the  
23 numerical classification of mesic grasslands of South Transdanubia (Lengyel et al. 2012a), we are  
24 not aware of any contribution that would help clarify the classification and syntaxonomy of this  
25 vegetation type on a quantitative basis. Therefore, their numerical revision is more than timely now.

1 In the latest syntaxonomical synthesis of Hungarian vegetation (Borhidi et al. 2012) some of the  
2 recent updates by Illyés et al. (2007, 2009) and Bauer (2012) have been adopted, however, there are  
3 still many questions to be answered. The complete list and hierarchy of the respective syntaxa  
4 according to Borhidi et al. (2012) are presented in Appendix 1. Mesic grasslands are represented by  
5 the *Arrhenatheretalia* order of the *Molinio-Arrhenatheretea* class. Within *Arrhenatheretalia*, three  
6 alliances are present in Hungary according to Borhidi et al. (2012): *Arrhenatherion elatioris*  
7 containing mesic, mown meadows of colline to submontane regions, *Cynosurion cristati* containing  
8 heavily grazed or frequently cut, mesic grasslands with similar distribution, and *Phyteumo-Trisetion*  
9 for hay meadows of montane and (sub-)atlantic areas with moderate nutrient supply. Semi-dry  
10 grasslands form a separate order within *Festuco-Brometea* class, called *Brometalia erecti* Koch  
11 1926. It is to be noted that the interpretation of this name is ambiguous and some authors (e.g.  
12 Korneck 1974, Mucina et al. 2009) argue that the name *Brachypodietalia pinnati* Korneck 1974  
13 should be used instead. However, in this study we follow the traditional nomenclature of orders,  
14 also applied recently by Austrian (Willner et al. 2013a, b), Slovak (Janišová et al. 2007,  
15 Hegedüšová Vantarová & Škodová 2014), and Czech authors (Chytrý 2007). According to Borhidi  
16 et al. (2012), *Brometalia erecti* order is represented by two alliances in Hungary: the subcontinental  
17 *Cirsio-Brachypodion* and the (sub-)Atlantic and Mediterranean *Bromion erecti*. However, the  
18 presence of *Bromion erecti* in Hungary is questioned by Illyés et al. (2007, 2009). Many of the  
19 stands of semi-dry and mesic grasslands are difficult to assign to the already described types due to  
20 the presence of transitions and the high number of shared species among different lower syntaxa.  
21 Nevertheless, there is a continuous variation even between associations of *Arrhenatheretalia* and  
22 *Brometalia erecti* orders, despite they are assigned to different classes.

23 Our aim is to prepare the numerical classification of Hungarian mesic and semi-dry grasslands  
24 jointly. Such a common analysis of these two vegetation orders would have the potential to 1)  
25 revise the mesic meadow and pasture associations, 2) clarify the situation of transitions between

1 mesic and semi-dry grasslands that caused most complications in former analyses, and 3) to refine  
2 the previous classifications and update our knowledge of semi-dry grasslands in Hungary.

3

#### 4 **Materials and Methods**

5 A data set comprising 2055 phytosociological relevés from Hungary was gathered. Their main  
6 sources were the ‘CoenoDat’ Hungarian plot database (GIVD ID EU-HU-003, Csiky et al. 2012)  
7 and private databases. Relevés needed to fulfil one of the following two criteria: 1) to be assigned  
8 by the original author to the *Arrhenatheretalia* or the *Brometalia erecti* order, or to their transitions;  
9 2) to contain at least 8 of a list of characteristic species of *Arrhenatheretalia* and *Brometalia erecti*  
10 obtained from the vegetation monographs of Slovakia (Janišová et al. 2007) and the Czech Republic  
11 (Chytrý 2007). Only those relevés were included for which geographical coordinates were  
12 available. More than 90% of the relevés were collected after 1995, while the oldest ones are from  
13 the 1950s. Plot size varied between 4 and 25 m<sup>2</sup>. From the 50 relevés by Juhász-Nagy (1959) we  
14 found no information on plot size but we assumed that he followed the practice of Hungarian  
15 phytosociologists of his time who recorded grassland relevés in 4 to 50 m<sup>2</sup> plots. Species covers  
16 were originally estimated on different scales. Cover codes on **Braun-Blanquet-type scales** were  
17 translated to percentages according to the mid-value of their categories. In the analyses the square-  
18 root transformed values of the percentage covers were used. The phytosociological tables by  
19 Juhász-Nagy (1959) were incomplete because for species with only a single occurrence no cover  
20 value was reported. We considered such species with “+” category on the Braun-Blanquet cover  
21 scale supposing that locally rare species should not have significant effect on the classification if  
22 otherwise the table represents a well defined type (Lengyel et al. 2012b). The nomenclature of plant  
23 taxa follows Király (2009). Some species with taxonomic or identification issues were merged into  
24 species aggregates (Appendix 2). The records of non-vascular plants, shrubs and trees were deleted

1 from the relevés. For the calculation of between-plot dissimilarities, Marczewski-Steinhaus index  
2 was used which is the dissimilarity version of the abundance form of Jaccard index (Podani 2000).

3 The initial data set included many relevés which belonged to syntaxa out of our scope. Filtering a  
4 data set in order to restrict it more on the focal vegetation unit is a very difficult task if the  
5 vegetation unit itself lacks formal definition, and this is now the case for Hungarian mesic and  
6 semi-dry grasslands. If the filtering is performed by a too strict rule, the risk of excluding relevés  
7 originally belonging to the type under scope is high, and this is a more serious error than keeping  
8 out-of-scope types in the sample. We decided to leave enough relevés in our data set from out-of-  
9 scope types in order to better detect their transitions with the focal types. To achieve this, a  
10 preliminary classification was applied. At the beginning, the unbalanced distribution of plots in  
11 compositional similarity and geographical space was reduced by heterogeneity-constrained random  
12 resampling with geographical stratification (Lengyel et al. 2011). The retained 1340 relevés were  
13 classified hierarchically by the beta-flexible method (beta = -0.25). We informally evaluated the  
14 resulting 50 clusters on the basis of species composition and author-supplied syntaxon assignments,  
15 and decided whether a cluster contains relevés that potentially belong to the target syntaxa, that is,  
16 *Arrhenatheretalia* and *Brometalia* orders. After this, the distance of each relevé, including those  
17 which were omitted during resampling, to each cluster was calculated using the Associa method  
18 (van Tongeren et al. 2008). Relevés (re-)assigned to clusters representing out-of-scope types were  
19 eliminated from the data set. Excluded relevés represented wet meadows with dominance of  
20 *Molinia caerulea* agg., alkali grasslands with *Peucedanum officinale*, open, dry grasslands with the  
21 dominance of *Stipa* spp., *Festuca valesiaca*, *F. pseudodalmatica*, *F. rupicola*, *Carex humilis*, and  
22 *Chrysopogon gryllus*. However, a certain number of relevés of out-of-scope types still remained in  
23 this filtered data set that contained 1424 relevés.

24 The HCR resampling procedure with the same settings as mentioned above was carried out on this  
25 filtered data set which reduced its size to 1204 relevés. The geographical distribution of the relevés

1 of the final data set is shown on Fig. 1. Many hierarchical classification methods were tried in order  
2 to recover as many patterns as possible from this data set. A common weakness of simple,  
3 hierarchical classifications was that the resulting clusters consisted of relevés which belonged to  
4 different associations. Such clusters may not be useful for syntaxonomic purposes, thus we tried  
5 improving our methodology by three solutions. Firstly, a non-hierarchical method, partitioning  
6 around medoids (PAM, Kaufman & Rousseeuw 1990), was used for classifying relevés, and we  
7 looked for hierarchical relations less formally on the basis of among-cluster patterns and  
8 syntaxonomical interpretation. Non-hierarchical methods tend to obtain more homogenous clusters  
9 without constraining the classification into a perfectly nested structure (Podani 2000). Secondly, a  
10 relatively fine solution consisting of 60 clusters were examined, ensuring that each cluster can  
11 represent a relatively narrow vegetation unit. Several methods (Optimclass with several different  
12 thresholds for p-values, Tichý et al. 2010; average silhouette, Kaufman & Rousseeuw 1990; the  
13 bootstrap method by Tichý et. al. 2011) were tried for finding the optimal number of clusters, but  
14 they all gave different results; however, in several cases, optima fell between 40 and 60 clusters,  
15 therefore, the 60-cluster solution seemed to be fine enough to detect all important types, allowing  
16 that some of the clusters may eventually belong to the same association. Thirdly, the silhouette  
17 index (Rousseeuw 1987) was calculated for each relevé and only those with a positive silhouette  
18 value were taken into account during the evaluation of clusters. Hereafter we call the relevés with  
19 positive silhouette value within a frame of any classification ‘core relevés’, while those with non-  
20 positive silhouette value as ‘non-core relevés’. For analysing the relationships of clusters, a matrix  
21 was calculated that contains average dissimilarities between core relevés of pairs of clusters. This  
22 dissimilarity matrix was classified by the minimum spanning tree method (MST, Podani 2000). The  
23 MST is the 2-dimensional, non-hierarchical representation of the single linkage clustering with  
24 lengths of between-neighbour branches corresponding to chaining values at the vertical axis of a  
25 dendrogram. MST can reveal closest neighbourhoods of clusters, thus it is an effective tool for  
26 analysing gradual variation among clusters. In some cases certain clusters came out as



1 representatives of the same association. For studying the relationships between associations, we  
2 merged the relevés of such clusters into one group, including non-core relevés. Only such clusters  
3 were allowed for merging which appeared as closest neighbours in the MST. After merging, we re-  
4 calculated the silhouette values of relevés, therefore, we re-defined the sets of core relevés for each  
5 cluster or group of clusters. Only core relevés obtained after merging were used for constructing  
6 synoptic tables and summary statistics. The fidelity of species to clusters was expressed by the phi  
7 coefficient (Chytrý et al. 2002) with equalized group sizes (Tichý & Chytrý 2006). Only fidelities  
8 with  $\phi > 20$  (on 0 to 100 scale) and Fisher's exact test  $p < 1e-3$  were considered meaningful.

9 The relationships of associations was also examined by principal coordinates analysis (PCoA)  
10 ordination of core relevés. The associations were graphed on a spider plot for two dimensions. Two  
11 separate ordinations were performed: one including both orders, and one separately for  
12 *Arrhenatheretalia*.

13 Data management and calculations were performed by softwares TurboVeg (Hennekens &  
14 Schaminée 2001), Juice (Tichý 2002), and R (R Core Team 2013), the latter one with the vegan  
15 (Oksanen et al. 2013), MASS (Venables & Ripley 2002), cluster (Maechler et al. 2013), vegclust  
16 (De Cáceres et al. 2010), and rapport (Blagotić & Daróczi 2013) packages.

## 17 **Results & Discussion**

### 18 *Interpretation of the minimum spanning tree*

19 There were 831 relevés with positive silhouette values in the 60 clusters of the PAM classification.  
20 The minimum spanning tree (Fig. 2) revealed major gradients in species composition of the data set.  
21 The left part of the graph, from Clusters 1 to 30, constituted mostly of mesic types (including all  
22 **associations of *Arrhenatheretalia* order**), while on the right side, from Clusters 31 to 60, drier types  
23 are presented (including all but one association of *Brometalia erecti* **order**). Within the mesic part,  
24 two large and a smaller, well-interpretable branches connected by Cluster 14 can be recognized.

