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Syntaxonomical revision of the *Triseto flavescentis-Polygonion bistortae* alliance in the Carpathians

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This phytosociological study of the Carpathian species-rich mesophilous mountain hay meadows (*Triseto flavescentis-Polygonion bistortae* alliance, *Molinio-Arrhenatheretea* class) presents the first unified large-scale classification system in four countries: Slovakia, Poland, Romania, and Ukraine. The starting dataset contained relevés of the *Molinio-Arrhenatheretea*, *Mulgedio-Aconitetea* and *Nardetea strictae* classes. Numerical classification and semi-supervised classification by K-means method were used for the analyses. An electronic expert system and diagnostic species for grassland vegetation served for identification of *a priori* groups in K-means method. The final dataset contained 612 relevés. Altitude, climatic data and Ellenberg indicator values were used for ecological differentiation of syntaxa. The main gradients in floristic composition were analysed by Detrended Correspondence Analysis. Finally, the eight well-differentiated associations and one newly described association were determined: *Campanulo glomeratae-Geranietum sylvatici*, *Geranio sylvatici-Trisetetum flavescentis*, *Crepido mollis-Agrostietum capillaris*, *Geranio-Alchemilletum crinitae*, *Alchemillo-Deschampsietum caespitosae*, *Phyteumo (orbicularis)-Trifolietum pratensis*, *Astrantio-Trisetetum flavescentis*, *Trollio altissimi-Knautietum dipsacifoliae* and *Violo declinatae-Agrostietum capillaris* ass. nova. The differences in vegetation diversity of mountain hay meadows between particular countries were confirmed: *Alchemillo-Deschampsietum caespitosae* occurs in all studied territories, *Campanulo glomeratae-Geranietum sylvatici* occurs predominantly in Slovakia and the newly described association *Violo declinatae-Agrostietum capillaris* ass. nova could be found only in Ukraine.

Keywords: Carpathians, diversity, Molinio-Arrhenatheretea, mountain hay meadows, Triseto flavescentis-Polygonion bistortae, semi-supervised classification, syntaxonomical revision

Introduction

The Carpathians are a recognised biodiversity hot-spot, harbouring many relatively undisturbed ecosystems and still rich in semi-natural, traditional landscapes (Björnsen-Gurung et al. 2009; Bálint et al. 2011; Solovyeva et al. 2011; Kliment et al. 2016; Mráz and Ronikier 2016). The species richness and extraordinarily high diversity of Carpathian vegetation is influenced by an important biogeographical position, fragmentation of the mountains, evolution of the vegetation and fauna in the glacial and post-glacial periods, geographical isolation, and a highly diverse geology and relief (Kliment 1999; Webster et al. 2001; Ruffini et al. 2006; Mráz et al. 2007; Björnsen-Gurung et al. 2009; Ronikier 2011; Kadlečík 2016; Kliment et al. 2016; Mráz and Ronikier 2016).

The Carpathian *Triseto flavescentis-Polygonion bistortae* Br.-Bl. et Tx. exMarschall 1947 alliance includes species-rich mesophilous montane meadows dominated by medium-tall grasses (*Agrostis capillaris*, *Festuca rubra* agg., *Trisetum flavescens*) and broad-leaved herbs (*Alchemilla* spec. div., *Crepis mollis*, *Geranium sylvaticum*, *Phyteuma spicatum*, *Pimpinella major*, *Astrantia major*) on nutrient-rich soils (Chytrý 2007; Hegedüšová and Ružičková 2007; Matuszkiewicz 2008; Hegedüšová et al. 2011a; Korzeniak 2013a; Hegedüšová Vantarová 2014). Although they are spread in the Western Carpathians of Slovakia and Poland, their areas are diminishing and increasingly restricted to the montane-subalpine belt due to both traditional and current land exploitation (Hegedüšová et al. 2011a,b; Korzeniak 2013a; Hegedüšová Vantarová 2014; Pruchniewicz 2017).They occur only in isolated places over calcareous bedrock in the wetter and colder conditions mostly on north-oriented saddles and slopes at 600 to 1700 m a.s.l.; and rarely on non-carbonate substrata (Korzeniak 2013a; Hegedüšová Vantarová 2014). Associations of this alliance have close relationships with *Arrhenatherion elatioris*, *Bromion erecti* and *Nardo strictae-Agrostion tenuis* alliances and it also hosts numerous species from the *Mulgedio-Aconitetea* class. Many endangered, protected and rare species occur here (Ioras 2003; Witkowski 2003; Coldea et al. 2009; Coldea 2012; Korzeniak 2013a; Hegedüšová Vantarová 2014) and some of them have an endemic character (Kliment et al. 2016). These meadows also occur in other temperate European mountain ranges, and become progressively more common in oceanic areas (Chytrý 2007). Their distribution centre is in the Alps (Ellmauer and Mucina 1993; Peter et al. 2008; Pierce et al. 2008). Detailed European distribution is reported by Hegedüšová et al. (2011a). From a nature conservation point of view, mountain hay meadows belong to the NATURA 2000 (6520 – Mountain hay meadows), EUNIS (E2.3 – Mountain hay meadows, E4.5 – Alpine and subalpine enriched grasslands) and CORINE (38.3 Mountain hay meadow).

Syntaxonomical revisions have a proven role in pattern recognition in several scientific fields. An increasing need for reliable and unified vegetation classifications across large regions has resulted in comprehensive supra-national vegetation surveys in several European countries (e.g. Dúbravková et al. 2010; Terzi 2015; Douda et al. 2016; Willner et. al. 2017; Willner et. al. 2019). Also, our study has brought new insights for e syntaxonomical classification of the *Triseto-Polygonion* alliance on supra-national level. The idea of a common order of mountain hay meadows was firstly adopted by Dierschke (1981) who introduced the syntaxonomy of *Triseto-Polygonion* alliance in Central Europe. Phytosociological research of these meadows has a long tradition especially in Slovakia (Hadač et al. 1969; Bělohlávková 1980; Ružičková 1997, 2001, 2002b, 2006). Nevertheless, up to the 1980s, only partial data of the vegetation of the *Triseto-Polygonion* alliance were published from particular countries (e.g. Puşcaru et al. 1956; Raclaru 1967; Zanoschi 1971; Sanda et al. 1977; Wojterski 1978). The syntaxonomy of this alliance was published by Sanda et al. (1999) and Coldea (2012) from Romania, Matuszkiewicz (2008) from Poland and Hegedüšová Vantarová (2014) from Slovakia. More detailed national syntaxonomical research was done by Kliment (1994), Ružičková (2002a, 2004), Brinkmann and Reif (2006), Hegedüšová and Ružičková (2007), Hegedüšová et al. (2011a) and Budzhak et al. (2016). Floristic studies were prepared by Mihăilescu (2001) and Coldea (2003). Some information on the studied alliance was published by Malynovskyy et al. (1992) and Solomakha (2008) from Ukraine. Further studies where the management of grasslands of the *Triseto-Polygonion* alliance is mentioned have been published in the last two decades (e.g. Perzanowska et al. 2004; Brinkmann et al. 2009; Hegedüšová et al. 2011b; Pozynych 2012; Korzeniak 2013a; Vadel and Dražil 2015).

The objectives of our study were (i) to prepare a revised and unified classification system for Carpathian mountain hay meadows of the *Triseto-Polygonion* alliance using formalized supervised and semi-supervised methods, (ii) to resolve some syntaxonomical problems, (iii) to evaluate the ecological variability of the distinguished associations, (iv) to determine the major environmental gradients responsible for variation in the floristic composition and (v) to assess the distribution of the distinguished vegetation units in the Carpathians.

Methods

Study area

The Carpathians are an important biogeographical location between the Balkan ranges in the south, the Alps in the west and the Scandinavian range in the north (Ozenda 1985; Ronikier 2011). They form an arch – the largest European mountain range, spanning Austria (Hainburger Berge), Slovakia, Czech Republic (the Moravian Carpathians, westward up to the Moravian Gate), Hungary (North Hungarian Mountains), Poland, Ukraine, Serbia (amid the river valleys of Morava and Timok, southward up to Niš) and Romania (Kondracki 1978, 1989; Ruffini et al 2006; Ronikier 2011; Hlásny et al. 2016; Kliment et al. 2016). Following the traditional division (Kliment 1999; Mráz 2005; Kliment et al. 2016), the Carpathians are divided into the Western Carpathians (Austria, Czech Republic, Hungary, Slovakia and Poland), Eastern Carpathians (Poland, Slovakia, Ukraine and Romania), Southern Carpathians (Romania and Serbia), Apuseni Mountains (Romania) and the Transylvanian Basin (Romania). They cover total surface of 209,000 km^2. From a geological viewpoint, the north-western Bulgarian highlands can also be assigned to the Carpathians (cf. Cankov 1974; Kliment et al. 2016) but their boundaries, and especially the inner zonation, have not yet been precisely defined (cf. Pax 1898; Soó 1930, 1933a, b; Balázs 1939; Pawłowski 1969, 1970; Starmühler 1995; Starmühler and Mitka 2001; Ruffini et al. 2006; Hurdu 2012; Kliment et al. 2016). The phytogeographical division of the whole Carpathian ranges was studied by Tasenkevich (Tasenkevich 2004, 2005; cf. Tasenkevich 2011, 2014).

The study area includes the Slovak, Polish, Romanian and Ukrainian Carpathians (Figs. 1 and 2). We omitted the Hainburger Berge (Austria) because of its low maximum altitude up to 480 m a.s.l. and unsuitable conditions for occurrence of the *Triseto-Polygonion* alliance. Existence of this alliance is not mentioned in the Northern Hungarian Mountains (Lengyel et al. 2016), Moravian (Chytrý 2007) and Serbian Carpathians (Aćić et al. 2013). Of the total area of the Carpathians, about 17% is in Slovakia, only 9.3% in Poland, 11% in Ukraine and as much as 50% in Romania. The western margin of the study area is formed by the Javorníky Mts in Slovakia, the northern by the Western and Central Beskids in Poland, the eastern by the Bucegi Mt. in Romania and the southern margin by the Leaota Mt. in Romania. The Ukrainian Carpathians then have an important role as a bridge linking the Western and Southern Carpathians (Kricsfalusy 2013).

The Carpathian climate is temperate-continental, with more extreme manifestations of the continental climate from west to east; Kadlečík (2016) considers that this mountain range acts as a barrier between the harsher continental climate of the east and the milder oceanic climate in the west, boreal in the north and mediterranean in the south. The temperature, precipitation and, wind change with altitude and the high mountain zone ensures a cold and moist climate with mean annual temperatures between +2 ˚C and -2 ˚C and annual precipitation from 1800 to 2000 mm in the north-western Carpathians. This then falls to 900–1600 mm in the Eastern, Southern and south-eastern Carpathians. In addition, quaternary glaciation affected only the highest peaks, and the current relief forms were shaped by running water (Kondracki 1978; Ronikier 2011). Geologically, the Carpathians were formed from structural parts situated along the arch and these are still mostly manifested in various parts of the mountains (Ronikier 2011). They extend in a geologic system of parallel structural ranges, with the flysch sandstone-shale band forming the main Carpathian outer zone. While crystalline and heat-altered metamorphic rocks are present as smaller isolated blocks surrounded by depressed areas which dominate the Southern Carpathians, the accompanying limestone rocks are discontinuous across the range. These features are supported by a rugged chain of volcanic rocks, which form important structural elements in areas such as the Romanian Eastern Carpathians (Kondracki 1978, 1989; Coldea 1991; Ronikier 2011). The soils are determined by the type of parental mountain rock, altitude, and vegetation cover. Brown acid soils and podzols are the most common; brown acid soils dominate the high mountain meadows and podzols predominate in the foothills and inter-montane basins (Uziak 1964).

Data preparation and analyses

Published relevés in the national phytosociological databases and unpublished relevés from private databases provided the source data for evaluating *Triseto-Polygonion* vegetation in the Carpathians. All phytosociological relevés were recorded according to the principles of the standard Central-European method (Zürich-Montpellier school; Braun-Blanquet 1921, 1964; Westhoff and van der Maarel 1973; Van Der Maarel 1975) and stored using TURBOVEG database software (Hennekens and Schaminée 2001). Plots with homogenous species composition and environmental conditions (aspect, slope, micro-relief) were chosen for sampling new recent relevés. Homogenous species composition was represented by clear vegetation type not transitional stages between other associations or alliances (classes). The plot selected for a relevé was choosen as a representative sample of vegetation occurring on a larger area and the species composition was similar across the entire plot.

The initial dataset of 23,965 relevés comprised all accessible published and unpublished relevés of *Molinio-Arrhenatheretea*, *Nardetea strictae* and *Mulgedio-Aconitetea* classes in the study area. We used 9029 relevés from Slovakia (Slovak Vegetation Database, Hegedüšová 2007; Šibík 2012, EU-SK-001 in the Global Index of Vegetation-Plot Databases, private databases of Katarína Hegedüšová, Iveta Škodová and Jana Májeková), 5220 relevés from Poland (Polish Vegetation Database, EU-PL-001, Kącki and Śliwiński 2012; Grasslands in the Polish Carpathian database, EU-PL-002, Korzeniak 2013b, private database of Joanna Korzeniak), 3748 from Romania (Romanian Grassland Database, EU-RO-008, Vasilev et al. 2018, private databases of Albert Reif, Adrian Stoica and Gheorghe Coldea, Cluj) and 5968 relevés from Ukraine (Ukrainian Grasslands Database, EU-UA-001, Kuzemko 2012; Zajac et al. 2016, private database of Vasyl Budzhak and Alla Tukaryuk, Chernivtsi). This initial dataset was processed using JUICE 7.0.194 program (Tichý 2002). Species found in several layers (especially juvenile species of shrubs and trees) were merged into one layer in each relevé. We eliminated relevés unsuitable for analysis from the unstratified dataset in the following steps: i) relevés without plot size and geographical coordinates were excluded from the dataset; ii) relevés which failed the < 4 m^2 or > 100 m^2 plot size for grassland vegetation were removed to minimise the negative impact of different plot size on species constancy and dataset homogeneity (Chytrý and Otýpková 2003; Dengler at al. 2009); iii) relevés with more than 25% cover of tree/shrub layers were removed; iv) relevés with altitude less than 600 m a. s. l. were excluded. After these steps, the dataset was thus reduced to 6938 relevés with 1672 taxa.

Relevés with less than four diagnostic species of the *Triseto-Polygonion* alliance according to literary sources (Matuszkiewicz 2007; Solomakha 2008; Coldea 2012; Hegedüšová 2014; the diagnostic species of the alliance are listed in Supplement S4) were excluded. Taxa determined only at the genus level together with cryptogams, woody and shrub species (except *Alchemilla* spec. div.) were excluded prior to analyses. To remove unbalanced distribution of the relevé plots (Knollová et al. 2005), heterogeneity-constrained resampling (Lengyel et al. 2011; Wiser and De Cáceres 2013) was performed. The strata were defined based on the geographical position of individual plots. For each stratum of 1.5' latitude and 2.5' longitude (approximately 2.8×3 km), one to ten plots were selected. Relevés of the target vegetation unit were selected based on numerical classification using PC-ORD 5.0 software package (McCune and Mefford 1999), with Jaccard Distance Measure and -0.25 Flexible Beta with Square Root Transformation at p = 0.5. Relevés of non-target vegetation units (*Nardetea strictae* and *Mulgedio-Aconitetea* classes) were deleted from the dataset in successive steps. Ordination graphs of preliminary DCA made in Canoco 5 program (Šmilauer and Lepš 2014) were used for visual detection of outliers, which were subsequently excluded from further analyses. These additional provisions established the progressive dataset of 3538 relevés with 1421 taxa.

Semi-supervised K-means

The Slovak expert system for identification of grassland syntaxa (Janišová 2007; Hegedüšová Vantarová and Škodová 2014) was used to set the *a priori* groups in the semi-supervised K-means classification (Tichý et al. 2014) representing typical relevés of clearly delimited associations. The typical relevés of vegetation units of the *Triseto-Polygonion* alliance delimited in Poland and Romania were selected and approved by phytosociological experts based on Polish and Romanian syntaxonomical literature and added to the *a priori* groups. Also relevés not matching the formal definitions in the Slovak expert system but confirmed by the phytosociological experts as typical relevés were included. The relevés clearly classified as non-target vegetation in the above-mentioned Slovak expert system were removed. These were; associations of *Arrhenatherion elatioris*, *Cynosurion cristati*, *Deschampsion caespitosae* and *Poion alpinae* alliances. Relevés with over 70% cover of *Alopecurus pratensis*, *Calamagrostis arundinacea*, *Festuca carpatica*, *F. picturata*, *F. rubra* and *Nardus stricta* species were also excluded. After these steps the dataset contained 1,204 relevés and 921 species. A total of 115 relevés in seven *a priori* groups consisting of six to 29 typical relevés were selected to represent core associations of the target vegetation. Semi-supervised classification including seven *a priori* groups was used to expand the *a priori* groups by the relevés most similar to typical relevés. K-means analysis was performed with fixed centroids, three pseudo-species cut-off levels (0%, 5% and 25%) and Hellinger transformation. This classification process was repeated in 15 cycles, and a further 428 relevés were assigned to the seven *a priori* groups after analysis. To set the final number of distinguished clusters we used semi-supervised K-means analysis again. Following several cycles of K-means with the same parameters as in previous analyses and with a different number of clusters, we set the final number of newly distinguished clusters to two. To verify clusters homogeneity, we used DCA. Outliers of each delimited cluster were excluded from the dataset after expert consideration. The final dataset contained nine groups, 612 relevés and 719 species.

Synoptic table

The synoptic table of the *Triseto-Polygonion* alliance was calculated in JUICE (Tichý 2002). Diagnostic species were determined by the fidelity concept (Bruelheide 1995; Chytrý et al. 2002, 2006; Chytrý and Tichý 2003; Chytrý 2007). Fisher's exact test at $P < 0.001$ was used to eliminate the fidelity value of species with a non-significant pattern of occurrence. The size of all clusters was standardized to an equal size and the size of each target group was set as 11% of the total data set (Tichý and Chytrý 2006). The critical coefficient phi value for diagnostic species was set as ≥ 0.20. Among them, only species with a frequency $\geq 20\%$ in particular clusters were adopted in the synoptic table. In the list of diagnostic species, constant species include those present in over 50% of relevés ordered according to species frequency. Dominant species were ordered according to the percentage of relevés in which they reached a cover of more than 25% in at least 5% of relevés. Diagnostic taxa differentiate particular community either by unique occurrence or by a markedly higher frequency. The difference in frequency of differential species was at least 20% and at the same time the species could not be constant (frequency 50% and more) in other units. If a diagnostic taxon was missing in other units of the same rank or had low/nul fidelity, it could reach a lower frequency than 20% in the particular unit.

Compositional variation

The main environmental gradients in the species composition of the *Triseto-Polygonion* alliance were analysed using DCA from the R-project package VEGAN (Okasen et al. 2011) under JUICE. Here, display parameters were sites, spider plots and centroids; cover values were log-transformed and rare species down-weighted. To establish the ecological interpretation of ordination axes, the average combined Ellenberg and Jurko indicator values (IV) for relevés (Jurko 1990; Ellenberg et al. 1992; Šibíková et al. 2010) with the altitude for each relevé were plotted on a DCA ordination diagram as supplementary environmental data. This combination of Ellenberg and Jurko IV was employed because many species present in the mountains in Slovakia, Poland, Ukraine and Romania do not possess Ellenberg's IV. Some species also behave differently in Slovakia than in Germany where Ellenberg's IV were derived; and Jurko's IV were created directly for Slovak flora which is more similar to Ukrainian and Romanian flora. The taxa which had no determined indicator value are listed in Supplement S5. The differences in ecological indicator values, number of vascular plants, altitude and selected climatic variables in the delimited vegetation types were tested by Kruskal-Wallis ANOVA, and multiple comparison tests of the mean ranks were completed using STATISTICA software (StatSoft Inc. 2013) with a critical value of p=0.05. These were expressed in Box and Whisker Plots. Spearman's correlation coefficient was then used to calculate the correlation between 10 selected environmental variables comprising IV, altitude, climatic factors (AMT – annual mean temperature, AP – annual precipitation and TAR – temperature annual range, AP, TAR) and the first two ordination axes. After multiple correlations, Bonferroni correction controlled the familywise error critical value rate of $\alpha = 0.05/12$.

Results

Classification and phytocoenological characteristics of the associations

The semi-supervised classification enabled the final determination of the entire Carpathian dataset. The eight known and one newly well-interpretable associations of the *Triseto-Polygonion* alliance were finally determined and described. The list of occurrences and number of relevés in each syntaxon is then reported in Table 1. The distribution map of the studied alliance and associations in the Carpathians is depicted in Figs. 1, 2 and 3. The synoptic table reveals the differences in floristic composition of each association based on diagnostic, constant and dominant species (Table 2); diagnostic, constant, and dominant species are listed in Supplement S2. The DCA of the 612 relevés featured in Fig. 4 highlights the main environmental gradients in the species composition. The interrelationships of the vegetation units and the number of species, AMT, TAR, AP, altitude and individual environmental factors are then shown in Fig. 5.

Campanulo glomeratae-Geranietum sylvatici **Ružičková 2002**

(Table 2, Supplement S2, Cluster 1, Figs. 1 and 2, Supplement S6 – Fig. 6/1)

The *Campanulo glomeratae-Geranietum sylvatici* association is the most xerothermic type of mountain hay meadows in the Carpathians. It represents species-rich multi-layer stands with dominant broad-leaved species (*Alchemilla* spec. div. and *Geranium sylvaticum*) together with graminoids (*Agrostis capillaris*, *Arrhenatherum elatius*, *Bromus erectus*, *Festuca rubra* agg. and *Trisetum flavescens*) and mesophilous species of the *Arrhenatherion elatioris* alliance. The thermophilous species indicate the alkaline and warm sites. The cryptogam coverage is very low and only reaches more than 25% at sites with sufficient humidity. The most common are *Climacium dendroides*, *Plagiomnium affine* agg., *P. cuspidatum* and *Pleurozium schreberi*. The community occurs on warm limestone areas of submontane to montane level (Table 4). The centre of its occurrence is in Slovakia, though we expect a marginal occurrence in Poland and Ukraine. This mountain meadow type is rare today and mainly dependent on abandonment of traditional land use and it is therefore considered a relic of semi-intensive traditional agriculture (Hegedüšová et al. 2011). It is often accompanied by numerous endangered rare and endemic species (e.g. *Campanula serrata*, *Crocus vernus* subsp. *vernus* and *Lilium bulbiferum*).

***Geranio sylvatici-Trisetetum flavescentis* Knapp ex Oberd. 1957**

(Table 2, Supplement S2, Cluster 2, Figs. 1 and 2, Supplement S6 – Fig. 6/2)

This association is relatively homogeneous, multi-layered and medium species-rich and is dominated by mesophilous species of the *Arrhenatherion elatioris* alliance combined with medium-tall grasses (*Agrostis capillaris*, *Anthoxanthum odoratum* agg. and *Trisetum flavescens*). The middle layer is dominated by the montane herb *Geranium sylvaticum*. The relatively abundant ground layer consists of clovers and the shade-tolerant species *Alchemilla* spec. div., *Arabidopsis halleri* and *Bellis perennis*. While *Alopecurus pratensis* and *Lychnis flos-cuculi* have higher abundance in humid areas, the nitrophilous species *Anthriscus sylvestris*, *Bellis perennis*, *Poa trivialis* and *Schedonorus pratensis* together with *Trisetum flavescens* occupy fertilised meadows. Abandonedt areas or areas with reduced farming activity are dominated by *Agrostis capillaris*, *Briza media*, *Carex pallescens*, *Crepis mollis*, *Festuca rubra* agg., *Hypericum maculatum* and *Luzula campestris* agg. These meadows occur in localities with specific climatic conditions and long-lasting snow cover predominantly in Slovakia (Table 4). A typical phenomenon is frequent mist and ground night inversion. Scattered stands with similar climatic conditions are also found in the mountain ranges of Poland. Nevertheless, we can expect it also in Romania (Apuseni Mts). To preserve this type of meadows as they were in the past, it is necessary to choose appropriate management practices (mowing once a year and moderate fertilizing).

***Crepido mollis-Agrostietum capillaries* Ružičková 2004**

(Table 2, Supplement S2, Cluster 3, Figs. 1 and 2, Supplement S6 – Fig. 7/3)

Species- rich semi-natural, two- to three-layer grasslands include regularly mowed and occasionally fertilised or recently abandoned mountain meadows and pastures. They are dominated by *Agrostis capillaris* and *Festuca rubra* agg. grasses with medium-fodder quality along with the constantly represented species *Anthoxanthum odoratum* agg. and *Dactylis glomerata*. While *Jacobaea subalpina*, *Potentilla aurea* and *Viola lutea* have greater frequency at higher altitudes, *Alopecurus pratensis*, *Heracleum sphondylium* and *Lychnis flos-cuculi* can be more abundant on wet and nutrient-rich soils. *Trollius europaeus* creates here a significant aspect with relatively high coverage. On the contrary, coenoses on nutrient-poor soils are dominated by *Hypericum maculatum*, *Luzula campestris* agg., *L. luzuloides*, *Ranunculus polyanthemos* and *Thymus pulegioides*. The middle layer is characterized by the presence of *Alchemilla* spec. div., *Leucanthemum vulgare* agg. and *Ranunculus acris* which require sufficient light. A large quantity of herb layer biomass prevents the development of mosses, the coverage of which usually does not exceed 10%. The most common mosses are *Climacium dendroides* and *Pleurozium schreberi*. The occurrence of rare, endangered and endemic species (e.g. *Campanula serrata*, *Crocus vernus* subsp. *vernus*, *Gladiolus imbricatus*, *Gymnadenia conopsea* and *Trollius europaeus*) is also important. The community of *Crepido mollis-Agrostietum capillaris* inhabits colder and wetter sites on mild slopes (Table 4). The centre of its occurrence is at submontane and montane levels in Slovakia and Poland. Finally, the factors most significantly affecting the floristic composition and the overall structure of these communities are the geographical position, microclimatic features and abandonment.

***Geranio-Alchemilletum crinitae* Hadač et al. 1969**

(Table 2, Supplement S2, Cluster 4, Figs. 1 and 2, Supplement S6 – Fig. 7/4)

These open, homogenous, chionophilous, mostly two-layer montane meadows are species medium-rich. They occur at higher altitudes with long-lasting snow cover and are dominated by broad-leaved species such as *Alchemilla* spec. div. and *Geranium sylvaticum*. The stand structure is complemented with flowering herbs (e.g. *Bistorta officinalis*, *Campanula serrata*, *Crepis mollis*, *Jacobaea subalpina*, *Phyteuma spicatum*, *Pimpinella major*, *Trollius europaeus* and *Viola biflora*). Grasses *Agrostis capillaris*, *Festuca rubra* agg. and *Trisetum flavescens* up to 60cm high have a high constancy in the upper layer. Depending on the soil chemistry and changes in management, almost monodominant stands of the species *Bistorta officinalis* or *Hypericum maculatum* are typical. In the humid places, the species *Geranium sylvaticum* is replaced by *G. phaeum*. These species, together with *Ligusticum mutellina*, *Soldanella carpatica* and *Trollius europaeus*, indicate poor leached soils and fallow land, in contrast to *Rhinanthus pulcher* which indicates regular farming. The moist soils host several hygrophilous species (e.g. *Alopecurus pratensis* and *Geum rivale*). The cryptogam layer is poorly developed, with normally less than 20% cover. The most frequent mosses are *Plagiomnium undulatum* and *Pleurozium schreberi*. The communities of *Geranio-Alchemilletum crinitae* occur at montane, supramontane to subalpine levels, mostly on moderate slopes (Table 4). Montane meadows with *Alchemilla* species are valuable not only for the occurrence of endangered, vulnerable and endemic species but also for their unique character. They are endangered due to their abandonment (Rozbrojová et al. 2010; Hegedüšová Vantarová 2014) and also air-pollution (Rusek 1993). Due to abandonment, these stands no longer exist in their previous form.The centre of its occurrence is in Slovakia and marginally in Poland.