1 The first main branch consisted of Clusters 1 to 11. This group of clusters represented lowland or  
2 colline hay meadow associations on mostly nutrient-rich, mesic or wet soils. Clusters 1 to 7  
3 includes *Arrhenatherion* communities dominated by *Arrhenatherum elatius* (*Ranunculo bulbosi-*  
4 *Arrhenatheretum*, *Tanaceto-Arrhenatheretum*, *Pastinaco-Arrhenatheretum*), and an unidentified  
5 cluster. In Clusters 8 to 13 the species of wet meadows have high frequency and cover; however,  
6 these types differ in syntaxonomical affiliation: Clusters 8 to 10 are wet meadows (in  
7 *Deschampsion*; out of scope), Cluster 11 and 13 are two associations in *Arrhenatherion* with  
8 temporal or permanent effect of high ground water (*Filipendulo-Arrhenatheretum*, *Ranunculo*  
9 *repentis-Alopecuretum*), while Cluster 12 contains intermediate stands and old-fields oversown with  
10 *Alopecurus pratensis*. The small branch from Clusters 14 to 18 contains mostly lowland pastures  
11 with dry (typically mid- to late summer) and wet (especially autumn spring) periods during the year  
12 (*Colchico-Festucetum rupicolae*, *Anthoxantho-Festucetum pseudovinae*, *Alopecuro-Festucetum*  
13 *pseudovinae*). They are characterized by the mixture of mesophilous and xerophilous species.  
14 Cluster 19 and 20 are two types with high cover of *Arrhenatherum elatius* and high frequency of  
15 xerophilous species (*Diantho-Arrhenatheretum* and an unidentified type). The common feature of  
16 Clusters 21 to 28 is that they are distributed in the most humid areas of Hungary, and they contain  
17 many montane, acidophilous or hygrophilous species. These clusters vary in management regime,  
18 since there are pastures, hay meadows, and abandoned types among them. According to the  
19 syntaxonomic system, they include types from *Arrhenatherion* (*Anthoxantho-Festucetum*  
20 *pratensis*), *Cynosurion* (unidentified at association level), *Cirsio-Brachypodion* (*Brachypodio-*  
21 *Molinietum*), and *Violion caninae* (out of scope) alliances. Cluster 29 and 30 are also joined to this  
22 branch of clusters, making a transition towards the nutrient-rich and less acidic but intensively  
23 grazed *Cynosuro-Lolietum* association of *Cynosurion*. In the semi-dry half of the minimum  
24 spanning tree, Clusters 31 to 40 are semi-dry or dry types with high participation of species of rocky  
25 grasslands. Within this branch, there is a moisture gradient from Clusters 31 and 32 (mesic-  
26 xeromesic; *Filipendulo-Brometum* and a transitional type) through Cluster 33 to 36 (xeromesic;

1 *Sanguisorbo-Brometum*) to Clusters 37 to 40 (dry grasslands; *Festucion valesiaca* and *Bromo-*  
2 *Festucion pallentis*; out of scope). Grasslands represented by Cluster 41 and onwards with a few  
3 exceptions thrive on deeper soils, either on loess-covered lowlands or colline to montane forest  
4 clearings, and they are usually dominated by *Brachypodium pinnatum*. Four well-delimited  
5 associations are recognized within this large group of clusters, which are differentiated according to  
6 base-rock, phytogeographical character, and landscape context. Clusters 41 to 43 belong to  
7 *Polygalo-Brachypodietum*, which is a termophilous, colline type. Clusters 44 to 48 represent  
8 *Euphorbio-Brachypodietum*, the widespread semi-dry grassland of loess-covered lowland plateaus  
9 and foothills. Clusters 57 to 59 include *Trifolio-Brachypodietum* that is distributed in montane,  
10 forested areas. The latter two associations are accompanied by some clusters of out-of-scope types  
11 (Clusters 49 to 51: *Festucion rupicola* and *Geranion sanguinei*, Cluster 60: *Stipenion tirsae*) and  
12 clusters with unclear interpretation but belonging to *Cirsio-Brachypodion* (Clusters 53 to 56).

### 13 ***Description of identified associations of Arrhenatheretalia and Brometalia erecti orders***

14 After merging clusters representing the same type, 33 groups remained, for which there were 898  
15 core relevés. The summaries of types identified as associations of *Arrhenatheretalia* and *Brometalia*  
16 **orders** with faithful, constant, and dominant species, and their distribution maps are presented in  
17 Appendix 3. A synoptic table is also supplied in Appendix 4.

### 18 *Ranunculo bulbosi-Arrhenatheretum* Ellmauer 1993 [in *Arrhenatherion*; Clusters 2 & 3]

19 This association has not been reported before **from** Hungary. According to Chytrý (2007), Willner  
20 et al. (2013b), and Uhliarová et al. (2014), *Ranunculo-Arrhenatheretum* is characterized by the  
21 dominance of *Arrhenatherum elatius* and the presence of less nutrient-demanding species of mesic  
22 and semi-dry meadows. In our data set, its dominant species are *Arrhenatherum elatius*, *Bromus*  
23 *erectus*, *Danthonia alpina*, and *Trisetum flavescens*. The accompanying species are elements of  
24 mesic or semi-dry, mown meadows with moderate nutrient availability (e.g. *Festuca rubra*,  
25 *Ranunculus polyanthemus*, *Vicia sativa* agg., *Rhinanthus minor*, *Anthoxanthum odoratum*, *Salvia*

1 *pratensis*). This association includes two variants according to soil base status, Cluster 1  
2 representing the base-rich subtype and Cluster 2 being the acidic one. Its **relations to similar**  
3 **associations are** presented at the discussion of respective types.

4 *Tanaceto-Arrhenatheretum* Fischer ex Ellmauer 1993 [in *Arrhenatherion*; Clusters 4, 5 & 6]

5 This association is also reported for the first time **from** Hungary. Its relevés represent mostly semi-  
6 ruderal stands dominated by *Arrhenatherum elatius* that are either abandoned meadows, disturbed  
7 or successional sites. Its characteristic features are the presence of ruderal and disturbance-tolerant  
8 species (e.g. *Medicago sativa*, *Eragrostis minor*, *Convolvulus arvensis*, *Artemisia vulgaris*,  
9 *Tanacetum vulgare*, *Anchusa officinalis*, *Potentilla argentea*) and the relatively low frequency of  
10 typical elements of *Arrhenatherion* (Ellmauer & Mucina 1993).

11 *Pastinaco-Arrhenatheretum* (Knapp 1954) Passarge 1964 [in *Arrhenatherion*; Cluster 7]

12 The dominant species is usually *Arrhenatherum elatius*, but other tall grasses (*Alopecurus*  
13 *pratensis*, *Bromus erectus*, *Dactylis glomerata*, *Festuca pratensis*) are also frequent. Constant and  
14 differential species are typical elements of productive, mesic meadows (e.g. *Cirsium canum*,  
15 *Pastinaca sativa*, *Ranunculus acris*, *Galium mollugo* agg.). These relevés come from colline to  
16 montane regions of different parts of Hungary. *Pastinaco-Arrhenatheretum* is often considered as a  
17 ‘central’ type among *Arrhenatherion* and it is especially difficult to **distinguish** from some very  
18 closely related associations (see also Stančić 2008, Willner et al. 2013b). According to our concept,  
19 *Pastinaco-Arrhenatheretum* in Hungary can be recognized by the dominance of tall grasses (see  
20 species mentioned above), the presence of mid-height grasses (e.g. *Trisetum flavescens*, *Poa*  
21 *pratensis*), and the high frequency of **generalistic** mesic meadow-elements (e.g. *Trifolium pratense*,  
22 *Vicia sativa* agg., *Leucanthemum vulgare* agg., *Campanula patula*, *Ranunculus acris*, *Galium*  
23 *mollugo* agg., *Cirsium canum*, *Pastinaca sativa*, *Tragopogon orientalis*). Although *Geranium*  
24 *pratense* is a diagnostic species of this association in neighbour countries with more mountainous  
25 landscape, in Hungary it is rare and occurs on moister habitats. Species typical of more nutrient-

1 poor habitats (e.g. *Agrostis capillaris*, *Festuca rubra*, *Luzula campestris* agg., *Thymus pulegioides*)  
2 and shared elements with semi-dry grasslands (*Plantago media*, *Salvia pratensis*, *Trifolium*  
3 *montanum*, *Briza media*) are rare (however, not completely absent), thus they can be used for  
4 separation from the otherwise very similar *Ranunculo bulbosi-Arrhenatheretum*. In *Pastinaco-*  
5 *Arrhenatheretum*, species of *Molinietalia* (e.g. *Symphytum officinale*, *Ranunculus repens*, *Carex*  
6 *otrubae*, *Gentiana pneumonanthe*, *Selinum carvifolia*, *Succisa pratensis*) are also rare in general,  
7 aiding its separation from wet meadows where they are much more common. Several  
8 subassociations of *Pastinaco-Arrhenatheretum* are reported by Hungarian authors (Lájer 2002,  
9 Borhidi 2003) but we could not recognize them as separate clusters.

10 *Filipendulo vulgaris-Arrhenatheretum* Hundt & Hübl ex Ellmauer 1995 [in *Arrhenatherion*; Cluster  
11 11]

12 The relevés representing this association not yet reported from Hungary are mostly from the  
13 southern and western parts of Transdanubia. These stands are situated on floodplains and along  
14 brooks on intermittently moist, less aired soils that have a wet and a dry period during the year. Due  
15 to the fluctuation of the water table, *Filipendulo-Arrhenatheretum* has a rather transitional character  
16 between semi-dry, mesic and wet conditions, containing species with different optima along the  
17 moisture gradient. An important feature of these grasslands is the presence of species that indicate  
18 fluctuation of soil moisture, e.g. *Alopecurus pratensis*, *Betonica officinalis*, *Potentilla alba*, and  
19 high cover of *Holcus lanatus* and *Helictotrichon pubescens*. There is usually no single dominant  
20 species of this type, probably because of the less stable water supply. According to Ellmauer &  
21 Mucina (1993) and Willner et al. (2013b), this association develops on less nutrient-rich soils than  
22 *Pastinaco-Arrhenatheretum*, and this is indicated by the presence of species like *Anthoxanthum*  
23 *odoratum*, *Briza media*, and *Luzula campestris* agg. It differs from *Ranunculo bulbosi-*  
24 *Arrhenatheretum* in the higher frequency of species indicating temporarily moist, packed soils, e.g.  
25 *Holcus lanatus*, *Betonica officinalis*, *Potentilla alba*, and in the lower frequency of drought-tolerant

1 species, e.g. *Plantago media*, *Securigera varia*, *Centaurea scabiosa*, *Onobrychis viciifolia*.  
2 Nevertheless, Cluster 11 differs from the Austrian data of *Filipendulo-Arrhenatheretum* in that  
3 *Bromus erectus* is rare, whereas it is constant and can reach high cover in the relevés of Willner et  
4 al. (2013b). In Hungarian relevés *Arrhenatherum elatius* neither is a typical dominant species,  
5 although, it is subconstant, and sometimes it can reach over 20% cover. Some of the relevés in  
6 Cluster 11 are dominated by *Holcus lanatus* and also contain several species of wetter meadows,  
7 like *Lychnis flos-cuculi*, *Cardamine pratensis*, *Silaum silaus*, and *Sanguisorba officinalis*. Such  
8 relevés resemble the *Holcetum lanati* Issler 1934 association in *Deschampsion* alliance, however,  
9 this is not sufficiently differentiated from *Arrhenatherion* communities (Stančić 2008). Here we  
10 interpret *Filipendulo vulgaris-Arrhenatheretum* in a broad sense, including wetter stands similar to  
11 *Holcetum lanati*, and drier ones, where the cover of *Festuca rupicola* reaches 15%. Further studies  
12 may clarify the relationship of *Holcetum lanati* and other associations of *Molinion* and  
13 *Arrhenatherion*.