***Alchemillo-Deschampsietum caespitosae* Hadač et al. 1969**

(Table 2, Supplement S2, Cluster 5, Figs. 1 and 2, Supplement S6 – Fig. 8/5)

Alchemillo-Deschampsietum caespitosae is a species-poor, closed, monodominant, two-layer, slightly chionophobic, physiognomically striking community with a height up to 100 cm. The association comprises predominantly thick and compact tussocks of *Deschampsia cespitosa*, with the lower layer dominated by broad-leaved species of *Alchemilla* spec. div., *Geranium sylvaticum*, *Hypericum maculatum*, *Jacobaea subalpina* and *Primula elatior* together with *Achillea millefolium* agg., *Campanula serrata*, *Potentilla aurea* and *Rumex arifolius*. Among the graminoids, *Agrostis capillaris*, *Festuca rubra* agg., *Luzula luzuloides* and *Phleum rhaeticum* are more constant. Moss coverage is relatively low and does not exceed 15%. The most common are *Brachythecium albicans*, *Pleurozium schreberi* and *Climacium dendroides*. Typical habitats are humid sites on the windward slopes (Table 4), close to saddlebacks and saddleback plains with a slightly undulating concave surface and relatively high (150 cm) snow cover which remains in some areas until the end of May/early June (Bělohlávková 1980). The soil surface usually does not freeze. The stands developed especially after deforestation and these are conditioned by long-term grazing. The centre of its occurrence is at the supramontane level. Finally, the community is relatively common, mainly in the mountains of Slovakia and marginally in Poland, Romania and Ukraine.

***Phyteumo (orbicularis)-Trifolietum pratensis* Balcerk. 1978**

(Table 2, Supplement S2, Cluster 6, Figc. 1 and 2, Supplement S6 – Fig. 8/6)

This association includes low-growing, calciphilous montane grasslands on limestone or dolomite bedrock and is used as meadows and pastures. It is species-rich, colourful and has a high abundance of small and medium-tall plants in the herb layer. The species composition is characterised by co-dominance of meadow species of the *Molinio-Arrhenatheretea* class and calcareous species of the *Elyno-Seslerietea* class. Another typical feature is the occurrence of thermophilous species (e.g. *Carex caryophyllea*, *Gentiana cruciata*, *Helianthemum nummularium* agg. and *Plantago media*). Usually there is no clear dominant. The cryptogam coverage varies and is even up to 70% in some sites; the most common are *Abietinella abietina*, *Brachythecium mildeanum*, *B. albicans*, *Hypnum* *lindbergii* and *Plagiomnium cuspidatum*. These grasslands occur predominantly on alluvial fans, with gentle inclination (Balcerkiewicz 1978) at the submontane and montane level, exclusively in the Western Carpathians.

Astrantio-Trisetetum flavescentis **Knapp et Knapp ex Oberd. 1957**

(Table 2, Supplement S2, Cluster 7, Figs. 1 and 2, Supplement S6 – Fig. 9/7)

These species-rich communities are mostly dominated by *Trisetum flavescens* and *Astrantia major* together with *Trollius europaeus*. The species *Centaurea phrygia* agg., *Cirsium erisithales* and *Lotus corniculatus*, together with species of the *Triseto-Polygonion* alliance and mesophilous species of the *Molinio-Arrhenatheretea* class occur with high frequency. Finally, *Alchemilla* spec. div. is frequently present as a co-dominant. The stand structure creates conditions for the occurrence of grasses of nutrient-poor sites (*Agrostis capillaris*, *Anthoxanthum odoratum* and *Festuca rubra* agg.) together with frequent occurrence of broad-leaved grasses of more nutrient-rich sites (*Cynosurus cristatus*, *Dactylis glomerata* and *Phleum pratense*). Loss of nitrate nutrients after abandonment of traditional farming induced community degradation to phytocoenoses dominated by *Agrostis capillaris* and *Festuca rubra*. In the moss layer, species like *Rhytidiadelphus squarrosus*, *Climacium dendroides*, *Pleurozium schreberi*, *Plagiomnium undulatum* and *Calliergonella cuspidata* are the most frequent with coverage of 1 to 75%. These communities occur frequently in small areas at the border of deciduous forests on gentle slopes (Table 4), near the villages in the mountain belt at submontane and montane levels. The geological substrate is mostly rich in limestone, which enable the development of soils with a high nutrient content. This vegetation type occurs throughout the entire study area.

Violo declinatae-Agrostietum capillaris **ass. nova**

(Tables 2 and 3, Supplement S3, Cluster 8, Nomenclatural type: relevé nr. 20, Figs. 1 and 3, Supplement S6 – Fig. 9/8)

This association includes homogenous, species medium-rich, floriferous mountain grasslands. The well developed herb layer (cover 90–100%) is mostly dominated by medium-tall graminoids (*Agrostis capillaris*, *Dactylis glomerata* agg., *Festuca rubra* agg. and *Trisetum flavescens*) and broad-leaved herbs (*Astrantia major*, *Alchemilla* spec. div. and *Cirsium erisithales*). *Viola declinata* is the significant diagnostic species of this community. Among the other constant species, there are common species of montane hay meadows (*Trollius europaeus*, *Astrantia major*, *Campanula serrata* and *Heracleum sphondylium*). This species combination together with *Geranium sylvaticum* and *Pimpinella major* corresponds to the *Triseto-Polygonion* alliance. However, occurrence of some thermophilous species (e.g. *Galium verum*, *Pimpinella saxifraga* and *Thymus pulegioides*) accompanied with species of mesic grasslands of the *Arrhenatherion elatioris* alliance is very common as well. Abandoned localities are indicated by the occurrence of *Hypericum maculatum*. Species of the *Nardetea strictae* class (*Potentilla erecta*, *Luzula campestris* agg. and *L. luzuloides*) are also frequent. In contrast, localities with high soil moisture content are indicated by *Angelica sylvestris*, *Crepis paludosa*, *Deschampsia cespitosa* and *Myosotis scorpioides* agg. The moss layer is slightly developed with coverage up to 5%. There is also typical occurrence of endemic species such as *Campanula serrata*, *Cyanus mollis* and *Viola declinata* together with the Eastern Carpathian species of *Centaurea kotschyana*, *Dianthus barbatus* subsp. *compactus*, *Euphorbia carniolica* and *Podospermum roseum* (Kliment et al. 2016). Following the DCA and cluster analysis, two different variants of this vegetation were distinguished (Table 3). The characteristic feature of the first variant *typicum* is the high species constancy and cover of the *Triseto flavescentis-Polygonion bistortae* alliance and *Molinio-Arrhenatheretea* and *Festuco-Brometea* classes. The second variant with *Cirsium erisithales* occurs on more humid soils with long-lasting snow cover at higher altitudes (1413–1647 m a.s.l.). The grasslands of *Violo declinatae-Agrostietum capillaris* are typical in the middle montane belt of submontane, montane and subalpine levels of Ukraine (Table 4). They have intensive agricultural use, being fertilised and now regularly mown. These communities need protection as examples of traditional farming in the Carpathian mountain areas which support grassland diversity conservation.

***Trollio altissimi-Knautietum dipsacifoliae* Winnicki ex Hegedüšová et al. ass. nov. hoc. loco**

Syn.: *Trollio altissimi-Knautietum dipsacifoliae* Winnicki Monogr. Bieszcz. 4: 102, 1999 (art. 5)

Nomenclatural type: Winnicki 1999, tab. 20, relevé nr. 14, lectotypus hoc loco designatus

Knautia maxima (Opiz) Ortmann = *K. dipsacifolia* Kreutzer

(Table 2, Supplement S2, Cluster 9, Tab. 20 (Winnicki 1999), Nomenclatural type: relevé nr. 14, Figs. 1and 2, Supplement S6 – Fig. 10/9)

These grasslands are usually dominated by broad-leaved herbs (*Alchemilla* spec. div., *Astrantia major* and *Knautia dipsacifolia = maxima*) and graminoids (*Carex pilosa*, *Deschampsia cespitosa*, *Poa chaixii* and *Trisetum flavescens*). The vegetation is multi-layered and dense with overgrowth; therefore, the bryophyte layer is reduced at most sites. There is an important presence of both tall herb species of wet meadows (*Geranium palustre*, *Filipendula ulmaria* and *Trollius europaeus*) and subalpine tall-forbs (*Aconitum lasiocarpum*, *Cirsium waldsteinii*, *Rumex arifolius* and *Veratrum album*). The phytocoenoses host Pan-Carpathian endemics (*Campanula serrata*) and subendemics (*Cyanus mollis*), as well as many Eastern Carpathian plant species (*Aconitum lasiocarpum*, *Aposeris foetida*, *Centaurea kotschyana*, *Cirsium waldsteinii*, *Dianthus barbatus* subsp. *compactus*, *Veratrum album* and *Viola dacica*). The high abundance of *Hypericum maculatum* indicates meadow degradation following cessation of traditional farming (Krahulec et al. 1996; Hegedüšová Vantarová 2014). This type of meadow grows on humid and fertile sites, in local depressions and on slopes with various inclinations (Table 4). The centre of *Trollio altissimi-Knautietum dipsacifoliae* distribution is in south-eastern Poland. This was previously grazed by oxen but since the complete abandonment of farming in this area after the Second world war it is grazed by deer. Most localities are abandoned, and although this semi-natural origin should endow the mountain meadows with resistance, the long-term lack of management has hastened conversion to tall grasslands with subalpine deciduous shrub communities.

Ordination analysis and ecological characteristics

The DCA scatter plot of individual relevés highlights the distribution of particular vegetation types along the first and second ordination axes (Fig. 4). The selected indicator values for relevés (temperature, moisture, light, soil reaction and nutrients), altitude, climatic variables (annual precipitation – AP, annual mean temperature – AMT and TAR – temperature annual range) and species number were post-hoc correlated with the ordination axes to reveal the main environmental gradients in our data set. The distribution of relevés depicts a continuous ecological transition of associations along the main gradient. The first axis was significantly positively correlated with AP, altitude, moisture and slightly with soil reaction and nutrients; and negatively correlated with AMT, TAR, light and slightly with temperature (Table 5). The main environmental gradient here was related to altitude and precipitation. While the right side of the ordination plot contains relevés which occur at higher altitudes with greater AP – *Geranio-Alchemilletum crinitae* (cluster 4), *Alchemillo-Deschampsietum caespitosae* (cluster 5) and *Trollio altissimi-Knautietum dipsacifoliae* (cluster 9), on the contrary, the left side of the ordination plot is occupied by relevés of the most xerothermic type of mountain hay meadows – *Campanulo glomeratae-Geranietum sylvatici* (cluster 1) and *Phyteumo (orbicularis)-Trifolietum pratensis* (cluster 6). These host many termophilous plant species together with *Astrantio-Trisetetum flavescentis* (cluster 7). The second axis is significantly negatively correlated with the indicator values for nutrients, moisture and slightly correlated with soil reaction and AP (Table 5). While the chionophobic vegetation of *Geranio sylvatici-Trisetetum flavescentis* (cluster 2) and *Alchemillo-Deschampsietum caespitosae* (cluster 5) grow on moist soils and are shifted along the second axis to the lower part of the ordination space, the stands of *Campanulo glomeratae-Geranietum sylvatici* (cluster 1) and *Violo declinatae-Agrostietum capillaris* (cluster 9) thrive on drier and less fertile soils and are concentrated on the opposite side of the diagram.

The comparison of IVs, climatic variables and altitude highlights the significant differences between associations, especially for altitude, AP and AMT (Fig. 5). The *Geranio-Alchemilletum crinitae*, *Alchemillo-Deschampsietum caespitosae* and *Trollio altissimi-Knautietum dipsacifoliae* associations occur at higher altitudes (1100–1700 m a.s.l.) where AP is significantly higher, AMT is lower and TAR is lower than in other delimited communities. In contrast, the *Campanulo glomeratae-Geranietum sylvatici*, *Geranio sylvatici-Trisetetum flavescentis* and *Crepido mollis-Agrostietum capillaris* grasslands are mostly at lower altitudes (600–1000 m a.s.l.).

While the *Alchemillo-Deschampsietum caespitosae* and *Trollio altissimi-Knautietum dipsacifoliae* communities occupy moist habitats, *Campanulo glomeratae-Geranietum sylvatici* and *Violo declinatae-Agrostietum capillaris* are found on drier stands. Although this latter association grows mainly at higher altitudes, soil humidity establishes it on the left of the ordination diagram (Fig. 4). The last two associations mentioned also have the lowest soil reaction values, and this contrasts significantly with most other communities. These grassland types often occur on sites with soils rich in $CaCO_3$ formed on calcareous rocks. The comparison of light IV revealed that light availability and use is significantly lower in *Trollio altissimi-Knautietum dipsacifoliae* grasslands than in other delimited communities because the presence of two- to three-layer stands ensures that only shade-tolerant plants can exist in the lowest layer.

Comparison of species number (Fig. 5) showed that *Campanulo glomeratae-Geranietum sylvatici* is the most species-rich hay mountain grassland type, while in *Alchemillo-Deschampsietum caespitosae* and *Trollio altissimi-Knautietum dipsacifoliae* grasslands the species number is the lowest.

Discussion

The present classification includes all known well-differentiated types of mountain hay meadows in the Carpathians. While this classification can be interpreted ecologically based on the selected environmental variables of climatic factors, altitude and IVs, it may not include all influences on grassland diversity because it is closely connected with the quality and availability of data from national databases, as well as with the stage of abandonment, management practice (Rozbrojová et al. 2010; Škodová et al. 2015) and time of origin (Rybníček and Rybníčková 2009).

What does the syntaxonomical revision bring?

The syntaxonomical concept adopted in this paper is largely based on that of Slovakian, Polish, Romanian and Ukrainian phytosociologists (Hegedüšová 2007; Matuszkiewicz 2008; Solomakha 2008; Hegedüšová et al. 2011a; Coldea 2012; Hegedüšová Vantarová 2014; Budzhak et al. 2016) with correction, which resulted from the specific environmental conditions and distribution of vegetation within the Carpathians. Because of some discrepancies between particular syntaxonomical systems of the *Triseto-Polygonion* alliance in the Carpathians, there was a necessity to unify it. Our results correspond with semi-supervised K-means analyses and expert view reflecting the environmental and phytogeographical gradients that influence species composition. We expected more associations than the *a priori* groups defined in our Carpathian dataset. Our classification provides a full overview of the variability of Carpathian mountain hay meadows. We also expected the most xerothermic vegetation type of mountain hay meadows – *Campanulo glomeratae-*

Geranietum sylvatici association with the typical occurrence of a large group of subxerophilous species – on the warm slopes of the Ukrainian and Polish Carpathians. However, only one relevé from each of these countries was assigned to this association. Both these relevés are similar to typical relevés described from Slovakia, but their designation is quite old (Ukraine: 1935, Poland: 1954) and based on our results we cannot confirm that this vegetation type occurs recently in those Carpathian areas. We therefore consider that *Campanulo glomeratae-Geranietum sylvatici* is a very specific and rare vegetation type occurring exclusively in the central Slovakian mountains.

The *Geranio sylvatici-Trisetetum flavescentis* association has a wider geographic distribution with its centre of occurrence in Germany (Chytrý 2007; Hegedüšová Vantarová 2014). This association has a more oceanic character. Six of the Polish relevés classified to the second cluster in the final data set were originally assigned to the *Gladiolo-Agrostietum* association. This indicates that *Gladiolo-Agrostietum* referred to as the most widespread hay meadow community in the Polish Carpathians (Kornaś 1967) described by Pawłowski et al. (1960) and placed originally to the *Arrhenatherion elatioris* alliance (Matuszkiewicz 2008), is a very heterogeneous and broadly defined syntaxon with wide altitudinal and ecological amplitude. Due to the diffuse boundaries between syntaxa, classification of this vegetation is even more complex. Moreover, Marschall (1951) and Dierschke (1981) included *Gladiolo-Agrostietum* in the *Triseto-Polygonion* alliance in contrast to Uhliarová et al. (2014) who consider it a syntaxonomical synonym for *Poo-Trisetetum flavescentis* in the *Arrhenatherion elatioris* alliance. In addition, Rozbrojová et al. (2010) reported that this vegetation type is classified in different associations in Slovakia and Poland despite their similar species composition: it is classed as *Poo-Trisetetum flavescentis* in Slovakia and *Gladiolo imbricati-Agrostietum capillaris* in Poland. According to the authors, this classification difference is conditioned by state borders rather than by any actual difference in species composition. Uhliarová et al. (2014) also provided a more thorough comparison of both communities in their syntaxonomic revision of *Arrhenatherion elatioris*. Their comparison also included published data from Germany (Oberdorfer 1983; Dierschke 1997) and Austria (Ellmauer and Mucina 1993) in addition to the phytosociological relevés from Poland (Pawłowski et al. 1960) and Slovakia. The analyses showed considerable species and ecology similarity of *Poo-Trisetetum* and *Gladiolo-Agrostietum typicum* associations. Relevés with the occurrence of mountain species (*Phleum alpinum*, *Poa alpina*, *Rumex arifolius, Jacobaea subalpina, Phyteuma spicatum* and *Primula elatior*) had a closer relationship with plant communities of the *Triseto-Polygonion* alliance. Our analyses identified that the Polish *Gladiolo-Agrostietum capillaris* relevés were also included in *Crepido mollis-Agrostietum capillaris* (19 relevés), *Geranio-Alchemilletum crinitae* (6 relevés), *Alchemillo-Deschampsietum caespitosae* (9 relevés) and *Astrantio-Trisetetum flavescentis* (7 relevés).

Crepido mollis-Agrostietum capillaris represents a transition to the other types of mountain hay meadows (Fig. 4), *Campanulo glomeratae-Geranietum sylvatici* and *Geranio-Alchemilletum crinitae* . It also has a close relationship to the *Arrhenatherion elatioris* and *Nardo strictae-Agrostion tenuis* alliances (Hadač et al. 1969; Kliment 1994; Ružičková 1997, 2004). In warmer places, mesophilous species of *Arrhenatherion elatioris* occur and the floristic composition is closely related to *Campanulo glomeratae-Geranietum sylvatici*, while *Geranio-Alchemilletum crinitae* is a contact phytocoenosis at higher altitudes. In addition, stands where traditional farming methods have been abandoned gradually pass into the *Nardo strictae-Agrostion tenuis* or *Violion caninae* communities (Hadač et al. 1969; Kliment 1994; Ružičková 1997, 2004) and at higher altitudes into the *Poion alpinae* association (Hegedüšová Vantarová 2014). Our analyses confirm that this association also occurs in Poland, with up to 26% of Polish relevés in this association originally assigned to the warmer *Gladiolo-Agrostietum*. However, we cannot include in the *Crepido mollis-Agrostietum capillaris* association the phytocoenosis from south-western Ukraine described by Budzhak et al. (2016) because of the lack of association and alliance diagnostic species. Moreover, the *Molinia caerulea* s. str. species has very high abundance here and these stands have close relationship to the *Calthion* alliance.

The *Geranio-Alchemilletum crinitae* association has a very close syngenetic relationship with *Alchemillo-Deschampsietum caespitosae* and *Mulgedio-Aconitetea* communities; proven by the presence of *Rumex arifolius*, *Gentiana asclepiadea*, *Ligusticum mutellina*, *Primula elatior*, *Jacobaea subalpina*, *Silene dioica* and *Veratrum lobelianum* species (Hegedüšová Vantarová 2014) and similar ecological contidions (same biotopes in higher altitudes). With these communities, there are continuous transitions clearly distinguished in the field. The type of management and site of occurrence also affect variability in association species composition (Kliment 1994; Ružičková 1997). Our analyses also confirmed their occurrence in Poland and documented in the Western Tatras by relevés research performed after 2000. Finally, although Malynovskyy (1980), Malynovskyy and Kricsfalusy (2000) and Prots and Kagalo (2012) mentioned these communities in Ukraine, our analysis did not confirm their presence.

The common cluster feature representing *Alchemillo-Deschampsietum caespitosae* vegetation is a transitional position to *Geranio-Alchemilletum crinitae*, *Phleo alpini-Deschampsietum caespitosae*, *Rhodiolo-Deschampsietum caespitosae*, *Aconitetum firmi* (*Trisetion fusci* alliances) and communities of the *Adenostylion alliariae* alliance. The floristic composition also encourages the conclusion that the association has a very close syngenetic relationship with *Nardion strictae*, and that it has gradual transitions to this on exposed and unprotected slopes. Further, stand species composition reflects the various ecological conditions and is visible in the form of transitions with contact phytocoenoses. The heterogeneity of this type of vegetation is best explained by the physio-geographical parameters of altitude, slope and aspect together with snow cover thickness and humidity ratios. While Hegedüšová and Ružičková (2007) recorded *Alchemillo-Deschampsietum caespitosae* as a syntaxonomical synonym for the *Geranio-Alchemilletum crinitae* association, Hegedüšová Vantarová (2014) now lists it separately due to its clear physiognomic distinctness confirmed by phytosociological relevés as well as the ecological requirements that enable it to dominate *Deschampsia caespitosa*. Our analyses also confirmed its occurrence in Poland, Ukraine and Romania. The Polish relevés were originally assigned to *Gladiolo-Agrostietum alpinetosum* (Tatra Mts, Pawłowski et al. 1960) and *Gladiolo-Agrostietum deschampsietosum* (Gorce Mts, Kornaś and Medwecka-Kornaś 1967). Both associations are considered as sub-associations of *Gladiolo-Agrostietum* at higher altitudes and relicts of previous traditional sheep farming. The Romanian relevés were previously assigned to *Deschampsion caespitosae* Horvatić 1930 by Puşcaru et al. (1956), Buia (1962) and Sanda et al. (1977). However, this alliance includes alluvial meadows at low altitudes characterised by the absence of montane species and specific ecological conditions. Additional assignments of *Alchemillo-Deschampsietum caespitosae* relevés were to *Calamagrostion villosae* by Stancu (2005), *Agrostion stoloniferae* by Neblea (2006) and to the *Adenostylion alliariae* alliance by Coldea (1990). Based on our analyses and the occurrence of *Triseto-Polygonion* species, we corrected these previous classifications – noting also that the relevés from the Ukrainian Chyvchyny Mts were not originally assigned to any syntaxa.

Phyteumo (orbicularis)-Trifolietum pratensis was described by Balcerkiewicz (1978) from Polana Chochołowska in the Polish Western Tatras. Although Hegedüšová Vantarová (2014) does not identify this community in Slovakia, our analyses confirmed its Slovak occurrence in the Chočské vrchy Mts, Malá Fatra Mts, Muránska planina plain, Nízke Tatry Mts, Slovenský raj Mt. and Veľká Fatra Mts due to both similar ecological conditions and species composition (Supp. 1). These relevés were not previously clearly assigned to any syntaxa (Bosáčková ined., Ujházy ined., Uhliarová ined., Ružičková ined.) or they were included in *Anthoxantho-Agrostietum tenuis* (Dzubinová 1978, 1984).

The centre of occurrence of *Astrantio-Trisetetum flavescentis* is in the Alps from where it was originally described (Dutoit 1924; Knapp and Knapp 1952; Oberdorfer 1957; Ellmauer 1995). From Slovakia, Poland and Ukraine, this community has not been mentioned until now. This association has a close relationship with the newly described Ukrainian *Violo declinatae-Agrostietum capillaris* association stands highlighted in Fig. 4. In comparison to other relevés from Slovakia, Poland and

Ukraine, the species *Astrantia major* has a higher abundance. Its dominance of Slovak vegetation is typical at both abandoned sites and those with changed management (Ružičková 1997). In addition, this vegetation type was previously assigned to *Geranio-Alchemilletum crinitae* based on species similarity (Hegedüšová Vantarová 2014).

Violo declinatae-Agrostietum capillaries, a new association, is typical only for Ukraine. This vegetation is floristically very homogeneous with a close relationship to *Campanulo glomeratae-Geranietum sylvatici* and *Astrantio-Trisetetum flavescentis* sharing thermophilous species.

Trollio altissimi-Knautietum dipsacifoliae was first described by Winnicki (1999) from the Bieszczady Mts as the tall-forb community *Trollio altissimi-Knautietum dipsacifoliae* Winnicki 1999 and classified to the *Adenostylion alliariae* alliance, *Betulo-Adenostyletea* (=*Mulgedio-Aconitetea*) class (Winnicki 1999). Iakushenko et al. (2012) then classified it as a syntaxonomical synonym of *Poo chaixii-Deschampsietum cespitosae* Pawłowski et Walas 1949 (*Mulgedio-Aconitetea* class). Comparing the diagnostic species of both communities, we decided to transfer *Trollio altissimi-Knautietum dipsacifoliae* to *Triseto-Polygonion* (*Molinio-Arrhenatheretea* class) instead of its traditional classification in the *Adenostylion alliariae* (Winnicki 1999) or *Calamagrostion villosae* (Iakushenko et al. 2012) alliances. According to semi-supervised analyses, relevés of Polish *Trollio altissimi-Knautietum dipsacifoliae* have a very close relationship with *Astrantio-Trisetetum flavescentis* and *Geranio-Alchemilletum crinitae* and have an intermediate position between them (Fig. 4). This analysis is based on similar stand species composition and the content of the following *Triseto-Polygonion* species: *Arabidopsis halleri*, *Astrantia major*, *Campanula serrata*, *Heracleum sphondylium*, *Phyteuma spicatum* and *Trollius altissimus*. However, Winnicki (1999) did not assign a nomenclatural type for *Trollio altissimi-Knautietum dipsacifoliae* and therefore its name is not considered valid. For validation, we chose relevé number 14 recorded in Table 20. The approved valid name is now *Trollio altissimi-Knautietum maximae* Winnicki ex Hegedüšová et al. ass. nov. hoc. loco.

K-means classification; advantages and limitations

Semi-supervised classification which formally reproduces the existing units in a supervised mode, and simultaneously identifies new units at unassigned sites in an unsupervised mode, is increasing in popularity and is currently used in several national and supra-national classification studies (Rodríguez-Rojo et al. 2014; Slezák et al. 2014; Tichý et al. 2014; De Cáceres et al. 2015; Smale and Wiser 2015; Wiser et al. 2015; Douda et al. 2016; Janišová et al. 2016; Kuzemko 2016; Zajac et al. 2016; Wiser and De Cáceres 2018).

We decided to use semi-supervised K-means classification instead of the common unsupervised and supervised methods mainly because of i) the heterogeneity of the initial dataset in the large Carpathian area and ii) our assumption that some Slovak, Romanian and Polish associations of the *Triseto-Polygonion* alliance exist also in other parts of the Carpathians, which we eventually confirmed.

We applied the revised classification of Slovakia (Electronic Expert System: Janišová 2007; Hegedüšová Vantarová and Škodová 2014) to assess *a priori* groups. However, this approach was preferentially developed for Slovakian territory, and we therefore performed an additional expert revision of typical relevés of *a priori* groups because final clusters have greater homogeneity when the *a priori* groups have more relevés (Zajac et al. 2016). The intermediate step extended *a priori* groups by semi-supervised k-means analysis with fixed centroids. Both classifications with fixed and non-fixed centroids were tested but similar to previous studies (Zajac et al. 2016) classification with non-fixed centroids provides more heterogeneous clusters.

An indisputable advantage of semi-supervised classification is the identification of new units (Tichý et al. 2014). We identified one new unit *Violo declinatae-Agrostietum capillaris* and confirmed *Trollio altissimi-Knautietum dipsacifoliae* previously described by Winnicki (1999) within the *Mulgedio-Aconitetea* class. Moreover, we finally confirmed that identical or similar vegetation units occur in all Carpathian countries. In the case of Polish *Triseto-Polygonion* classification, we verified the occurrence of five extra associations in addition to the recognised *Phyteumo (orbicularis)-Trifolietum pratensis* (Matuszkiewicz 2008). Based on our results of semi-supervised classification we can conclude that there are also mountain grasslands of the *Triseto-Polygonion* alliance in some parts of the Ukrainian Carpathians where its occurrence was previously uncertain and controversial (Solomakha 2008; Škodová et al. 2015; Budzhak et al. 2016; Zajac et al. 2016). Further, the semi-supervised classification of vegetation data from the neighbouring Carpathian countries enabled syntaxa standardisation throughout the region and this proved successful in a supra-national classification.