14 *Ranunculo repentis-Alopecuretum pratensis* Ellmauer 1993 [in *Arrhenatherion*; Cluster 13]

15 Cluster 13 represents mesic meadows on nutrient-rich soils with the dominance of *Alopecurus*  
16 *pratensis*, *Trisetum flavescens*, *Festuca pratensis*, and other nutrient-demanding species. The  
17 constant and faithful species are also nutrient-demanding elements of *Arrhenatherion*, e.g. *Poa*  
18 *trivialis*, *Trisetum flavescens*, *Taraxacum officinale*, and *Glechoma hederacea*. In the Hungarian  
19 phytosociological literature, formerly this type was frequently identified with “*Alopecuro-*  
20 *Arrhenatheretum* (Máthé & Kovács) Soó 1971”. This name was introduced by Soó (1971) and it  
21 included the “*Arrhenatheretum alopecuretosum*” and the “*Festuco-Cynosuretum*  
22 *arrhenatheretosum*” tables by Máthé & Kovács (1960). However, as it is pointed out by Borhidi et  
23 al. (2012), all these three names are invalid. Based on the original relevés, Borhidi et al. (2012)  
24 described *Anthoxantho-Festucetum pratensis* Borhidi 2012 for replacing the former name, and  
25 *Anthyllido-Festucetum rubrae arrhenatheretosum* Borhidi 2012 to validate the latter one (for update

1 on this subassociation, see *Diantho-Arrhenatheretum*). However, according to the original relevés  
2 by Máthé & Kovács (1960) and the descriptions by Borhidi et al. (2012), both syntaxa are  
3 characterized by species of nutrient-poor soils, e.g. *Polygala vulgaris*, *Ranunculus auricomus*,  
4 *Dianthus deltoides*, therefore, Cluster 13 should not be identified with any of them, and the former  
5 interpretation of “*Alopecuro-Arrhenatheretum*” by Hungarian authors was mistaken. Nevertheless,  
6 the *Ranunculo repentis-Alopecuretum* Ellmauer 1993 association described from Austria is rather  
7 similar to Cluster 13, therefore we introduce it in Hungary. It occurs in the valleys of colline and  
8 montane areas. From *Pastinaco-Arrhenatheretum*, *Ranunculo-Alopecuretum* differs in the higher  
9 proportion of nutrient-demanding and wet grassland species, e.g. *Alopecurus pratensis*, *Crepis*  
10 *biennis*, *Carex hirta*, *Poa trivialis*; however, the delimitation of these two associations is unclear.  
11 The relationship between *Ranunculo-Alopecuretum* and *Deschampsion* associations also needs  
12 further studies.

13 *Diantho-Arrhenatheretum* (Máthé & Kovács 1960) Lengyel nom. nov. [in *Arrhenatherion*; Cluster  
14 20]

15 Synonyms: *Festuco rubrae-Cynosuretum arrhenatheretosum* Máthé & Kovács 1960, *Anthyllido-Festucetum*  
16 *rubrae arrhenatheretosum* (Máthé & Kovács 1960) Borhidi 2012

17 Lectotypus: Máthé & Kovács (1960), Table III., Relevé 5, designated by A. Borhidi for *Anthyllido-*  
18 *Festucetum rubrae arrhenatheretosum* in Borhidi et al. (2012).

19 Cluster 20 shows high similarity with the relevés and description of *Anthyllido-Festucetum rubrae*  
20 *arrhenatheretosum* (Máthé & Kovács 1960) Borhidi 2012. (For more discussion on *Anthyllido-*  
21 *Festucetum rubrae*, see *Festuca rubra*-type.) However, in our classification we could not recognize  
22 the other subassociations with satisfactory confidence, including the typical one, of *Anthyllido-*  
23 *Festucetum*, therefore we propose to raise *arrhenatheretosum* to the association level with the name  
24 *Diantho deltoidis-Arrhantheretum elatioris* (Máthé & Kovács 1960) Lengyel nom. nov.. *Diantho-*  
25 *Arrhenatheretum* is a meadow type found on mountain areas that were traditionally mown and  
26 grazed in the past, but after the cessation of grazing tall grasses became dominant. The

1 characteristic feature of this cluster is the joint occurrence of less nutrient-demanding plants (e.g.  
2 *Agrostis capillaris*, *Festuca rubra*, *Viola canina*, *Thymus pulegioides*) and drought-tolerant species  
3 (e.g. *Teucrium chamaedrys*, *Trifolium montanum*, *Thesium linophyllum*), elements of forest edges  
4 (e.g. *Melampyrum nemorosum*, *Luzula luzuloides*, *Primula veris*, *Cruciata glabra*), and the  
5 dominance of tall grasses, usually *Arrhenatherum elatius* or *Helictotrichon pubescens*. *Diantho-*  
6 *Arrhenatheretum* is similar to **other** nutrient-poor types of *Arrhenatherion*: *Ranunculo bulbosi-*  
7 *Arrhenatheretum* and *Filipendulo vulgaris-Arrhenatheretum*. From the latter two, *Diantho-*  
8 *Arrhenatheretum* differs in the higher number and constancy of elements of *Violion caninae* (e.g.  
9 *Thymus pulegioides*, *Dianthus deltoides*, *Viola canina*, *Carlina acaulis*), and forest edge species  
10 (e.g. *Luzula luzuloides*, *Primula veris*, *Cruciata glabra*). This association shows a landscape-scale  
11 change in vegetation due to the disappearance of traditional, extensive farming, since it is most  
12 common in higher elevation in the place of former mountain pastures. Nowadays these stands are  
13 mown or abandoned.

14 *Anthoxantho-Festucetum pratensis* Borhidi 2012 [in *Arrhenatherion*; Cluster 23]

15 The dominant species are *Festuca pratensis* and *Agrostis capillaris*, while there are many elements  
16 of wet meadows, forests, and clearings among the diagnostic species: *Ranunculus auricomus*,  
17 *Galium boreale*, *Carex pallescens*, *Lysimachia nummularia*, and *Ranunculus repens*. Similarly to  
18 *Filipendulo-Arrhenatheretum*, this type thrives on soils with wet and dry periods during a year but  
19 *Anthoxantho-Festucetum pratensis* is distributed on colder areas, and it contains more species of  
20 wet meadows and montane forests (e.g. *Carex pallescens*, *Ranunculus auricomus*), and acidic  
21 grasslands (e.g. *Agrostis capillaris*, *Polygala vulgaris*, *Viola canina*, *Dianthus deltoides*). Many of  
22 the sampled stands belonging to this cluster were grazed formerly as it is indicated by the presence  
23 of *Cynosurion* elements (e.g. *Plantago major*, *Leontodon autumnalis*, *Cynosurus cristatus*). This  
24 association is distributed **in** higher elevations of the North Hungarian Mountains.



1 *Colchico autumnalis-Festucetum rupicolae* Lengyel, Csiky, Dénes & Király *ass. nov. hoc loco* [in  
2 *Cynosurion*; Clusters 14 to 16]  
3 Holotypus – Author: Andrea Dénes; Date: 20/May/1997; Location (WGS84): N 45.885°, E 17.764°,  
4 Drávafok (Hungary); **Altitude: 100 m.a.s.l.** Relevé area: 16 m<sup>2</sup>. Species covers are in percentages. Herb  
5 layer: *Festuca rupicola* 35, *Luzula campestris* agg. 20, *Anthoxanthum odoratum* 15, *Filipendula vulgaris* 15,  
6 *Plantago lanceolata* 7, *Holcus lanatus* 4, *Centaurea jacea* agg. 3, *Colchicum autumnale* 2, *Ononis arvensis*  
7 s.lat. 2, *Saxifraga bulbifera* 1, *Trifolium montanum* 1, *Achillea millefolium* agg. 0.5, *Ajuga genevensis* 0.5,  
8 *Betonica officinalis* 0.5, *Carex caryophyllea* 0.5, *Cerastium vulgare* 0.5, *Euphorbia cyparissias* 0.5,  
9 *Fragaria viridis* 0.5, *Galium verum* 0.5, *Lathyrus pratensis* 0.5, *Leontodon hispidus* 0.5, *Leucanthemum*  
10 *vulgare* agg. 0.5, *Moenchia mantica* 0.5, *Myosotis ramosissima* 0.5, *Orchis morio* 0.5, *Ornithogalum*  
11 *umbellatum* agg. 0.5, *Pastinaca sativa* 0.5, *Polygala comosa* 0.5, *Ranunculus acris* 0.5, *Ranunculus bulbosus*  
12 0.5, *Rumex acetosa* .lat. 0.5, *Taraxacum officinale* 0.5, *Veronica chamaedrys* agg. 0.5, *Viola canina* 0.5.  
13 **Total cover of herb layer: 100%.** Cryptogamous plants **were** not recorded.