This approach, however, is limited by the high percentage of unassigned relevés in the dataset because only 612 of the initial 1204 relevés were classified to known and new units. Although this contrasts with Zajac et al. (2016) classification of the majority of relevés in the final selected dataset, it was an expected result due to the high heterogeneity of Carpathian mountain hay meadows and theirs differences in substrate, altitude, exposition, land use, etc. The remaining 592 relevés were classified by relevé authors and also by Expert systems as *Arrhenatherion* (*Poo-Trisetetum*, *Gladiolo-Agrostietum* in Poland), *Cynosurion*, *Nardo strictae-Agrostion*, *Poion alpinae* and *Mulgedio-Aconitetea* class which are contact phytocoenoses of the *Triseto-Polygonion* alliance. A few relevés might belong to *Triseto-Polygonion* but most of them are transitional types between *Triseto-Polygonion, Arrhenatherion* and *Nardo strictae-Agrostion* alliances and it is hard to classify them to particular associations of these alliances. This has also been discussed by Ružičková (2002). Additional problems encountered were the multiple methods used in data collection, and different national syntaxonomical systems used to classify them, as well as the large time span of data collection.

In conclusion, our study supported the previous findings by Tichý (2014), Kuzemko (2016) and Zajac et al. (2016) that the semi-supervised method is an appropriate tool for vegetation syntaxonomical classification at the supra-national level.

Compositional variation – the most important environmental factors

DCA correlates the major compositional gradient primarily with altitude and precipitation, and this is consistent with the results of several other studies (Lososová et al. 2004; Bruelheide and Jandt 2007; Prach et al. 2007; Janišová et al 2010; Hanzlik and Gerowitt 2011; Pal et al. 2013; Škodová et al. 2015). The Polish and Slovak mountains have a more oceanic climate, with a relatively high rainfall, which could be unfavourable for the development of *Astrantio-Trisetetum flavescentis* and *Violo declinatae-Agrostietum capillaries* association. While communities with *Astrantia major* in Poland and Slovakia only occur on sites with specific ecological conditions induced by abandonment (Ružičková 1997; Zarzycki 2008), there is no existence of *Violo declinatae-Agrostietum capillaris* recorded in these countries. Distribution of this association appears to be concentrated predominantly in the more continental climate parts of the Ukraine Carpathians. However, EIJV for continentality was excluded from all analyses, because the study area (Fig. 1) is geographically limited to reflect its effect. By contrast, Hegedüšová and Senko (2011) declare that the main compositional gradient of Slovakian mountain hay meadows correlates with moisture and nutrient availability. Differences in opinion here may be due to different study area sizes and consequent specific geological substrata, soil and climatic conditions.

Plant species richness in mountain areas is generally considered to decrease with increasing altitude. This has also been discussed by Stevens (1992), Körner (2000), Theurillat et al. (2003) and

Boscutti et al. (2018). It clearly supports our results, where *Campanulo glomeratae-Geranietum sylvatici* is the most species-rich community and it occurs at a lower altitude contrary of the higher-altitude and significantly less species-rich *Alchemillo-Deschampsietum caespitosae*, *Geranio-Alchemilletum crinitae* and *Trollio altissimi-Knautietum dipsacifoliae* communities (Figs. 4 and 5). Moreover, precipitation increases with increasing altitude and annual mean temperature decreases, with the result that higher moisture and cooler temperatures at higher altitudes particularly influence soil properties, producing a general decrease in nutrients and pH with increasing altitude (Strong et al. 2011; Škodová et al. 2015; Zajac et al. 2016; Mardari et al. 2019). This implies that among the abiotic habitat conditions, nutrient content is also important for species richness in the studied grasslands. Nevertheless, it is obvious that the nutrient content may depend both on management and productivity (Poldini et al. 2011; Gillet et al. 2016; Brun et al. 2019) as well as on environmental factors.

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Author contributions

KH designed the study and compiled the manuscript; KH, IŠ, JK, JM, conducted the phytosociological sampling; KH and IŠ performed the statistical analyses; KH, JK, AS, GC, VB, AT and IC have provide unpublished relevés; JM has prepared maps; KH coordinated the manuscript compilation; IŠ, JK, AS and AK revised and completed some parts of manuscript and all the authors commented on the manuscript.

Declaration of interest statement

The authors declare that they have no conflict of interest.

Taxonomic references: The taxonomic nomenclature for vascular plants followed Euro+Med Plant Database (Euro+Med 2015) (http://ww2.bgbm.org/EuroPlusMed/query.asp). The names of missing taxa were according to Flora Europaea (Tutin et al. 1968-1993). The nomenclature of non-vascular plants was in accordance with Marhold and Hindák (1998). Narrowly defined species and subspecies which were not distinguished in the older literature or may have been incorrectly determined, were unified into a broader concept of species aggregates (agg., Supplement S1) according to Marhold and Hindák (1998).

Syntaxonomic reference: The nomenclature of syntaxa is unified as in Hegedüšová Vantarová and Škodová (2014).

Abbreviations: AMT – annual mean temperature, AP – annual precipitation, TAR – temperature annual range; DCA – Detrended Correspondence Analysis; AK – Anna Kuzemko, AS – Adrian Stoica, AT – Alla Tokaryuk, GC – Gheorghe Coldea, IC – Illya Chorney, IŠ – Iveta Škodová, JK – Joanna Korzeniak, JM – Jana Májeková, KH – Katarína Hegedüšová, VB – Vasyl Budzhak; PL – Poland; RO – Romania; SK – Slovakia; UA – Ukraine.

References

Aćić S, Šilc U, Lakušić D, Vukojičić S, Dajić Stevanović Z. 2013. Typification and correction of syntax from the class *Molinio-Arrhenatheretea* Tx. 1937 in Serbia. Hacquetia. 12(2):39–54.

Balázs F. 1939. A Kárpátok endemikus növényfajai [Endemic plant species of the Carpathians]. Acta Geobot Hung. 2:3–62. Hungarian.

Balcerkiewicz S. 1978. Vegetation of Polana Chochołowska (Chochołowska Clearing) in the West Tatras. In: Wojterski T, editor. Guide to the Polish International Excursion 1–20 June 1978. Uniwersytet im. Adama Mickiewicza w Poznaniu. Seria Biologia. 11:355–381.

Bálint M, Ujvárosi L, Theissinger K, Lehrian S, Mészáros N, Paulus SU. 2011. The Carpathians as a Major Diversity Hotspot in Europe, Chapter 11. In: Zachos FE, Habel JC, editors. Biodiversity Hotspots, Distribution and Protection of Conservation Priority Areas. Berlin, Heidelberg: Springer; p. 189–205.

Bělohlávková R. 1980. Rostlinná společenstva alpínského stupně Kriváňské Malé Fatry [Plant communities of the alpine Krivánska Malá Fatra Mts]. [dissertation]. Varín: Správa NP Malá Fatra. Slovak.

Björnsen-Gurung A, Bokwa A, Chełmicki W, Elbakidze M, Hirschmugl M, Hostert P, Ibisch P, Kozak J, Kuemmerle T., Matei E, et al. 2009. Global Change Research in the Carpathian Mountain Region. Mountain Res Developm. 29:282–288.

Boscutti F, Casolo V, Beraldo P, Braidot E, Zancani M, Rixen Ch. 2018. Shrub growth and plant diversity along analtitude gradient: Evidence of indirect effects of climate on alpine ecosystems. PLoS ONE. 13(4): e0196653.

Braun-Blanquet J. 1921. Principien einer Systematik der Pflanzengesellschaften auf floristischer Grundlage [Principles of a system of plant communities on floristic basis]. Jahrb St. Gallen Naturw Ges. 57: 305–351. German.

Braun-Blanquet J. 1964. Pflanzensoziologie. Grundzüge der Vegetationskunde [Plant sociology. Basics of vegetation science]. 3rd ed. Wien: Springer. German.

Brinkmann K, Reif A. 2006. Vegetation, landuse and landscape in the Apuseni Mountains, Romania. Bulletin of University of Agricultural Sciences and Veterinary Medicine Cluj-Napoca. 62:1–13.

Brinkmann K, Păcurar F, Reif A. 2009. Secondary succession and fluctuations in meadows of the Apuseni Mountains (Transylvania, Romania) under different fertilisation regimes. Transylvanian Review of Systematical and Ecological Research. 7:41–57.

Bruelheide H. 1995. Die Grünlandgesellschaften des Harzes und ihre Standortsbedingungen. Mit einem Beitrag zum Gliederungsprinzip auf der Basis von statistisch ermittelten Artengruppen [The grassland communities of the Harz Mts and their site conditions. With a contribution to the structure principle on the basis of statistically determined species groups]. Diss Bot. 244:1–338. German.

Bruelheide H, Jandt U. 2007. The relationship between dry grassland vegetation and micro-climate along a west-east gradient in Central Germany. Hercynia. 40:153–176.

Brun P, Zimmermann NE, Ghraham CH, Lavergne S, Pellissier L, Münkemüller T, Thuiller W. 2019. The productivity-biodiversity relationship varies across diversity dimensions. Nat Commun. 10:5691.

Budzhak VV, Chorney II, Tokariuk AI, Kuzemko AA. 2016. Numeric syntaxonomical analysis of communities of the *Molinia caerulea* complex in Southwestern of Ukraine. Hacquetia. 15(2):63–77.

Buia A, editor. 1962. Pajiştile din Masivul Parîng şi îmbunătăţirea lor [Grasslands from the Parâng Massif and methods of improvement]. Bucureşti: Edit. Agro-Silvică. Romanian.

Cankov C. 1974. The Bulgarian Carpathian-Balkan region. The Southern Carpathians. In: Maheľ M, editor. Tectonics of the Carpathian-Balkan regions. Bratislava: Veda; p. 303–307.

Chytrý M, editor. 2007. Vegetace České republiky 1. Travinná a keříčková vegetace [Vegetation of the Czech Republic 1. Grassland and Heathland Vegetation]. Praha: Academia. Czech.

Chytrý M, Otýpková Z. 2003. Plot sizes used for phytosociological sampling of European vegetation. J Veg Sci. 14:563–570.

Chytrý M, Tichý L. 2003. Diagnostic, constant and dominant species of vegetation classes and alliances of the Czech Republic: a statistical revision. Folia Fac Sci Nat Univ Masaryk Brun. 108:1–231.

Chytrý M, Tichý L, Holt J. 2006. The fidelity concept. In: Tichý L, Holt J, editors. JUICE, program for management, analysis and classification of ecological data. First part of the program manual. Brno: Vegetation Science Group, Masaryk University; p. 44–52.

Chytrý M, Tichý L, Holt J, Botta–Dukát Z. 2002. Determination of diagnostic species with statistical fidelity measures. J Veg Sci. 13:79–90.

Coldea Gh. 1991. Prodrome des associations végétales des Carpates du Sud-Est (Carpates Roumaines) [Prodrome of plant associations of the South-East Carpathians (Romanian Carpathians)]. Doc Phytosoc. 13:317–538. French.

Coldea Gh. 2003. The alpine flora and vegetation of the south-eastern Carpathians. In: Nagy L, Grabherr G, Körner C, Thompson DBA, editors. Alpine Biodiversity in Europe. Berlin: Springer; p. 65–72.

Coldea Gh, editor. 2012. Les associations végétales de Roumanie. 2. Les associations anthropogènes [The plant associations of Romania. 2. Anthropogenic associations]. Cluj: Presa Universitară Clujeană. French.

Coldea Gh, Stoica AI, Puşcaş M, Ursu T, Opera A, The IntraBioDiv Consortium. 2009. Alpine–subalpine species richness of the Romanian Carpathians and the current conservation status of rare species. Biodivers Conserv. 18:1441–1458.

De Cáceres M, Chytrý M, Agrillo E, Attore F, Botta-Dukát Z, Capelo J, Czúcz B, Dengler J, Ewald J, Faber-Langendoen D, et al. 2015. A comparative framework for broad-scale plot-based vegetation classification. Appl Veg Sci. 18:543–560.

Dengler J, Lobel S, Dolnik C. 2009. Species constancy depends on plot size – a problem for vegetation classification and how it can be solved. J Veg Sci. 20:754–766.

Dierschke H. 1997. *Molino-Arrhenatheretea* (E1). Kulturgrasland und verwandte Vegetationstypen. Teil 1: *Arrhenatherretalia*. Wiesen und Weiden frischer Standorte [*Molino-Arrhenatheretea* (E1). Cultivated grassland and related vegetation types. Part 1: *Arrhenatherretalia*. Meadows and pastures of fresh locations]. In: Dierschke H, editor. Synopsis der Pflanzengesellschaften Deutschlands 3 [Synopsis of the Plant Communities of Germany 3]. Göttingen; p. 1–74. German.

Dierschke H. 1981. Syntaxonomische Gliederung der Bergwiesen Mitteleuropas *Polygono–Trisetion* [Syntaxonomic structure of the mountain meadows of Central Europe *Triseto-Polygonion*]. In: Dierschke H, editor. Syntaxonomie. Ber Internat Symp IVV. Vaduz: Gantner Verlag Kommanditgesellschaf; p. 311–336. German.

Douda J, Boublík K, Slezák M, Biurrun I, Nociar J, Havrdová A, Doudová J, Aćić S, Brisse H, Brunet J, et al. 2016. Vegetation classification and biogeography of European floodplain forests and alder carrs. Appl Veg Sci. 19:147–163.

Dutoit D. 1924. Les associations végétales des sous-Alpes de Vevey (Suisse) [The plant associations of the sub-Alps of Vevey (Switzerland)] [dissertation]. Université de Lausanne. French.

Dúbravková D, Chytrý M, Willner W, Illyés E, Janišová M, Kállayné Szerényi J. 2010. Dry grasslands in the Western Carpathians and the northern Pannonian Basin: a numerical classification. Preslia. 82:165–221.

Dzubinová Ľ. 1978. Flóra a vegetácia Chránenej krajinnej oblasti Slovenský Raj [Flora and vegetation of Protected area Slovanský raj]. Biologické práce. XXIV(6):81–93. Slovak.