14 This association includes extensive pastures and, occasionally, less productive hayfields that have a  
15 transitional position between mesic and semi-dry grasslands. They are similar to but drier than the  
16 driest forms of *Filipendulo vulgaris-Arrhenatheretum* but still contain many mesophilous species.  
17 The dominant species is usually *Festuca rupicola*, but other, short or medium-height grasses (e.g.  
18 *Briza media*, *Cynosurus cristatus*) can also be abundant, while tall grasses are scarce. Most relevés  
19 come from lowlands and floodplains from the Transdanubian Region and the north-eastern part of  
20 the Great Hungarian Plain. Such stands can develop on the place of former wet habitats that had  
21 been dried due to river regulation and also in clearings of alluvial forests that had been cut in favour  
22 of pasturing. They are typically located in the highest parts of the sandy dunes, just emerging from  
23 the levels directly affected by spring flood events. Cluster 14 and 15 contain relevés of the most  
24 typical, species-rich and moderately grazed or mown stands, while Cluster 16 represents a more  
25 weedy, heavily grazed subtype, however, we consider all the three belonging to the same  
26 association. Some of the relevés were published under the name *Anthoxantho-Festucetum*

1 *pseudovinae* Juhász-Nagy 1959 and were assigned to its least intensively grazed variant dominated  
2 by *Festuca rupicola* (Juhász-Nagy 1959). Borhidi (2003) referred to the same type as  
3 “*Anthoxantho-Festucetum rupicolae* Dénes 1997”, however, Dénes (1997) did not present a valid  
4 syntaxonomic description (Weber et al. 2000: 5. §). In our classification, the relevés from the  
5 *Festuca rupicola*-variant of *Anthoxantho-Festucetum pseudovinae* by Juhász-Nagy together with  
6 many other relevés from Transdanubia were separated from the ‘typical’ *Anthoxantho-Festucetum*  
7 *pseudovinae*, therefore, we describe the type represented by Clusters 14 to 16 as a new association,  
8 *Colchico autumnalis-Festucetum rupicolae*. As this is typically a pasture type, and  
9 physiognomically it is more similar to *Cynosurion* communities, we assign it to this alliance.  
10 However, a much needed international revision of *Cynosurion* communities may refine its position  
11 in the future. *Colchico autumnalis-Festucetum rupicolae* can be recognized by the dominance of  
12 *Festuca rupicola* with *Briza media* and *Anthoxanthum odoratum* as subdominant grasses, the low  
13 cover of tall grasses (*Helictotrichon pubescens*, *Alopecurus pratensis*, *Arrhenatherum elatius*), the  
14 occurrence of mesic meadow species (e.g. *Campanula patula*, *Leucanthemum vulgare*, *Colchicum*  
15 *autumnale*, *Trisetum flavescens*), drought-tolerant species (e.g. *Dianthus pontederiae*, *Trifolium*  
16 *montanum*, *Filipendula vulgaris*, *Viola hirta*), and, occasionally, species preferring periodically  
17 waterlogged soils (e.g. *Carex pallescens*, *C. tomentosa*, *Sanguisorba officinalis*). Species of  
18 nutrient-poor and acidic grasslands are also often present (e.g. *Luzula campestris*, *Agrostis*  
19 *capillaris*, *Rumex acetosella*). This association is found in the peripheral areas of lowlands of the  
20 Carpathian Basin but can also occur in colline landscapes. The *Colchico autumnalis-Festucetum*  
21 *rupicolae* is maintained by moderate grazing, but after abandonment or replacement of grazing by  
22 mowing, stands can transform into *Filipendulo-Arrhenatheretum*.

23 *Anthoxantho odorati-Festucetum pseudovinae* Juhász-Nagy 1959 [in *Cynosurion*; Cluster 17]

24 Lectotypus: Juhász-Nagy (1959), Table IV., Relevé 14., designated here.

1 Cluster 17 represents a type that is similar to the previous one in its environmental conditions, but it  
2 is more heavily grazed and the dominant species is usually *Festuca pseudovina* instead of *F.*  
3 *rupicola*. Most of the relevés are from Juhász-Nagy's (1959) tables of the typical form of  
4 *Anthoxantho-Festucetum pseudovinae*. In the original description no holotype relevé was selected,  
5 therefore we identify Relevé 14 in Table IV of Juhász-Nagy (1959) as a lectotype. Despite some  
6 similarities in species composition and environmental conditions between *Anthoxantho-Festucetum*  
7 *pseudovinae* and *Colchico-Festucetum rupicolae*, we suggest to treat them as two separate  
8 associations. Their dominant species are different that can indicate difference in management or  
9 environmental factors, and several species in the original description of the former are absent or rare  
10 in the relevés from the wide distribution range of the latter. Such characteristic elements mentioned  
11 by Juhász-Nagy (1959) are *Hieracium auriculoides*, *H. caespitosum*, *Viola pumila*, and *Linum*  
12 *catharticum*, which could have been typical elements of grasslands of the Bereg Plain. The presence  
13 of grazing-tolerant species (e.g. *Veronica serpyllifolia*, *Myosotis stricta*) and the lack or low  
14 frequency of mesophilous species of more humid regions (e.g. *Trisetum flavescens*, *Cynosurus*  
15 *cristatus*, *Moenchia mantica*) are also indicative of *Anthoxantho-Festucetum pseudovinae*. Since  
16 this is a low-grass pasture type with many grazing-tolerant species, we consider this association  
17 within the alliance *Cynosurion*, in contrast with Borhidi et al. (2012) who assigned it to  
18 *Arrhenatherion*. Most relevés come from the north-eastern corner of the Great Hungarian Plain, and  
19 from lowland areas of West Transdanubia. According to Juhász-Nagy (1959), this type was much  
20 widespread in floodplains, but due to the decline of extensive animal husbandry and probably also  
21 due to the drop of ground water level in the Great Hungarian Plain, it became much rarer.

22 *Alopecuro pratensis-Festucetum pseudovinae* Juhász-Nagy 1959 [in *Cynosurion*; Cluster 18]

23 *Alopecuro-Festucetum pseudovinae* is a wetter substituent of *Anthoxantho-Festucetum pseudovinae*  
24 with more water-demanding species but similar, or even heavier effect of grazing. The relevés are  
25 from Juhász-Nagy's (1959) paper, in which they were included in the original description of the

1 association. Soon after its description, Soó (1964) mentioned it as a subassociation *Carici vulpinae-*  
2 *Alopecuretum pratensis festucetosum pseudovinae* within *Molinietalia*, but later Botta-Dukát (2004)  
3 proposed to exclude it from the syntaxa of wet meadows. Similarly to the concept applied in  
4 Slovakia (Janišová et al. 2014), we consider *Alopecuro-Festucetum pseudovinae* an association in  
5 *Cynosurion*. This type develops on packed soils of wet meadows, as a result of heavy grazing. The  
6 stands are dominated by *Festuca pseudovina*, taller grasses are usually not abundant. The  
7 accompanying species are remnants of the original wet habitats (e.g. *Alopecurus pratensis*, *Inula*  
8 *britannica*), disturbance-tolerant plants of lowland areas (e.g. *Eryngium planum*, *Galega officinalis*)  
9 and pioneer species (e.g. *Erophila verna*, *Anthemis arvensis*, *Ranunculus sardous*) but elements of  
10 *Arrhenatheretalia* order are usually rare. In the Great Hungarian Plain, degraded wet meadows  
11 dominated by *Festuca pseudovina* are common in various environmental and land-use conditions,  
12 and their appropriate place in the syntaxonomic system should be clarified in further studies.

13 *Cynosuro cristati-Lolietum perennis* Br.-Bl. & De Leeuw 1936 [in *Cynosurion*; Cluster 30]

14 Synonym: *Lolio-Cynosuretum* Tx. 1937, for explanation on nomenclature, see Willner et al. 2013b

15 This association represents overgrazed, nutrient-rich pastures on mesic or wet soils. They are  
16 usually dominated by *Trifolium repens*, *Cynodon dactylon*, or *Cynosurus cristatus*, while the most  
17 faithful species are *Lolium perenne*, *Bromus racemosus* agg., and *Poa annua*. However, in the  
18 moister stands, more hygrophilous and salt-tolerant species also occur, e.g. *Carex distans*, *Agrostis*  
19 *stolonifera* agg., and, (regionally) *Hordeum secalinum*. We use the name *Cynosuro-Lolietum* in a  
20 broad sense now, because we include also those relevés which are from wetter habitats and are  
21 probably transitional towards *Deschampsion*. Their more accurate position should be investigated in  
22 the future. From *Colchico-Festucetum rupicolae*, *Anthoxantho-Festucetum pseudovinae*, and  
23 *Alopecuro-Festucetum pseudovinae* it can be easily separated by the low cover of xerophilous  
24 *Festuca* species and the high cover and frequency of nutrient-demanding, grazing-tolerant species  
25 (e.g. *Trifolium repens*, *Lolium perenne*, *Poa annua*, *Agrostis stolonifera*). This association was

1 previously reported from submontane and montane regions of Hungary (Borhidi et al. 2012), but it  
2 is also distributed at lower elevations, if the climate is humid enough to provide mesic conditions.

3 *Brachypodio pinnati-Molinietum arundinaceae* Klika 1939 [in *Cirsio-Brachypodion*; Cluster 26]

4 The relevés of Cluster 26 are collected from meadows of mountain ranges, dominated by  
5 *Brachypodium pinnatum* and containing species of semi-dry grasslands (e.g. *Cirsium pannonicum*,  
6 *Helianthemum ovatum*, *Carex montana*), acidic grasslands (e.g. *Viola canina*, *Luzula campestris*),  
7 forest edges (e.g. *Cruciata glabra*, *Genista germanica*, *Potentilla alba*) and *Molinion* meadows  
8 (e.g. *Molinia caerulea* agg., *Succisa pratensis*, *Gladiolus imbricatus*). According to its mixed  
9 species composition, we identify this cluster with the *Brachypodio pinnati-Molinietum*  
10 *arundinaceae* Klika 1939 that until now was known only from the Czech and Slovak parts of the  
11 Western Carpathians (Chytrý 2007, Škodová & Ujházy 2014, Chytrý et al. 2015). However, its  
12 stands in Hungary are rather fragmental, and their development may also be a result of their special  
13 situation regarding vegetation dynamics. These stands were mown in the past, but currently many of  
14 them are abandoned. After abandonment, *Brachypodium pinnatum* and *Molinia caerulea* agg.  
15 spread and can quickly become dominant. The occurrence of some forest species (e.g. *Convallaria*  
16 *majalis*, *Symphytum tuberosum* agg.) is probably due to the landscape context, that is, mixed  
17 patches of forests and meadows. The presence of forest and edge species is also due to the mass  
18 effect, since these stands are usually situated in smaller forest clearings. Stands with such species  
19 composition are rare in Hungary, we have data only from a few locations in the Mátra, Bükk, and  
20 Zemplén Mts. This association can be recognized by containing xeromesic, mesic, wet grassland,  
21 and forest edge elements. *Brachypodio-Molinietum* was assigned to *Bromion* by Chytrý (2007) and  
22 Škodová & Ujházy (2014), however, we follow the concept of Roleček et al. (2014) who classified  
23 it to *Cirsio-Brachypodion*.