Dzubinová Ľ. 1984. Trávnaté a litorálne spoločenstvá Slovenského raja [Grasslands and litoral vegetation of Slovenský raj Mt.] [dissertation]. Bratislava: Prírodovedecká fakulta UK. Slovak.

Ellenberg H, Weber HE, Düll R, Wirth W, Werner W, Paulißen D. 1992. Zeigerwerte von Pflanzen in Mitteleuropa [Plant indicator values in Central Europe]. 2nd ed. Scripta Geobot. 18:1–258. German.

Ellmauer T. 1995. Nachweis und Variabilität einiger Wiesen- und Weidegesellschaften in Österreich [Detection and variability of some meadow and pasture communities in Austria]. Verh Zool-Bot Ges Österreich. 132:13–60. German.

Ellmauer T, Mucina L. 1993. *Molinio–Arrhenatheretea*. In: Mucina L, Grabher G, Ellmauer T, editors. Die Pflanzengesellschaften Osterreichs. Teil I [The plant communities of Austria. Part 1]. Jena: Gustav Fischer Verlag; p. 297–401. German.

Euro+Med. 2015. The Euro+Med PlantBase – the information resource for Euro-Mediterranean plant diversity. [accessed 2005 Dec 7]. http://ww2.bgbm.org/EuroPlusMed/.

Gillet F, Mauchamp L, Badot PM, Mouly A. 2016. Recent changes in mountain grasslands: a vegetation resampling study. Ecol Evol. 6(8): 2333–2345.

Hadač E, Březina P, Ježek V, Kubička J, Hadačová V, Vondráček M. 1969. Die Pflanzengesellschaften des Tales “Dolina Siedmich prameňov “in Belauer Tatra [The plant communities of the valley “Dolina Siedmich prameňov” in Belauer Tatra]. Vegetácia ČSSR, Ser. B. 2:1–343. German.

Hanzlik K, Gerowitt B. 2011. The importance of climate, site and management on weed vegetation in oilseed rape in Germany. Agric Ecosyst Environ. 141:323–331.

Hegedüšová K. 2007. Central database of phytosociological samples (CDF) in Slovakia (state to January 2007). Bull Slov Bot Spoloč. 29:124–129.

Hegedüšová K, Ružičková H. 2007. MAC *Polygono bistortae-Trisetion flavescentis*. In: Janišová M, editor. Travinnobylinná vegetácia Slovenska – elektronický expertný systém na identifikáciu syntaxónov [Grassland vegetation of Slovakia – electronic expert system for identification of syntaxa]. Bratislava: Botanický ústav SAV; p. 118–127. Slovak.

Hegedüšová K, Senko D. 2011. Successional changes of dry grasslands in southwestern Slovakia after 46 years of abandonment. Pl Biosyst. 145:666–687.

Hegedüšová K, Ružičková H, Senko D, Zuccarini P. 2011a. Plant communities of the montane mesophilous grasslands (*Polygono bistortae–Trisetion flavescentis* alliance) in central Europe: Formalized classification and syntaxonomical revision. Pl Biosyst. 146:1–16.

Hegedüšová K, Ružičková H, Janák M. 2011b. Mountain hay meadows. In: Šefferová Stanová V, Plassman Čierna M, editors. Management models for grassland habitats. Bratislava: DAPHNE – Institute of Applied Ecology; p. 16–17.

Hegedüšová Vantarová K. 2014. *Polygono bistortae-Trisetion flavescentis*. In: Hegedüšová Vantarová K, Škodová I, editors. Rastlinné spoločenstvá Slovenska. 5. Travinno-bylinná vegetácia [Plant communities of Slovakia 5. Grassland vegetation]. Bratislava: Veda; p. 252–268. Slovak.

Hegedüšová Vantarová K, Škodová I, editors. 2014. Rastlinné spoločenstvá Slovenska 5. Travinno-bylinná vegetácia [Plant communities of Slovakia 5. Grassland vegetation]. Bratislava: Veda.

Hennekens SM, Schaminée JHJ. 2001. TURBOVEG, a comprehensive data base management system for vegetation data. J Veg Sci. 12:589–591.

Hlásny T, Trombik J, Dobor L, Barcza Z, Barka I. 2016. Future climate of the Carpathians: climate change hot-spots and implications for ecosystems. Reg Environ Change. 16:1495–1506.

Hurdu BI. 2012. Floristic and phytogeographic characterisation of areas of endemism from the Romanian Carpathians [dissertation]. Cluj-Napoca: Babeş-Bolyai University.

Iakushenko D, Burlaka M, Chornei I, Kvakovska I, Solomakha V, Tokaryuka A. 2012. Syntaxonomy of subalpine tall-grass communities (*Calamagrostietalia villosae*) in the Ukrainian districts of the Eastern Carpathians. Ann Bot (Rome). 2:67–78.

Ioras F. 2003. Trends in Romanian biodiversity conservation policy. Biodivers Conserv. 12:9–23.

Janišová M, editor. 2007. Travinnobylinná vegetácia Slovenska – elektronický expertný systém na identifikáciu syntaxónov [Grassland vegetation of Slovakia – electronic expert system for identification of syntaxa]. Bratislava: Botanický ústav SAV. Slovak.

Janišová M, Uhliarová E, Hlásny T, Turisová I. 2010. Vegetation-environment relation-ships in grassland communities of central Slovakia. Tuexenia. 30:423–444.

Janišová M, Dengler J, Willner W. 2016. Classification of Palaearctic grasslands. Phytocoenologia. 46:233–239.

Jurko A. 1990. Ekologické a socioekonomické hodnotenie vegetácie [Ecological and socio-economic assessment of vegetation.]. Bratislava: Príroda. Slovak.

Kącki Z, Śliwiński M. 2012. Polish Vegetation Database. In: Dengler J, Oldeland J, Jansen F, Chytrý M, Ewald J, Finckh M, Glöckler F, Lopez-Gonzalez G, Peet RK, Schaminée JHJ, editors. Vegetation databases for the 21st century. Biodivers Ecol. 4:411.

Kadlečík J, editor. 2016. Carpathians hidden treasures. Banská Bystrica: Štátna ochrana prírody Slovenskej republiky.

Kliment J. 1994. Die *Triseto-Polygonion*-Gesellschaften in der Slowakei [The *Triseto-Polygonion* communities in Slovakia]. Preslia. 66:133–149. German.

Kliment J. 1999. Komentovaný prehľad vyšších rastlín flóry Slovenska, uvádzaných v literatúre ako endemické taxóny [Annotated survey of the vascular plants of Slovak flora recorded in literature as endemic taxa]. Bull Slov Bot Spoloč. 21, Suppl. 4:1–434. Slovak.

Kliment J, Turis P, Janišová M. 2016. Taxa of vascular plants endemic to the Carpathian Mts. Preslia. 88:19–76.

Knapp G, Knapp R. 1952. Über Goldhafer-Wiesen (*Trisetetum flavescentis*) im nördlichen Vorarlberg und im Oberallgäu [About Goldgrass Meadows (*Trisetetum flavescentis*) in northern Vorarlberg and Upper Allgäu.]. Landw Jahrb Bayern 29:239–256. German.

Knollová I, Chytrý M, Tichý L, Hájek O. 2005. Stratified resampling of phytosociological databases: some strategies for obtaining more representative data sets for classification studies. J Veg Sci. 16:479–486.

Kondracki J. 1978. Karpaty [*Carpathians*]. Warszawa: Wydawnictwa Szkolne i Pedagogiczne. Polish.

Kondracki J. 1989. Karpaty [*Carpathians*]. 2nd ed. Warszawa: Wydawnictwa Szkolne i Pedagogiczne. Polish.

Kornaś J. 1967. Montane hay-meadow *Gladiolo-Agrostietum* in the Polish Western Carpathians. – Contrib Bot. 1967:167–176.

Kornaś J, Medwecka-Kornaś A. 1967. Zespoły roślinne Gorców. I. Naturalne i na wpół naturalne zespoły nieleśne [Plant communities of the Gorce Mts. I. Natural and seminatural non-forest communities]. Fragm Florist Geobot. 13:167–316. Polish.

Korzeniak J. 2013a. 6520 Mountain Yellow trisetum and Bent-grass Hay meadows (*Triseto-Polygonion* and *Arrhenatherion*). In: Mróz W, editor. Monitoring of natural habitats. Methodological guide. Warszawa: GIOŚ; p. 55–67.

Korzeniak J. 2013b. Scope and data set of the phytosociological database 'Grasslands in the Polish Carpathians'. Acta Soc Bot Poloniae. 82:237–242.

Körner C. 2000. Why are there global gradients in species richness? Mountains might hold the answer. Trends Ecol Evol. 15:513–514.

Krahulec F, Blažková D, Balátová-Tuláčková E, Štursa J, Pecháčková S, Fabšičová M. 1996. Louky Krkonoš: rostlinná společenstva a jejich dynamika [Grasslands of the Krkonoše Mountains: plant communities and their dynamics]. Opera Corcontica. 33:1–250. Czech.

Kricsfalusy VV. 2013. Mountain grasslands of high conservation value in the Eastern Carpathians: syntaxonomy, biodiversity, protection and management. Thaiszia. 23:67–112.

Kuzemko AA. 2012. Ukrainian Grasslands Database. Biodivers Ecol. 4:430.

Kuzemko AA. 2016. Classification of the class *Molinio-Arrhenatheretea* in the forest and forest-steppe zones of Ukraine. Phytocoenologia. 46:241–256.

Lengyel A, Chytrý M, Tichý L. 2011. Heterogeneity-constrained random resampling of phytosociological databases. J Veg Sci. 22:175–183.

Lengyel A, Illyés E, Bauer N, Csiky J, Király G, Purger D, Botta-Dukát Z. 2016. Classification and syntaxonomical revision of mesic and semi-dry grasslands in Hungary. Preslia. 88:229–322.

Lososová Z, Chytrý M, Cimalová Š, Otýpková Z, Pyšek P, Tichý L. 2004. Weed vegetation of arable land in Central Europe: Gradients of diversity and species composition. J Veg Sci. 15:415–422.

Malynovskyy KA. 1980. Vysokohirna roslynnist' Ukrajins'kykh Karpat [Highland vegetation of the Ukrainian Carpathians]. Kyiv: Naukova Dumka. Ukrainian.

Malynovskyy KA, Mirkin BM, Ishbirdin AR, Komendar VI, Kricsfalusy VV. 1992. Syntaxonomy of riverside-aquatic, marsh, grassland, and shrub communities of the highland of the Ukrainian Carpathians. Ukr Bot J. 49:5–13.

Malynovskyy KA, Kricsfalusy VV. 2000. Visokohirna roslynnist' [Highland vegetation]. Kyiv: Phytosociocentr. Ukrainian.

Mardari C, Bîrsan C, Ştefanache C, Şchiopu R, Grigoraş V, Balaeş T, Dănilă D, Tănase C. 2019. Tuexenia. 39:401–421.

Marhold K, Hindák F, editors. 1998. Zoznam nižších a vyšších rastlín Slovenska [Checklist of Non-Vascular and Vascular Plants of Slovakia]. Bratislava: Veda. Slovak.

Marschall F. 1951. Beiträge zur Kenntnis der Goldhaferwiese (*Trisetetum flavescentis*) der Schweiz [Contributions to the knowledge of the golden oat meadow (*Trisetetum flavescentis*) of Switzerland]. Vegetatio. 3:195–209. German.

Matuszkiewicz W. 2008. Przewodnik do oznaczania zbiorowisk roślinnych Polski [A guide for identifying plant communities of Poland]. 3rd ed. Warszawa: Wydawnictvo Naukowe PWN. Polish.

Mihăilescu S. 2001. Flora și vegetația masivului Piatra Craiului [The flora and vegetation of Piatra Craiului massif]. București: Vergiliu. Romanian.

McCune B, Mefford MJ. 1999. PC–ORD. Multivariate analysis of ecological data. Version 4. Gleneden Beach: MjM Software Design.

Mráz P, editor. 2005. Chromosome number and DNA ploidy level reports from Central Europe 1. Biologia. 60:99–103.

Mráz P, Ronikier M. 2016. Biogeography of the Carpathians: evolutionary and spatial facets of biodiversity. Biol J Linn Soc. 119:528–559.

Mráz P, Gaudeul M, Rioux D, Gielly L, Choler Ph, Taberlet P, IntraBioDiv Consortium. 2007. Genetic structure of *Hypochaeris uniflora* (Asteraceae) suggests vicariance in the Carpathians and rapid post-glacial colonization of the Alps from an eastern Alpine refugium. J Biogeogr. 34:2100–2114.

Neblea MA. 2006. Flora si vegtaţia Munţilor Leaota şi a sectorului vestic al Munţilor Bucegi [The flora and vegetation of Leaota Mountains and the western sector of Bucegi Mountains] [dissertation]. Bucureşti: Institut de Biologie Bucureşti, Academia Romana. Romanian.

Oberdorfer E. 1957. Süddeutsche Pflanzengesellschaften [Plant Communities of Southern Germany]. Jena: Gustav Fischer. German.

Oberdorfer E, editor. 1983. Süddeutsche Pflanzengesellschaften. Teil III, Wirtschaftswiesen und Unkrautgesellschaften [Plant Communities of Southern Germany. Part III. Economic meadows and weed communities]. 2nd ed. Jena: Gustav Fischer Verlag. German.

Okasen J, Kindt R, Legendre P, O'Hara B. 2011. Vegan: Community Ecology Package. http://CRAN.R-project.org/package=vegan. R package version 2.0-0.

Ozenda P. 1985. La végétation de la chaine alpine dans l’espace montagnard européen [The vegetation of the alpine chain in the European mountain area]. Paris: Masson. French.

Pal WR, Pinke G, Botta-Dukát Z, Campetella G, Bartha S, Kalocsai R, Lengyel A. 2013. Can management intensity be more important than environmental factors? A case study along an extreme altitude gradient from Central Italian cereal fields. Pl Biosyst. 147:343–353.

Pawłowski B, Pawłowska S, Zarzycki K. 1960. Zespoły roślinne kośnych łąk połnocnej części Tatr i Podtatrza [Plant communities of hay meadows of the northern part of the Tatra Mountains and the Podtatrza]. Fragm Florist Geobot. 6:95–222. Polish.

Pawłowski B. 1969. Die Karpaten und die Sudeten – eine vergleichende pflanzengeographische Studie [The Carpathians and the Sudetes – a comparative plant geographic study]. Arch Naturschutz Landschaftsf. 9:251–263. German.

Pawłowski B. 1970. Remarques sur l’ endémisme dans la flore des Alpes et des Carpates [Remarks on endemism in the flora of the Alps and the Carpathians]. Vegetatio. 21:181–243. French.

Pax F. 1898. Grundzüge der Pflanzenverbreitung in den Karpathen. 1 [Main features of plant distribution in the Carpathians]. Leipzig: Wilhelm Engelmann. German.

Perzanowska J, Świerkosz K, Mróz W. 2004. Górskie łàki konietlicowe użytkowane ekstensywnie (*Triseto-Polygonion*) [Mountain Yellow Trisetum and Bent-grass Hay Meadows (*Triseto-Polygonion*)]. In: Herbich J, editor. Murawy, łàki, ziołorośla, wrzosowiska, zarośla. Poradniki ochrony siedlisk i gatunków Natura 2000 – podr´cznik metodyczny [Grasslands, meadows, tall-herbs, heathlands, shrublands. Manual of conservation of Natura 2000 habitats and species – methodological guide]. Warszawa: Ministerstwo Środowiska; p. 212–219. Polish.

Peter M, Edwards PJ, Jeanneret P, Kampmann D, Lüscher A. 2008. Changes over three decades in the floristic composition of fertile permanent grasslands in the Swiss Alps. Agric Ecosyst Environm. 125:204–212.

Pierce S, Luzzaro A, Ossola A, Cerabolini B. 2008. The use of species diversity and functional diversity as indicators of the environmental and economic value of subalpine herbaceous communities (Foppolo – Orobie Alps). In: La scienza della vegetazione per l'analisi e la gestione ambientale; Feb 27–29; Ravenna. Communication at the National Scientific Conference. http://dipbsf.uninsubria.it/botanica/UEVF_PROCs/2008_Pierce_et_al_SISV. pdf.

Poldini L, Sburlino G, Buffa G, Vidali M. 2011. Correlations among biodiversity, biomass and other plant community parameters using the phytosociological approach: A case study from the south-eastern Alps. Pl Biosyst. 145: 131–140.

Pozynych IS. 2012. Coenopopulations of plants that need protection in Carpathian part of Dnister River. Chornomorsij Botanichnij Žurnal. 8:329–334.

Prach K, Pyšek P, Jarošík V. 2007. Climate and pH as determinants of vegetation succession in Central European man-made habitats. J Veg Sci. 18:701–710.

Prots B, Kagalo A, editors. 2012. Catalogue of Habitat Types of the Ukrainian Carpathians and Transcarpathian Lowland. Lviv: Mercator.

Pruchniewicz D. 2017. Abandonment of traditionally managed mesic mountainmeadows affects plant species composition and diversity. Basic Appl Ecol. 20:10–18.

Pușcaru D, Pușcaru-Soroceanu E, Paucă A, Șerbănescu I, Beldie Al, Ștefureac Tr, Cernescu N, Saghin F, Crețu V, Lupan L, et al. 1956. Păşunile alpine din munții Bucegi [Alpine grasslands from the Bucegi]. Mountains Editura Academiei Republicii Populare Române. Romanian.

Raclaru P. 1967. Vegetația pajiștilor din masivul Rarău [The vegetation of grasslands from the Rarău massif]. București: Comunicări de Botanică. Romanian.

Rodríguez-Rojo MP, Fernández-González F, Tichý L, Chytrý M. 2014. Vegetation diversity of mesic grasslands (*Arrhenatheretalia*) in the Iberian Peninsula. Appl Veg Sci. 17:780–796.

Ronikier M. 2011. Biogeography of high-mountain plants in the Carpathians: An emerging phylogeographical perspective. Taxon. 60:373–389.

Rozbrojová Z, Hájek M, Hájek O. 2010. Vegetation diversity of mesic meadows and pastures in the West Carpathians. Preslia. 82:307–332.

Ruffini FL, Streifeneder T, Eiselt B. 2006. Implementing an International Mountain Convention: An Approach for the Delimitation of the Carpathian Convention Area. Bolzano: European Accademy of Bolzano Institute for Regional Development.

Rusek J. 1993. Air-Pollution-Mediated Changes in Alpine Ecosystems and Ecotones. Ecol Applic. 3:409–416.

Ružičková H. 1997. Horské lúky zväzu *Triseto-Polygonion* na SZ úpätí Belianskych Tatier v oblasti Javoriny a Podspádov [Mountain meadows of the alliance *Triseto-Polygonion* at the foot of the Belianske Tatry Mts in the area of the Javorina and Podspády]. Štúdie o Tatranskom Národnom Parku. 35:135–142. Slovak.

Ružičková H. 2001. Asociácia *Geranio sylvatici-Trisetetum* v Osturni – relikt intezívneho spôsobu využívania lúk v Spišskej Magure [Association *Geranio sylvatici-Trisetetum* in the village Osturňa – a relict of intensive grassland utilization in the Spišská Magura Mts]. Bull Slov Bot Spoloč. 23:171–178.

Ružičková H. 2002a. Plant communities of mesophilous meadows of the alliance *Arrhenatherion elatioris* W. Koch 1926 and *Triseto-Polygonion* Br.-Bl. et R. Tx. ex Marschall 1947 in Slovakia. The present state of their knowledge and distribution. Acta Fac Rer Natur Univ Comen. 41:125–131.

Ružičková H. 2002b. Species-rich meadows of the Starohorské vrchy Mts and the southeastern part of the Veľká Fatra Mts – relict of the extensive and semiintensive agriculture of the Central Western Carpatians. Biologia. 57:493–504.

Ružičková H. 2004. *Crepido mollis-Agrostietum* ass. nova and *Poo-Trisetetum* Knapp ex Oberd. 1957 – grassland associations in the N and E part of the Nízke Tatry Mts and their present species composition as the consequence of changes in grassland utilization. Thaiszia. 14:75–92.

Ružičková H. 2006. Zanikajúce senníkové lúky v Šípskej Fatre (Veľká Fatra, Hrboltová) [Extinction of the hay meadows in Šípská Fatra Mt. (Veľká Fatra Mts, Hrboltová village)]. Biosozológia. 4:1–9. Slovak.

Rybníček K, Rybníčková E. 2009. Precultural vegetation in the western foothills of the Kremnické vrchy Mts in central Slovakia and its transformation by man. Preslia. 81:423–437.

Sanda V, Popescu A, Doltu MI. 1977. Vegetaţia masivului Piatra craiului [The vegetation of the Piatra Craiului massif]. Muzeul Brukenthal – Studii şi Comunicări. Ştiintele Naturii. 21:115–212. Romanian.

Sanda V, Popescu A, Arcuş M. 1999: Revizia critic a comunitţilor de plante din România [A critical review of plant communities in Romania]. Constanţa: Tilia Press International. Romanian.

Slezák M, Hrivnák R, Petrášová A. 2014. Numerical classification of alder carr and riparian forests in Slovakia. Phytocoenologia. 44:283–308.

Smale CM, Wiser K. 2015. A Classification of the Geothermal Vegetation of the Taupo Volcanic Zone, New Zealand. In: Proceedings World Geothermal Congress 2015 Melbourne, Australia, April 19–25; p. 1–11.

Solomakha VA. 2008. Sintaksonomiya roslinnosti Ukrayini. Trete nablizheniya [Syntaxonomy of the vegetation of Ukraine. Third approximation]. Kyiv: Phytosociocentre. Ukrainian.

Solovyeva I, Nuppenau EA, Biro R, Larkham K. 2011. Traditional farming systems and transition pathways to sustainable agriculture: a comparative analysis of institutions and cooperation in Romanian and Ukrainian rural areas of the Carpathian Mountains. In: IASC Conference proceedings “Shared resources in a rapidly changing world, European regional conference of the International association for the study of the commons”; Sept 14–17; Plovdiv, Bulgaria; Digital Library of the Commons. p. 1–23.

Soó R. 1930. Vergleichende Vegetationsstudien – Zentralalpen-Karpathen-Ungarn – nebst kritischen Bemerkungen zur Flora der Westkarpathen [Comparative vegetation studies – Central Alps-Carpathian-Hungary – along with critical remarks on the flora of the Western Carpathians]. Veröff Geobot Inst Rübel. 6:237–322. German.

Soó R. 1933a. Analyse der Flora des historischen Ungarns. (Elemente, Endemismen, Relikte) [Analysis of the flora of historical Hungary. (Elements, endemisms, relics)]. A Magyar Biológiai Kutató Intézet Munkái. 6:173–194. German.

Soó R. 1933b. Floren- und Vegetationskarten des historischen Ungarns [Floral and vegetation maps of historical Hungary]. Debreceni Tisza István Tudományos társaság honismertetö bizottságának kiadványa 8(1931–1932):5–35. German.

Stancu ID. 2005. Flora si vegetatia Munţilor Râiosu şi Buda, Masivul Făgăraş [The flora and vegetation of Râiosu and Buda mountains, Făgăraș Massif]. University of Pitesti Publishing House. Romanian.

Starmühler W. 1995. Flora und Vegetation der Karpaten mit besonderer Berücksichtigung der Süd-Karpaten [Flora and vegetation of the Carpathians with special consideration of the Southern Carpathians]. Carinthia II.185/105:71–79. German.

Starmühler W, Mitka J. 2001. Systematics and chorology of *Aconitum* sect. *Napellus* (Ranunculaceae) and its hybrids in the Northern Carpathians and Forest Carpathians. Thaiszia. 10:115–136.

StatSoft Inc. 2013. Electronic statistics textbook. Tulsa: Statsoft. http://www.statsoft.com/text-24 book/stahme.html. [accessed 2018 09 29].

Stevens GC. 1992. The altitudeal gradient in altitudinal range: An extension of rapoport's latitudinal rule to altitude. Amer Naturalist. 140:893–911.

Strong CL, Boulter SL, Laidlaw MJ, Maunsell SC, Putland D, Kitching RL. 20011. The physical environment of an altitudinal gradient in the rainforest of Lamington National Park, southeast Queensland. Memoirs of the Queensland Museum. Nature. 55:251–270.

Šibík J. 2012. Slovak Vegetation Database. In: Dengler J, Oldeland J, Jansen F, Chytrý M, Ewald J, Finckh M, Glöckler F, Lopez-Gonzalez G, Peet RK, Schaminée JHJ, editors. Vegetation databases for the 21st century. Biodiv Ecol. 4:429.

Šibíková I, Šibík J, Hájek M, Kliment J. 2010. The distribution of arctic-alpine elements within high-altitude vegetation of the Western Carpathians in relation to environmental factors, life forms and phytogeography. Phytocoenologia. 40:189–203.

Škodová I, Janišová M, Hegedüšová K, Borsukevych L, Smatanová J, Kish R, Píš V. 2015. Sub-montane seminatural grassland communities in the Eastern Carpathians (Ukraine). Tuexenia. 35:355–380.

Šmilauer P, Lepš J. 2014. Multivariate Analysis of Ecological Data using Canoco 5. 2nd ed. Cambridge: Cambridge University Press.

Tasenkevich L. 2004. Regional'nyj fitoheografičnyj podil Karpat [Regional phytogeographical division of the Carpathians]. Naukovi Zapiski Derzhavnovo Pryrodoznavgoho Muzeu. 19:29–39. Ukrainian.

Tasenkevich L. 2005. Regional phytogeographical division of the Carpathians. Roczniki Bieszczadzkie. 13:15–28.

Tasenkevich L. 2011. Endemism in the Carpathian flora – a chorological aspect. In: Zemanek B, editor. Geobotanist and taxonomist. A volume dedicated to Professor Adam Zając on the 70th aniversary of his birth; Krakow: Institute of Botany Jagellonian University. p. 157–168.

Tasenkevich L. 2014. Endemizm flory Karpat – ekolohični ta chorolohični osoblyvosti [Endemism of the Carpathians' flora – ecological and chorological peculiarities]. Pratsi Naukovoho Tovarystva im. Shevchenka. 39:22–36. Ukrainian.

Terzi M. 2015. Numerical analysis of the order *Scorzoneretalia villosae*. Phytocoenologia. 45:11–32.

Theurillat JP, Schlüssel A, Geissler P, Guisan A, Velluti C, Wiget L. 2003. Vascular Plant and Bryophyte Diversity along Altitude Gradients in the Alps. In: Nagy L, Grabherr G, Körner C, Thompson DBA, editors. Alpine Biodiversity in Europe. Ecol Stud Analysis Synth. 167:185–193.

Tichý L. 2002. JUICE, software for vegetation classification. J Veg Sci. 13:451–453.

Tichý L, Chytrý M. 2006. Statistical determination of diagnostic species for site group of unequal size. J Veg Sci. 17:809–818.

Tichý L, Chytrý M, Botta-Dukát Z. 2014. Semi-supervised classification of vegetation: preserving the good old units and searching for new ones. J Veg Sci. 25:1504–1512.

Tutin TG, Heywood VH, Burges NA, Moore DM, Valentine DH, Walters SM, Webb DA, editors. 1968–1993. Flora Europaea. Cambridge: Cambridge University Press.

Uziak S. 1964. The typology of more important soils of the Flysch Carpathian Mountains. Roczniki Gleboznawcze. Soil Sci Ann.14:205–212.

Vadel Ľ, Dražil T. 2015. Vegetation characteristics of species-rich grasslands in the National Park Slovenský raj, Slovakia. Folia Oecol. 42:54–66.

Van Der Maarel E. 1975. The Braun-Blanquet approach in perspective. Pl Ecol. 30:213–219.

Vasilev K, Ruprecht E, Alexiu V, Becker T, Beldean M, Biță-Nicolae C, Csergő AM, Dzhovanova I, Filipova E, Frink JP, et al. 2018. The Romanian Grassland Database (RGD): Historical background, current status and future perspectives. Phytocoenologia. 48:91–100.

Webster R, Holt S, Avis Ch. 2001. The status of the Carpathians. Vienna: WWF.