24 *Filipendulo vulgaris-Brometum erecti* Hundt & Hübl ex Willner 2013 [in *Cirsio-Brachypodion*;  
25 Cluster 31]

1 In Cluster 31, the dominant species is *Bromus erectus*, and it is accompanied by a mixture of  
2 mesophilous and xero-mesophilous species, e.g. *Dianthus carthusianorum*, *Saxifraga bulbifera*,  
3 *Festuca rupicola*. In the Hungarian literature, this type is sometimes referred to as “*Arrhenathero-*  
4 *Brometum erecti* Balázs 1951”, however this is an invalid name, since Balázs (1951) used it only as  
5 a workname without the purpose of describing a new syntaxon. “*Arrhenathero-Brometum*” is not  
6 mentioned by Borhidi et al. (2012), but he assigns similar stands to *Onobrychido viciifoliae-*  
7 *Brometum erecti* within the alliance *Bromion erecti*. Illyés et al. (2009) did not support the presence  
8 of the *Bromion* alliance in Hungary, however, their data set probably did not contain enough relevés  
9 of the transitional types between *Brometalia erecti* and *Arrhenatheretalia* orders. According to  
10 Willner et al. (2013a,b), *Onobrychido-Brometum* and the *Bromion* alliance do not reach the  
11 Carpathian Basin, thus such transitional types should not be identified as *Onobrychido-Brometum*.  
12 Instead, for the meadows dominated by *Bromus erectus* and containing species of semi-dry and  
13 mesic grasslands, they described a new association in *Cirsio-Brachypodion*, *Filipendulo vulgaris-*  
14 *Brometum erecti* Hundt & Hübl ex Willner 2013. They consider also the records of *Onobrychido-*  
15 *Brometum* (sensu Janišová et al. 2007) in Slovakia referring to *Filipendulo-Brometum*. We treat  
16 Cluster 31 as belonging to this association. In Hungary this type differs from *Arrhenatherion*  
17 associations in the dominance of *Bromus erectus* and the higher frequency of xerophilous species  
18 (e.g. *Centaurea scabiosa*, *Festuca rupicola*, *Thesium linophyllum*, *Seseli annuum*) and less nutrient-  
19 demanding species of intermittently wet to semi-dry sites (e.g. *Sesleria uliginosa*, *Sanguisorba*  
20 *officinalis*, *Betonica officinalis*). In Austria, *Filipendulo-Brometum* shows a continuous transition  
21 with *Filipendulo-Arrhenatheretum*. In our classification, we identified Cluster 31, that is dominated  
22 by *Bromus erectus*, with *Filipendulo-Brometum*, and Cluster 11 that is (co-)dominated by other  
23 species, with *Filipendulo-Arrhenatheretum*, therefore their differentiation may be less problematic  
24 in Hungary. Besides the dominant species, *Filipendulo-Brometum* usually develops on drier and  
25 more calcareous sites than *Filipendulo-Arrhenatheretum*; for that reason, the proportion of  
26 xerophilous and calciphilous species is also indicative. From other associations of *Cirsio-*

1 *Brachypodium*, *Filipendulo-Brometum* can be separated by the high cover of *Bromus erectus* and the  
2 presence of moisture-demanding species, while species of rocky habitats are usually absent.

3 *Sanguisorbo minoris-Brometum erecti* Illyés, Bauer & Botta-Dukát 2009 (in *Cirsio-Brachypodium*;  
4 Clusters 33 to 36]

5 Clusters 33 to 36 represent dry to semi-dry grasslands dominated by *Bromus erectus* from shallow  
6 soils of the calcareous mountains and colline ranges. We identify these clusters with the association  
7 *Sanguisorbo minoris-Brometum erecti* Illyés, Bauer & Botta-Dukát 2009. This syntaxon has been  
8 described recently by Illyés et al. (2009) as the common, calciphilous semi-dry grassland type of the  
9 Transdanubian Region with *Bromus erectus* as the dominant grass and many species of *Festuco-*  
10 *Brometea*. The generalist species of calcareous, dry grasslands (e.g. *Teucrium chamaedrys*, *Festuca*  
11 *valesiaca*, *Thymus pannonicus* agg., *Sanguisorba minor*) are common in this association. Several  
12 variants can be recognized. In stands on deeper soils (mostly Cluster 33) and with better nutrient-  
13 and water-supply, meadow species (e.g. *Lotus corniculatus* agg., *Arrhenatherum elatius*, *Knautia*  
14 *arvensis* agg.) are more frequent, however, they typically do not reach that high proportion as in  
15 *Filipendulo-Brometum*. In more open stands with eroded or shallow stony soils and rarely bare rock  
16 surfaces (mostly Cluster 34), calcareous species of shallow and dry soils (e.g. *Stipa capillata*, *S.*  
17 *pennata*, *Carex humilis*) are characteristic, although, such stands also contain indicators of grazing  
18 due to their past management regime (e.g. *Lepidium campestre*, *Eryngium campestre*). Stands  
19 situated mosaically in smaller clearings of thermophilous oak forests (mostly Cluster 36) are rich in  
20 forest edge species (e.g. *Euphorbia angulata*, *Campanula persicifolia*, *Geranium sanguineum*).

21 From *Filipendulo-Brometum*, *Sanguisorbo-Brometum* can be separated by the lower cover or  
22 absence of some rather acidophilous species (e.g. *Luzula campestris*, *Moenchia mantica*,  
23 *Anthoxanthum odoratum*), the high frequency of calciphilous rocky and dry grassland species (e.g.  
24 *Acinos arvensis*, *Anthyllis vulneraria* subsp. *polyphylla*, *Aster linosyris*, *Euphorbia seguieriana*,  
25 *Hippocrepis comosa*, *Stachys recta*) instead of mesophilous ones. In the Slovak and Czech literature

1 *Scabioso ochroleucae-Brachypodietum pinnati* is reported to thrive on similar habitats and  
2 eventually dominated by *Bromus erectus*. However, *Sanguisorbo-Brometum* lacks many of the  
3 diagnostic species of *Scabioso-Brachypodietum*, e.g. *Cirsium acaule*, *Carlina acaulis*, *Ononis*  
4 *spinosa*, and *Linum catharticum*. Moreover, *Brachypodium pinnatum* is rather rare in *Sanguisorbo-*  
5 *Brometum* (see also Illyés et al. 2009), while it is the most typical dominant species of *Scabioso-*  
6 *Brachypodietum*. About separation from other associations of *Cirsio-Brachypodion*, see therein.

7 *Polygalo majoris-Brachypodietum pinnati* Wagner 1941 [in *Cirsio-Brachypodion*; Clusters 41, 42  
8 & 43]

9 This association represents species-rich, semi-dry grasslands from the colline region with the  
10 dominance of *Brachypodium pinnatum*, sometimes *Bromus erectus* or *Inula ensifolia*, with a wide  
11 pool of termophilous and calciphilous species, e.g. *Adonis vernalis*, *Polygala major*, *Carex*  
12 *halleriana*, *Onobrychis arenaria*, *Pulsatilla grandis*. According to the interpretation by Borhidi et  
13 al. (2012), this syntaxon is represented by two variants in Hungary: a western one containing sub-  
14 Mediterranean and Pontic-Pannonian elements, and an eastern one with montane and continental  
15 species. Illyés et al. (2009) identified a small cluster with distinct distribution from the Bükk Mts as  
16 the eastern variant with many montane species (e.g. *Carlina acaulis*, *Dracocephalum ruyschiana*,  
17 *Primula elatior*), while they did not support the existence of the western type. We could not confirm  
18 this montane type in our classification as a variant of *Polygalo-Brachypodietum*, but according to  
19 the descriptions and evaluations by Illyés et al. (2009), it is probably more similar to our Cluster 26,  
20 i.e. to *Brachypodio-Molinietum* and should be interpreted under this association or as a transition to  
21 it. It is notable that according to Škodová & Ujházy (2014) in Slovakia *Brachypodio-Molinietum*  
22 forms a transition towards *Polygalo-Brachypodietum*. Such transitional subtypes contain many of  
23 the diagnostic species of *Polygalo-Brachypodietum*, but they also contain mesophilous species. In  
24 our classification, *Polygalo-Brachypodietum* differs from *Sanguisorbo-Brometum* in the higher  
25 cover of *Brachypodium pinnatum*, the higher frequency and cover of forbs (e.g. *Inula ensifolia*,



1 *Chamaecytisus austriacus* agg., *Pulsatilla grandis*, *Polygala major*, *Onobrychis arenaria*,  
2 *Scorzonera hispanica*, *Cirsium pannonicum*, *Peucedanum cervaria*), among which the proportion  
3 of Pontic-Pannonian species is high. *Polygalo-Brachypodietum* harbours less montane,  
4 mesophilous, and *Molinion*-species than *Brachypodio-Molinietum*.

5 *Euphorbio pannonicae-Brachypodietum pinnati* Horváth 2010 [in *Cirsio-Brachypodion*; Clusters  
6 44 to 48]

7 This association is a semi-dry grassland dominated by *Brachypodium pinnatum*, and distributed in  
8 the Pannonian loess-covered lowlands and foothills. Similarly to *Polygalo-Brachypodietum*, it is  
9 also rich in forbs but mostly in species preferring deeper soils on loess (e.g. *Euphorbia glareosa*,  
10 *Filipendula vulgaris*, *Thalictrum minus*, *Inula hirta*, *Ranunculus polyanthemus*). It has a few loess  
11 specialist species (e.g. *Nepeta parviflora*, *Ajuga laxmannii*, *Viola ambigua*, *Taraxacum serotinum*),  
12 that are very distinctive elements, however, since they are rare even within this type, they did not  
13 obtain high enough fidelity values. This community differs from *Polygalo-Brachypodietum* in the  
14 lower proportion of Pontic and sub-Mediterranean species (e.g. *Aster amellus*, *Polygala major*,  
15 *Inula ensifolia*, *Pulsatilla grandis*, *Carex halleriana*). A subtype of *Euphorbio-Brachypodietum* is  
16 dominated by *Bromus erectus* thus **confusion is possible** with *Sanguisorbo-Brometum*. However, in  
17 *Euphorbio-Brachypodietum* species of shallow, dry soils (e.g. *Acinos arvensis*, *Sanguisorba minor*,  
18 *Dianthus pontederiae*, *Hippocrepis comosa*, *Petrorhagia saxifraga*), are least frequent.

19 *Trifolio medii-Brachypodietum pinnati* Illyés, Bauer & Botta-Dukát 2009 [in *Cirsio-Brachypodion*;  
20 Clusters 57 to 59]

21 Clusters 57 to 59 are from grasslands dominated by *Danthonia alpina*, *Brachypodium pinnatum*, or  
22 *Helictotrichon adsurgens* from the North Hungarian Mountains. They contain many forest edge  
23 species (e.g. *Pulmonaria mollis*, *Trifolium medium*, *Aconitum anthora*, *Dictamnus albus*), species  
24 which are shared with mesic meadows (e.g. *Briza media*, *Filipendula vulgaris*, *Salvia pratensis*)  
25 and rather **acidotolerant** species (e.g. *Potentilla alba*, *Luzula campestris* agg.). This association was

1 described with the name *Trifolio medii-Brachypodietum pinnati* by Illyés et al. (2009). It differs  
2 from *Polygalo-Brachypodietum* and *Euphorbio-Brachypodietum* in the higher frequency of forest  
3 edge species, mesophilous, and acidophilous grassland plants and the lower proportion of Pontic  
4 and Pannonian species. From *Brachypodio-Molinietum* it can be separated by the lower proportion  
5 of montane and wet meadow species (e.g. *Cruciata glabra*, *Potentilla erecta*, *Carex pallescens*,  
6 *Viola canina*, *Succisa pratensis*, *Molinia caerulea*), although some generalist species that are  
7 frequent also on *Molinion* meadows (e.g. *Betonica officinalis*, *Serratula tinctoria*, *Potentilla alba*)  
8 can occur in *Trifolio-Brachypodietum*. Considering the definitions and descriptions of *Brachypodio-*  
9 *Molinietum* (Chytrý 2007, Janišová et al. 2007, Škodová & Ujházy 2014), relevés fulfilling our  
10 criteria of *Trifolio-Brachypodietum* were probably previously assigned to *Brachypodio-Molinietum*  
11 in Slovakia. The relationship between these two associations needs to be clarified in the future.

## 12 ***Description of types assigned to alliances without identification at association level***

### 13 *Sanguisorba officinalis*-type [in *Arrhenatherion*; Cluster 27]

14 Cluster 27 represents a type that is distributed in the most humid, western part of Transdanubia on  
15 slightly acidic soils. The most common dominant species is *Sanguisorba officinalis*, that is  
16 accompanied by elements of *Arrhenatherion* (e.g. *Trisetum flavescens*, *Tragopogon orientalis*,  
17 *Festuca rubra*), *Polygono-Trisetion* (e.g. *Hypericum maculatum* agg., *Pimpinella major*), and  
18 *Violion caninae* (e.g. *Viola canina*, *Danthonia decumbens*). The co-occurrence of these species  
19 groups points to *Poo-Trisetetum flavescens* association in *Arrhenatherion*. However, *Poo-*  
20 *Trisetetum* is known as a very variable but usually intensively mown meadow type of humid areas,  
21 mostly dominated by *Trisetum flavescens*, *Poa trivialis*, *P. pratensis*, *Festuca rubra*, and other  
22 medium-tall grasses (Dierschke 1997, Chytrý 2007, Uhliarová et al. 2014). In contrast, the stands of  
23 Cluster 27 are managed extensively by infrequent mowing (maximum once a year), resulting in  
24 high cover of forbs (e.g. *Sanguisorba officinalis*, *Betonica officinalis*, *Hieracium umbellatum*)  
25 instead of graminoids. Despite its distinctness, we could not identify Cluster 27 with either *Poo-*

1 *Trisetum* or other associations previously known from Hungary and the neighbour countries.  
2 Further analyses with the involvement of Austrian and Slovenian data of montane meadows may  
3 help clarify its syntaxonomical position.

4 *Agrostis capillaris-Trifolium pratense*-type [in *Cynosurion*; Cluster 21]

5 Cluster 21 contains relevés from mesic pastures and nutrient-poor meadows from the colline and  
6 montane sites. The dominant species (*Agrostis capillaris*, *Trifolium pratense*, *Holcus lanatus*), and  
7 also the constant, and diagnostic species (e.g. *Anthoxanthum odoratum*, *Festuca rubra*, *Trisetum*  
8 *flavescens*, *Clinopodium vulgare*) are rather generalist, therefore, it is difficult to delimit its  
9 variation along environmental and land-use gradients, or identify it at the association level.  
10 However, there are some typical elements of pastures among the diagnostic species, e.g. *Plantago*  
11 *major*, *Cynosurus cristatus*, *Trifolium dubium*, and *Phleum pratense* agg. (mostly *Phleum*  
12 *bertolonii*), thus we consider this type belonging to *Cynosurion*. Although *Festuco commutatae-*  
13 *Cynosuretum* is mentioned as the mesic pasture association of colline and montane regions (e.g. Soó  
14 1973, Borhidi et al. 2012), its descriptions often highlight the presence of montane species, e.g.  
15 *Alchemilla* spp., *Danthonia decumbens*, *Carlina acaulis*, *Rhinanthus alectorolophus*, *Rh. wagneri*,  
16 which are rare or absent in this cluster. According to Ellmauer & Mucina (1993), there are several  
17 elements of nutrient-poor grasslands among the diagnostic species of *Festuco-Cynosuretum*, e.g.  
18 *Thymus pulegioides* and *Potentilla erecta*, which are also not typical in Cluster 21. Therefore, we  
19 assign this cluster to *Cynosurion*, and note that the identification at the association level needs  
20 further studies.

21 *Vulpia-Festuca rubra*-grasslands [in *Cynosurion*; Cluster 29]

22 Cluster 29 includes relevés from overgrazed pastures and old-fields from eroded soils. It is  
23 characterized by species of disturbed, open, nutrient-poor vegetation, like *Sherardia arvensis*,  
24 *Vulpia* spp., *Aphanes arvensis* agg., and *Trifolium striatum*, while the dominant species is *Festuca*  
25 *rubra*. This type is likely to be a disturbed variant of other associations in the *Cynosurion* alliance.

1 It is probably more widespread on leached soils in the more humid regions of Hungary than as it is  
2 represented in our database, because such stands are often considered as disturbed, pioneer or  
3 transitional types, and thus rarely recorded by phytosociologists. Due to the shortness of data, we  
4 cannot evaluate it in more detail here.

5 *Linum tenuifolium-Brachypodium pinnatum*-type [in *Cirsio-Brachypodion*; Clusters 55 & 56]

6 Cluster 55 and 56 are from grasslands of calcareous, shallow soils, dominated by *Brachypodium*  
7 *pinnatum*. Accompanying species are xerophilous and calciphilous, e.g. *Linum tenuifolium*, *Carex*  
8 *liparicarpos*, *Seseli hippomarathrum*, *Teucrium montanum*. This type is similar to *Lino tenuifolii-*  
9 *Brachypodietum pinnati* (Dostál 1933) Soó 1971 according to the description of Borhidi et al.  
10 (2012). According to Soó (1971) this name includes *Polygalo-Brachypodietum* from Austria  
11 (Wagner 1941), while Škodová (2014) considers it as a syntaxonomical synonym of *Scabioso-*  
12 *Brachypodietum* Klika 1933. Since the nomenclature of *Scabioso-Brachypodietum* and its  
13 delimitation from other associations is unclear, we avoid using this name. In this cluster, Pontic and  
14 Pannonian elements (e.g. *Aster amellus*, *Polygala major*, *Inula ensifolia*) and shared species of  
15 semi-dry and mesic grasslands (e.g. *Campanula glomerata*, *Filipendula vulgaris*, *Ranunculus*  
16 *polyanthemos*, *Salvia pratensis*) are rarer, while some species of drier grasslands (e.g. *Festuca*  
17 *valesiaca*, *Carex liparicarpos*, *Teucrium montanum*) are more frequent. The occurrence of grazing  
18 tolerant species (e.g. *Ononis spinosa*, *Eryngium campestre*, *Carlina vulgaris*) may be an indicator  
19 of former pasturing that may have led to lower species richness. Despite the dominant species, its  
20 environmental background and species pool are similar to the *Sanguisorbo-Brometum* on thicker  
21 soils.

22 ***Description of out-of-scope types with nomenclatural relations to Arrhenatheretalia or***

23 ***Brometalia erecti***

24 *Festuca rubra*-type [in *Violion caninae*; Cluster 22]

1 Cluster 22 comprises nutrient-poor, montane, mesic grasslands that are either grazed or recently  
2 abandoned. The dominant species are *Festuca rubra*, *Agrostis capillaris*, *Galium verum*, and  
3 *Anthoxanthum odoratum*, and the differential species are *Thymus pulegioides*, *Viola canina*,  
4 *Solidago virgaurea*, and *Veronica officinalis*. Previously mesic grasslands of nutrient-poor sites  
5 dominated by *Festuca rubra* and *Agrostis capillaris* were traditionally assigned to *Anthyllido-*  
6 *Festucetum rubrae* (in *Arrhenatherion*) in Hungary; however, the species composition of Cluster 22  
7 does not match satisfactorily with its descriptions (Soó 1971, Borhidi 2003). Moreover, there are  
8 issues concerning the separation of this association from other nutrient-poor grasslands. According  
9 to Borhidi et al. (2012), *Anthyllido-Festucetum* includes three subassociations: *typicum*,  
10 *agrostidetosum*, and *arrhenatheretosum*; each of them relying on nomenclatural tables originally  
11 published by Máthé & Kovács (1960) as subassociations of *Festuco-Cynosuretum* (but see *Diantho-*  
12 *Arrhenatheretum* for our concept on the *Arrhenatherum*-dominated type). However, Jurko (1974)  
13 classified these tables to *Anthoxantho-Agrostietum tenuis* Sillinger 1930. The differentiation  
14 between *Anthyllido-Festucetum rubrae* and *Anthoxantho-Agrostietum tenuis* was never made  
15 explicit by any authors, and it is very likely that they should be considered synonyms (or *pro parte*  
16 synonyms). However, there is also a disagreement among foreign authors on the interpretation of  
17 *Anthoxantho-Agrostietum*. Jurko (1974) classified many nutrient-poor grassland types to this  
18 association within *Cynosurion*, including variants which are now treated under *Violion caninae*.  
19 More recently authors tended to use this syntaxon name in a narrower sense, although, in slightly  
20 different ways, that is also mirrored by its assignment to alliances. Chytrý (2007) assigned  
21 *Anthoxantho-Agrostietum* to *Cynosurion*, Janišová et al. (2007), Rozbrojová et al. (2010), and  
22 Uhliarová et al. (2014) classified it to *Arrhenatherion*, while Willner et al. (2013b) considered it as  
23 a part of *Violion caninae*. The species composition of Cluster 22 is also very similar to *Campanulo*  
24 *rotundifoliae-Dianthetum deltoidis* (in *Violion caninae*) in the Czech Republic according to Chytrý  
25 (2007). However, according to Ujházy & Kliment (2014), an important feature of this association is  
26 the constant occurrence and significant (over 5%) cover of *Nardus stricta*, that is absent in Cluster

1 22. The delimitation between *Campanulo-Dianthetum* and *Anthoxantho-Agrostietum* is also  
2 unclear, therefore, Willner et al. (2013b) treated the former as a part of “*Anthoxantho-Agrostietum*  
3 *s. lat.*”. The syntaxonomy of nutrient-poor, mesic grasslands obviously needs a supra-national  
4 revision, therefore, we cannot identify Cluster 22 at the level of association. Since in this type the  
5 proportion of mesotrophic species of *Arrhenatherion* and *Cynosurion* is rather low, similarly to  
6 Willner et al. (2013b) we consider it in *Violion caninae*, that is out of the scope of this paper.

7 *Stipenion tirsae* Borhidi 2012 [in *Festucion valesiaca*; Cluster 60]

8 Cluster 60 represents a type dominated by *Stipa tirsae*, and this is out of our scope. Although, similar  
9 grasslands (with the name *Stipetum tirsae* Meusel 1938) are classified to *Cirsio-Brachypodion* by  
10 Dengler et al. (2012), we follow a more common viewpoint that considers *Stipenion tirsae* as a  
11 separate suballiance in *Festucion valesiaca* (Borhidi et al. 2012; see also Chytrý 2007,  
12 **Hegedúšová Vantarová & Škodová 2014**).

### 13 ***Ordinations***

14 In the principal coordinates analysis of all identified associations, 9.59% and 6.18% of the total  
15 variation were explained by the first two axes, respectively. *Arrhenatheretalia* and *Brometalia*  
16 *erecti* were separated along Axis 1 (Fig. 3) with more mesic associations being on the left and semi-  
17 dry association on the right side of the diagram. Associations of *Brometalia* containing a high  
18 proportion of mesophilous species (*Brachypodio-Molinietum*, *Filipendulo-Brometum*) are placed in  
19 intermediate position. The two driest associations, *Sanguisorbo-Brometum* and *Euphorbio-*  
20 *Brachypodietum* are well separated from all other associations, while *Polygalo-Brachypodietum* and  
21 *Trifolio-Brachypodietum* are in central position in the variation range of *Cirsio-Brachypodion*. Fig.  
22 4 shows the ordination of *Arrhenatheretalia* associations. The first two axes revealed 11.04% and  
23 5.74% of the total variation, respectively. Along Axis 1 the types dominated by *Arrhenatherum*  
24 *elatius* (*Tanaceto-Arrhenatheretum*, *Ranunculo-Arrhenatheretum*, *Pastinaco-Arrhenatheretum*) are  
25 placed on the left-hand side. *Cynosurion* communities are separated along Axis 2, with

1 *Anthoxantho-Festucetum pseudovinae* and *Alopecuro-Festucetum pseudovinae* being the most  
2 extremes along this gradient, while *Colchico-Festucetum* and *Cynosuro-Lolietum* are closer to  
3 *Arrhenatherion* communities. The species-rich meadow associations with various management and  
4 environmental background (i.e. *Filipendulo-Arrhenatheretum*, *Anthoxantho-Festucetum pratensis*,  
5 *Diantho-Arrhenatheretum*, *Ranunculo-Alopecuretum*) are close to each other at the bottom right-  
6 hand corner of the diagram.

### 7 *Syntaxonomical summary*

8 On the basis of our classification, we suggest the following system for the mesic and semi-dry  
9 grasslands in Hungary:

10 Order: *Arrhenatheretalia* Tx. 1931 (in *Molinio-Arrhenatheretea*)

11 1. Alliance: *Arrhenatherion elatioris* Koch 1926

12 1.1. Association: *Ranunculo bulbosi-Arrhenatheretum* Ellmauer 1993

13 1.2. Association: *Tanaceto vulgaris-Arrhenatheretum* Fischer ex Ellmauer 1993

14 1.3. Association: *Pastinaco sativae-Arrhenatheretum* (Knapp 1954) Passarge 1964

15 1.4. Association: *Filipendulo vulgaris-Arrhenatheretum* Hundt & Hübl ex Ellmauer 1995

16 1.5. Association: *Diantho deltoidis-Arrhenatheretum* (Máthé & Kovács 1960) Lengyel *nom.*  
17 *nov.*

18 1.6. Association: *Anthoxantho odorati-Festucetum pratensis* Borhidi 2012

19 1.7. Association: *Ranunculo repentis-Alopecuretum pratensis* Ellmauer 1993

20 2. Alliance: *Cynosurion cristati* Tüxen 1947

21 2.1. Association: *Colchico autumnalis-Festucetum rupicolae* Lengyel, Csiky, Dénes & Király  
22 *ass. nov.*

23 2.2. Association: *Anthoxantho odorati-Festucetum pseudovinae* Juhász-Nagy 1959

24 2.3. Association: *Alopecuro pratensis-Festucetum pseudovinae* Juhász-Nagy 1959

25 2.4. Association: *Cynosuro cristati-Lolietum perennis* Br.-Bl. & De Leeuw 1936

1 Order: *Brometalia erecti* Br.-Bl. 1936 (in *Festuco-Brometea*)

2 1. Alliance: *Cirsio pannonici-Brachypodium pinnati* Hadač & Klika 1944

3 1.1. Association: *Brachypodio pinnati-Molinietum arundinaceae* Klika 1939

4 1.2. Association: *Filipendulo vulgaris-Brometum erecti* Hundt & Hübl ex Willner 2013

5 1.3. Association: *Sanguisorbo minoris-Brometum erecti* Illyés, Bauer & Botta-Dukát 2009

6 1.4. Association: *Polygalo majoris-Brachypodietum pinnati* Wagner 1941

7 1.5. Association: *Euphorbio pannonicae-Brachypodietum pinnati* Horváth 2010

8 1.6. Association: *Trifolio medii-Brachypodietum pinnati* Illyés, Bauer & Botta-Dukát 2009

9 With the above suggestions, we introduce significant changes in syntaxonomy of the  
10 *Arrhenatheretalia* and *Brometalia erecti* orders in Hungary. In the *Arrhenatherion* order, five new  
11 associations have been introduced. Four of them (*Ranunculo bulbosi-Arrhenatheretum*,  
12 *Filipendulo-Arrhenatheretum*, *Tanaceto-Arrhenatheretum*, *Ranunculo-Alopecuretum*) are adopted  
13 from the Austrian and Slovak literature, while a former subassociation has been proposed to be  
14 raised at the association level with the name *Diantho-Arrhenatheretum*. We excluded the  
15 *Anthyllido-Festucetum rubrae* from the *Arrhenatherion* communities in Hungary. *Anthoxantho-*  
16 *Festucetum pseudovinae*, that was assigned to *Arrhenatherion* by Borhidi et al. (2012), has been  
17 moved to *Cynosurion*. *Alopecuro-Festucetum pseudovinae* as a separate association appeared in  
18 synthetic reviews for the first time in literature of Hungarian vegetation after its original  
19 publication. *Colchico-Festucetum rupicola* has been described as a new association. According to  
20 Willner et al. (2013b), the name *Cynosuro-Lolietum* has been adopted in order to replace the invalid  
21 name *Lolio-Cynosuretum*. Neither our analyses nor our field experiences supported the presence of  
22 *Phyteumo-Trisetion* alliance in Hungary. In *Brometalia erecti*, the most fundamental changes  
23 regarded the treatment of *Bromion erecti*. *Carlino acaulis-Brometum* was not recognized as a  
24 separate cluster in our analysis. The type that was mentioned as *Onobychido-Brometum* by Borhidi  
25 et al. (2012) was identified with *Filipendulo-Brometum* (belonging to *Cirsio-Brachypodium*), which



1 is a new element in the list of Hungarian syntaxa. Therefore, we suggest rejecting both names,  
2 *Carlino-Brometum* and *Onobrychido-Brometum* that were considered as the representatives of  
3 *Bromion* in our country. We detected *Brachypodio-Molinietum* for the first time in Hungary and  
4 assigned it to *Cirsio-Brachypodion*. Apart from detecting *Filipendulo-Brometum* and *Brachypodio-*  
5 *Molinietum* as associations new to the country, our findings about *Cirsio-Brachypodion* are in a  
6 good match with Illyés et al. (2009). We supported the presence of *Polygalo-Brachypodietum*,  
7 *Euphorbio-Brachypodietum*, *Trifolio-Brachypodietum*, and *Sanguisorbo-Brometum* in Hungary. We  
8 could not recognize and interpret *Poo badensis-Caricetum montanae* (see Varga 1997) and *Lino-*  
9 *Brachypodietum* unambiguously; therefore, we also suggest removing the latter two from the list of  
10 Hungarian syntaxa. We separated four **vegetation** types belonging to *Arrhenatheretalia* or  
11 *Brometalia* but without identification at the association level. Further studies should focus on the  
12 clarification of their position.

### 13 *Possible biases and open questions*

14 Present work is currently the most comprehensive synthesis of mesic and semi-dry grasslands in  
15 Hungary that was based on statistical analysis of a large data set of phytosociological relevés. The  
16 size of the data set applied falls short compared to certain national syntheses (Chytrý 2007,  
17 Hegedüšová Vantarová & Škodová 2014), however, we still consider it sufficient for detecting the  
18 most significant types in Hungary. Although, we paid great attention to fully cover the  
19 compositional variation of the target syntaxa, there are differences among regions in the degree of  
20 representativeness. Clearly, areas which were subject to more detailed, regional studies in the near  
21 past (e.g. Bakony Region: Bauer 2012; South Transdanubia: Lengyel et al. 2012a) are better  
22 represented than others, and not all of such inequalities may have been corrected by the applied  
23 geographically stratified HCR resampling. Moreover, geographical biases may have interacted with  
24 the uneven temporal coverage. Relevés by Juhász-Nagy (1959) from the Bereg Plain played a big  
25 role in the recognition of *Anthoxantho-Festucetum pseudovinae* and *Alopecuro-Festucetum*

1 *pseudovinae*, since Cluster 17 and 18 were formed almost only of these relevés. At the time of  
2 sampling, in the 1950s, the management of meadows and pastures may have been different from the  
3 current one, not only in the Bereg Plain but across the country (Molnár et al. 2012). Moreover, the  
4 Bereg Plain is a rather special and marginal part of the distribution of mesic grasslands due to its  
5 continental climate. In addition, comparison of old and recent phytosociological data is always  
6 biased due to differences in the concept of sampling and taxonomy (Podani 2006). In addition, the  
7 relevés by Juhász-Nagy (1959) lacked information on plot size and covers of rare species, however,  
8 we expected insignificant influence of these shortcomings on the classification. Unfortunately, we  
9 have no more recent data from the Bereg Plain. For these reasons, we admit that biogeographical  
10 patterns, temporal changes in the management and conceptual differences in the methodology may  
11 have equally contributed to the separation of these two clusters, and therefore, the information on  
12 these types presented here should be interpreted with more caution. Nevertheless, *Festuca rupicola*-  
13 dominated relevés of Juhász-Nagy (1959) were classified together with many relevés from  
14 Transdanubia with clearly similar habitat conditions, which can be interpreted as a positive example  
15 of the applicability of old data for current investigations.

16 During the evaluation of types (i.e. one or more clusters assigned to the same low syntaxon) we  
17 only considered relevés with positive silhouette values, i.e. those which are surely more similar to  
18 the other relevés in the same type than to relevés of the most similar other type. With this decision  
19 we made separations between types clearer in order to ease their interpretation. However, it is  
20 important to bear in mind that our descriptions refer to the most typical forms of each association  
21 (or their variants, in some cases). Undoubtedly, transitional stands do exist between several types  
22 and many of them cannot be reliably identified syntaxonomically.

23 In our classification we aimed at identifying vegetation types at the association level, however, no  
24 revisions of associations can avoid questions related to higher-level syntaxa. Despite many

1 arguments about their nomenclature and interpretation, e.g. *Brometalia erecti*, regarding the  
2 treatment of orders and alliances we followed the concept of Borhidi et al. (2012).

3 We clustered the data set at a relatively fine resolution (60 clusters), and then evaluated  
4 relationships between clusters by a minimum spanning tree, literature data, and field experiences.  
5 Then, certain clusters were merged, if they were judged as belonging to the same association. In  
6 cases of several associations, when it was reasonable, we preferred to adopt names from literatures  
7 of neighbour countries in order to reduce idiosyncrasy in the syntaxonomy of Hungarian grasslands.  
8 Such adoptions were done on the basis of informal examination of phytosociological data or  
9 textural descriptions of associations from reference literature, but no quantitative approaches were  
10 applied for the assignment of unclassified relevés to existing types. Although, several supervised or  
11 semi-supervised methods have been published with this aim (van Tongeren et al. 2008, Tichý et al.  
12 2014), due to the strong biogeographical pattern in species composition of grasslands, we  
13 experienced their limitations when the geographical origin of the reference data differed from that  
14 of the relevés to be classified. Due to the lack of quantitative support for the adoption of certain  
15 names applied in foreign literature and for rejection of names previously used in Hungary, in the  
16 future, the distribution and geographical variation of grassland syntaxa should be revised in a supra-  
17 national analysis. Such broader-scale investigations should be supplemented by studies on local and  
18 regional scales with the aim of revealing dynamics, local variation, and conservation aspects of  
19 these threatened vegetation types.

20

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4

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- 16

1 **Figure captions**

2 Figure 1. The geographical distribution of the analyzed relevés

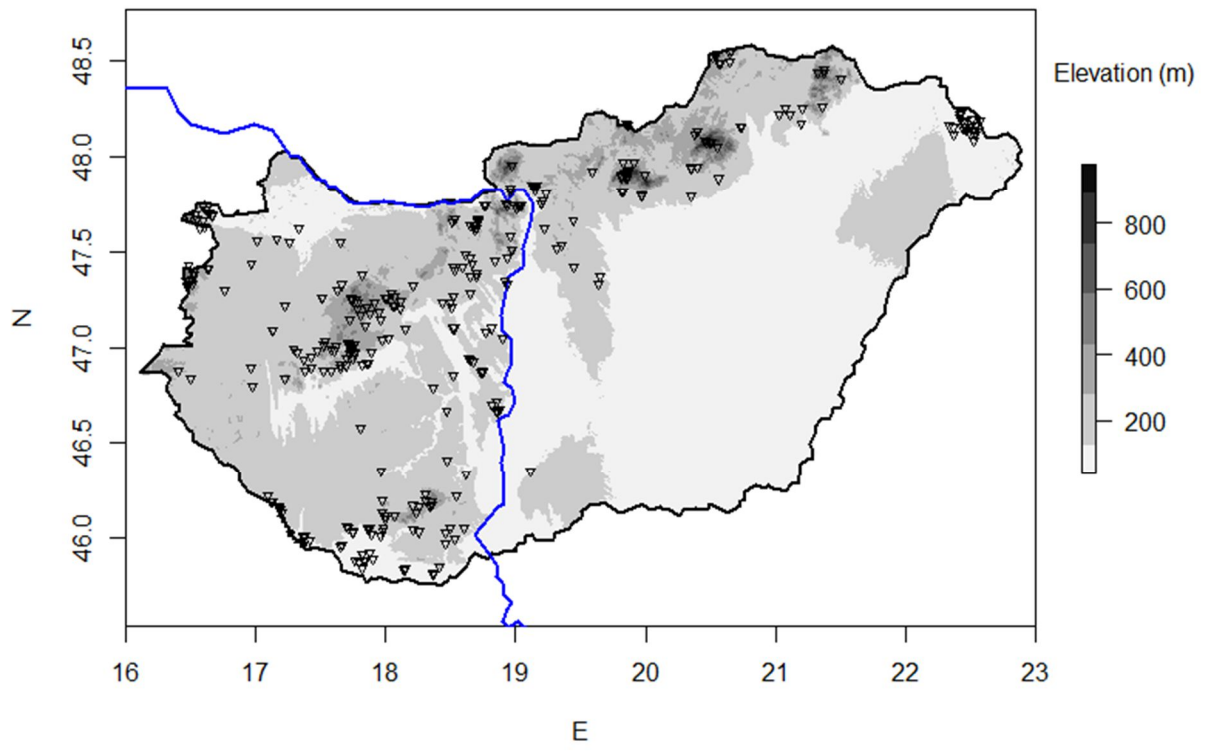
3 Figure 2. The minimum spanning tree of the 60 distinguished clusters

4 Figure 3. Principal coordinates analysis of all distinguished associations. A – *Ranunculo-*  
5 *Arrhenatheretum*; B – *Tanaceto-Arrhenatheretum*; C – *Pastinaco-Arrhenatheretum*; D –  
6 *Filipendulo-Arrhenatheretum*; E – *Ranunculo-Alopecuretum*; F – *Diantho-Arrhenatheretum*; G –  
7 *Anthoxantho-Festucetum pratensis*; H – *Colchico-Festucetum*; I – *Anthoxantho-Festucetum*  
8 *pseudovinae*; J – *Alopecuro-Festucetum pseudovinae*; K – *Cynosuro-Lolietum*; L – *Brachypodio-*  
9 *Molinietum*; M – *Filipendulo-Brometum*; N – *Sanguisorbo-Brometum*; O – *Polygalo-*  
10 *Brachypodietum*; P – *Euphorbio-Brachypodietum*; Q – *Trifolio-Brachypodietum*.

11 Figure 4. Principal coordinates analysis of the associations in *Arrhenatheretalia* order. A –  
12 *Ranunculo-Arrhenatheretum*; B – *Tanaceto-Arrhenatheretum*; C – *Pastinaco-Arrhenatheretum*; D –  
13 *Filipendulo-Arrhenatheretum*; E – *Ranunculo-Alopecuretum*; F – *Diantho-Arrhenatheretum*; G –  
14 *Anthoxantho-Festucetum pratensis*; H – *Colchico-Festucetum*; I – *Anthoxantho-Festucetum*  
15 *pseudovinae*; J – *Alopecuro-Festucetum pseudovinae*; K – *Cynosuro-Lolietum*.

16

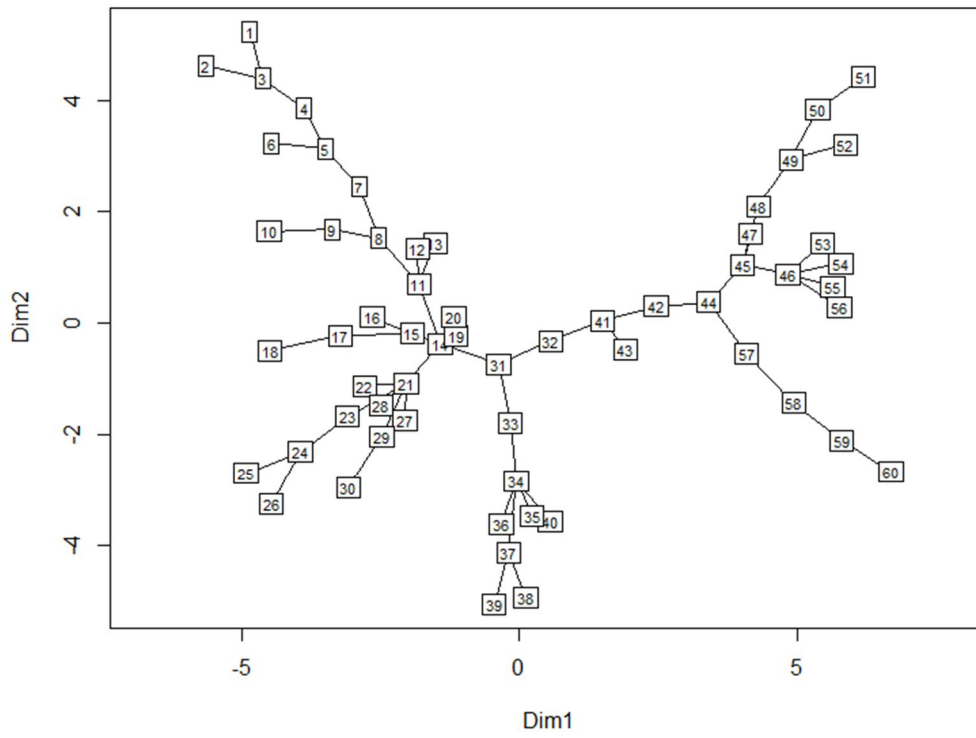
1 Figure 1.



2

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1 Figure 2.

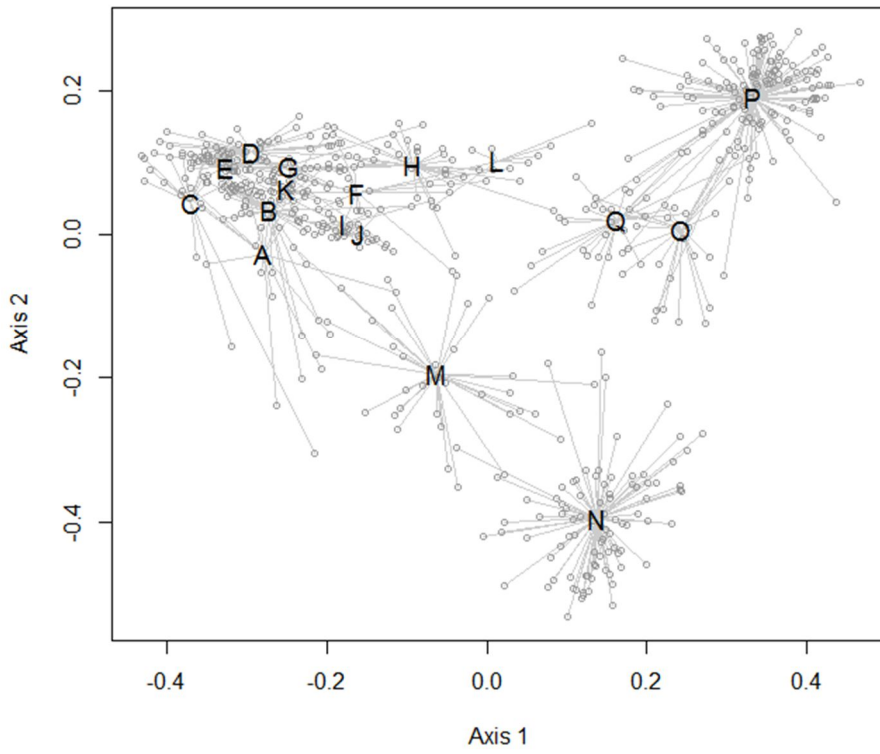


2

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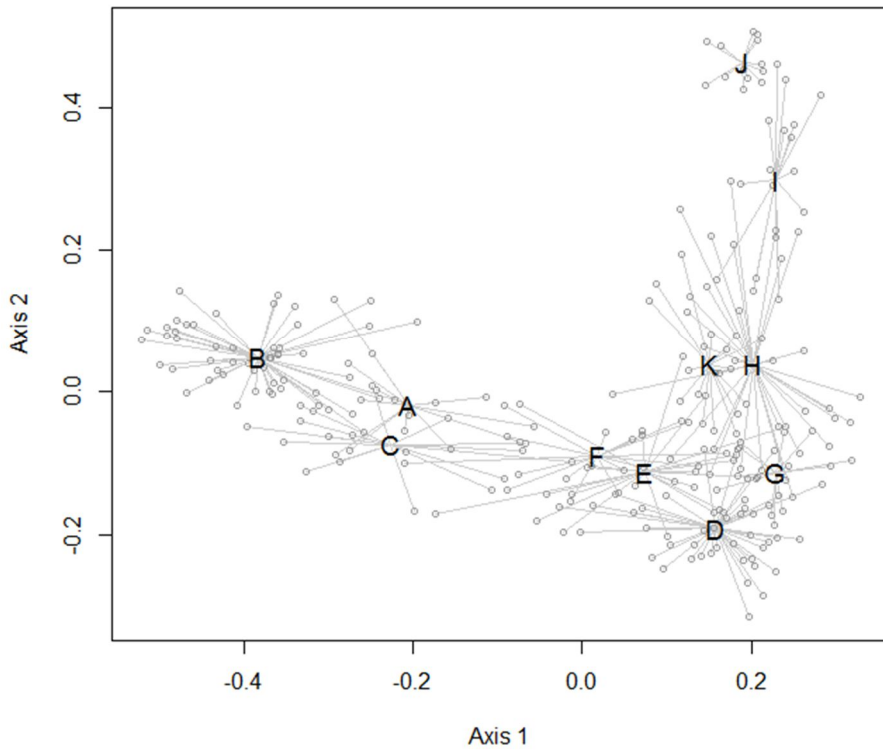
1 Figure 3.



2

3

1 Figure 4.



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