Westhoff V, Van Der Maarel E. 1973. The Braun-Blanquet approach. In: Whittaker RH, editor. Ordination and classification of communities. The Hague: Junk. p. 617–726.

Willner W, Kuzemko A, Dengler J, Chytrý M, Bauer N, Becker T, Biţă-Nicolae C, Botta-Dukát Z, Čarni A, Csiky J, et al. 2017. A higher-level classification of the Pannonian and western Pontic steppe grasslands (Central and Eastern Europe). Appl Veg Sci. 20:143–158.

Willner W, Roleček J, Korolyuk AY, Dengler J, Chytrý M, Janišová M, Lengyel A, Aćić S, Becker T, Ćuk M, et al. 2019. Formalized classification of the semi-dry grasslands of central and eastern Europe. Preslia. 91:25–49.

Winnicki T. 1999. Zbiorowiska roślinne połonin Bieszczadzkiego Parku Narodowego (Bieszczady Zachodnie, Karpaty Wschodnie) [Plant communities of subalpine meadows (poloninas) in the Bieszczady National Park (Western Bieszczady Mts, Eastern Carpathians]. Monografie Bieszczadzkie. 4:1–215. Polish.

Wiser SK, De Cáceres M. 2013. Updating vegetation classifications: an example with New Zealand's woody vegetation. J Veg Sci. 24:80–93.

Wiser SK, De Cáceres M. 2018. New Zealand's plot-based classification of vegetation. Phytocoenologia. 48:153–161.

Wiser SK, Thomson FJ, De Cáceres M. 2015. Expanding an existing classification of New Zealand vegetation to include non-forested vegetation. New Zealand J Ecol. 40:160–178.

Witkowski JZ, editor. 2003. Carpathian List of Endangered Species. Kraków: EUROPRESS.

Wojterski TW, editor. 1978. Guide to the Polish international excursion. Uniwersytet im. Adama Mickiewicza w Poznaniu. Seria Biologia 11. Poznań: Polish Assembly.

Zanoschi V. 1971. Flora și vegetația masivului Ceahlău [The flora and vegetation of the Ceahlău massif] [dissertation]. Cluj-Napoca: Universitatea Cluj-Napoca. Romanian.

Zajac M, Ujházy K, Škodová I, Kuzemko A, Borsukevych L, Danylyuk K, Duchoň M, Figura T, Kish R., Smatanová J, et al. 2016. Classification of semi-natural mesic grasslands in the Ukrainian Carpathians. Phytocoenologia. 46:257–293.

Zarzycki J. 2008. Roślinnośćłąkowa pasma Radziejowej (Beskid Sądecki) i czynniki wpływające na jej zróżnicowanie [Grassland vegetation of the Radziejowa Range (Beskid Sądecki Mts) and the factors contributing to its diversity.]. Zeszyty Naukowe AR w Krakowie. 325:1–113. Polish.

Table 1. Syntaxonomical affiliation of the associations of Carpathian *Triseto-Polygonion* alliance combined with the list of occurrence and number of relevés in each syntaxon. SK – Slovakia, PL – Poland, UA – Ukraine, RO – Romania.

Cluster No.	Syntaxonomical affiliation	Country code (No. of Relevés)
	Molinio-Arrhenatheretea R. Tx. 1937 em. 1970	
	Poo alpinae-Trisetetalia Ellmauer et Mucina 1993	
	Polygono bistortae-Trisetion flavescentis Br.-Bl. et R. Tx. ex Marshall 1947	
1.	*Campanulo glomeratae-Geranietum sylvatici* Ružičková 2002	SK (46), PL (1), UA (1)
2.	*Geranio sylvatici-Trisetetum flavescentis* Knapp ex Oberd. 1957	SK (36), PL (6), RO (1)
3.	*Crepido mollis-Agrostietum capillaris* Ružičková 2004	SK (84), PL (30)
4.	*Geranio-Alchemilletum crinitae* Hadač et al. 1969	SK (133), PL (11), UA (1)
5.	*Alchemillo-Deschampsietum caespitosae* Hadač et al. 1969	SK (43), PL (22), UA (10), RO (15)
6.	*Phyteumo (orbicularis)-Trifolietum pratensis* Balcerk. 1978	SK (23), PL (14)
7.	*Astrantio-Trisetetum flavescentis* Knapp et Knapp ex Oberd. 1957	SK (6), PL (13), UA (2), RO (49)
8.	*Violo declinatae-Agrostietum capillaris* ass. nova	UA (40)
9.	*Trollio altissimi-Knautietum dipsacifoliae* Winnicki 1999	PL (27)

Table 2: Shortened synoptic table of *Triseto-Polygonion* alliance based on the semi-supervised classification. Percentage frequency and modified fidelity index *phi* coefficient (as upper index) are displayed. Diagnostic species (DS) of particular clusters are ranked by decreasing frequency to each cluster. Diagnostic species (DS) with fidelity value equal or higher than 0.20 and frequency value equal or higher than 0.20 (Fisher's exact test p <0.001) are on a grey background. Only species with frequency ≥ 10% were included to the "Other abundant species". *Crocus vernus* subsp. *vernus* – *Crocus *vernus*, *Dianthus barbatus* subsp. *compactus* – *Dianthus *compactus*, *Hieracium flagellare* subsp. *flagellare* – *Hieracium *flagellare*, *Ranunculus polyanthemos* subsp. *nemorosus* – *Ranunculus *nemorosus*, *Sesleria sadlerana* subsp. tatrae – Sesleria *tatrae.

Group No.	1	2	3	4	5	6	7	8	9
Association	Cg-Gs	Gs-Tf	Cm-Ac	G-Ac	A-Dc	Po-Tp	A-Tf	Vd-Ac	Ta-Kd
No. of relevés	48	43	114	143	90	37	70	40	27
Avverage no. of species per relevés	67	39	46	33	27	46	41	39	26
Polygono-Trisetion									
Geranium sylvaticum	83 $^{28.4}$	91 $^{33.7}$	25 ---	99 $^{39.3}$	41 ---	8 ---	10 ---	28 ---	7 ---
Pimpinella major	79 $^{32.4}$	44 ---	21 ---	49 $^{10.0}$	13 ---	22 ---	53 ---	38 ---	---
Campanula serrata	79 $^{29.5}$	9 ---	16 ---	57 $^{13.6}$	28 ---	24 ---	20 ---	80 $^{30.1}$	33 ---
Heracleum sphondylium	42 ---	58 ---	31 ---	62 $^{15.3}$	20 ---	11 ---	30 ---	78 $^{26.3}$	37 ---
*Crocus *vernus*	33 $^{17.0}$	35 $^{18.5}$	18 ---	1 ---	16 ---	27 ---	13 ---	---	---
Phyteuma spicatum	31 ---	72 $^{35.0}$	53 $^{19.6}$	26 ---	18 ---	24 ---	11 ---	---	15 ---
Astrantia major	23 ---	7 ---	22 ---	40 ---	11 ---	22 ---	100 $^{38.4}$	92 $^{33.1}$	96 $^{35.7}$
Arabidopsis halleri	17 ---	51 ---	51 $^{14.3}$	9 ---	29 ---	54 $^{16.7}$	23 ---	2 ---	52 ---
Trollius europaeus	8 ---	9 ---	13 ---	31 ---	4 ---	16 ---	50 $^{19.3}$	92 $^{46.8}$	56 ---
DS *Campanulo glomeratae-Geranietum sylvatici*									
Tragopogon pratensis agg.	88 $^{46.5}$	19 ---	35 ---	22 ---	---	46 ---	20 ---	10 ---	15 ---
Silene vulgaris	75 $^{55.4}$	7 ---	4 ---	3 ---	6 ---	8 ---	10 ---	8 ---	30 ---
Dianthus carthusianorum agg.	73 $^{59.6}$	2 ---	11 ---	13 ---	---	24 ---	1 ---	2 ---	---
Knautia arvensis agg.	73 $^{40.9}$	19 ---	34 ---	13 ---	2 ---	30 ---	29 ---	18 ---	---
Galium mollugo agg.	69 $^{34.9}$	30 ---	31 ---	25 ---	2 ---	35 ---	31 ---	---	7 ---
Arrhenatherum elatius	60 $^{45.4}$	26 ---	18 ---	3 ---	---	22 ---	4 ---	---	---
Trifolium montanum	54 $^{37.4}$	---	26 $^{10.3}$	8 ---	---	32 ---	10 ---	10 ---	---
Polygala vulgaris	48 $^{31.4}$	12 ---	25 $^{8.7}$	3 ---	1 ---	19 ---	21 ---	12 ---	---
Potentilla heptaphylla	46 $^{54.6}$	2 ---	3 ---	---	---	11 ---	---	---	---
Anthyllis vulneraria	46 $^{31.3}$	9 ---	18 ---	5 ---	---	30 ---	13 ---	10 ---	---
Sanguisorba minor	44 $^{46.9}$	2 ---	6 ---	---	---	16 ---	3 ---	---	---
Lilium bulbiferum	40 $^{34.7}$	2 ---	1 ---	---	---	3 ---	1 ---	---	---
Fragaria vesca	35 $^{33.2}$	7 ---	10 ---	3 ---	4 ---	3 ---	1 ---	15 ---	---
Arabis hirsuta agg.	21 $^{29.5}$	2 ---	---	1 ---	---	11 ---	3 ---	---	---
Salvia pratensis	21 $^{28.3}$	2 ---	4 ---	1 ---	---	11 ---	1 ---	---	---
Aquilegia vulgaris	19 $^{26.7}$	---	9 ---	1 ---	---	5 ---	1 ---	---	---
DS *Geranio sylvatici-Trisetetum flavescentis*									
Silene flos-cuculi	2 ---	67 $^{56.5}$	28 $^{15.4}$	8 ---	3 ---	5 ---	3 ---	2 ---	---
Alopecurus pratensis	2 ---	58 $^{46.0}$	19 ---	10 ---	22 ---	5 ---	3 ---	2 ---	---
Myosotis scorpioides agg.	10 ---	53 $^{20.2}$	35 ---	21 ---	19 ---	38 ---	27 ---	32 ---	15 ---
Anthriscus sylvestris	6 ---	35 $^{41.8}$	5 ---	1 ---	---	---	9 ---	---	---
Bellis perennis	2 ---	26 $^{28.9}$	---	---	2 ---	16 ---	9 ---	---	---
DS *Crepido mollis-Agrostietum capillaris*									
Crepis mollis	33 ---	40 ---	89 $^{43.8}$	55 $^{17.8}$	11 ---	38 ---	16 ---	---	---
Luzula campestris agg.	40 ---	53 ---	68 $^{27.1}$	17 ---	21 ---	38 ---	30 ---	25 ---	---

DS *Geranio-Alchemilletum crinitae*									
Geum rivale	4	14	19	45 [illegible]	12	14	10	2	15
*Ranunculus *nemorosus*	8	2	8	38 $^{25.1}$	18	3	3	8	37
Viola biflora		2		35 [illegible]	14				
Soldanella carpatica	4	2	4	27 [illegible]	17		1		
Cirsium eriophorum	2		2	22 [illegible]	10	5	1		
DS *Alchemillo-Deschampsietum caespitosae*									
Phleum alpinum		5	7	5	43 [illegible]	8	1	2	
Bistorta officinalis		16	7	21	37 $^{29.5}$	11	3	2	
Rumex alpinus			1	1	20 [illegible]	5			
Carex leporina		2	8	1	20 [illegible]				
DS *Phyteumo (orbicularis)-Trifolietum pratensis*									
Trifolium pratense	73	77	74 [illegible]	43	23	97 [illegible]	69	22	4
Phyteuma orbiculare	29	5	16	13	6	89 [illegible]	4	2	
Poa alpina	4		3	4	12	35 $^{40.5}$	1		
Thymus pulcherrimus	2			3	6	22 [illegible]			
Polygala amara agg.	6		2	1	1	22 [illegible]	3		
Campanula rotundifolia agg.	4		4	5	7	22 [illegible]			
Silene dioica	10	12	4	3	8	22 [illegible]	1	8	
Pilosella lactucella				1		19 $^{40.5}$			
Carex flacca			4	3		19 [illegible]	4		
Ranunculus breyninus				1	2	19 [illegible]		5	
DS *Astrantio-Trisetetum flavescentis*									
Cynosurus cristatus	12	19	17	5	2	38	59 [illegible]	25	
Viola dacica	2	2					21 [illegible]		19
DS *Violo declinatae-Agrostietum capillaris* ass. nova									
Angelica sylvestris	4	5	4	5			4	65 [illegible]	11
Lotus ucrainicus					1		1	55 [illegible]	
Trifolium alpestre	2		1		1		4	55 [illegible]	
Stachys officinalis	4		4	3		5	10	48 [illegible]	
Centaurea jacea	2	7	19	1	4	3	16	45 $^{38.7}$	7
Hieracium umbellatum							1	40 [illegible]	7
Trifolium pannonicum							4	38 [illegible]	
Galium verum agg.	2	2	12	1	6	8	6	38 [illegible]	
Stachys alpina	2				1			28 [illegible]	
Cyanus mollis					1		1	25 [illegible]	11
Achillea carpatica					4		1	22 $^{39.1}$	
Viola declinata					10 [illegible]			22 [illegible]	
DS *Trollio altissimi-Knautietum dipsacifoliae*									
Knautia dipsacifolia = maxima	23		7	28 [illegible]	9		3	20	100 [illegible]
Poa chaixii	8	5	41 [illegible]	34	20	8	6	8	63 [illegible]
Carex pilosa									56 [illegible]
Aposeris foetida					3		17 $^{10.1}$	5	56 $^{57.5}$
Filipendula ulmaria	2	9	4	6	2		4	25 [illegible]	56 [illegible]
Gentiana asclepiadea	2	7	17	16	2	3	16	2	48 [illegible]
Trifolium medium agg.	12	2	18 [illegible]	4	1	3	10	5	44 [illegible]
Cirsium waldsteinii									33 [illegible]
Centaurea kotschyana	2						1	15 $^{14.0}$	33 $^{41.5}$
Veratrum album	4	2	4	10	7	3	3		33 [illegible]
Aconitum lasiocarpum									30 [illegible]
Tussilago farfara	4	5	3	3		3	1		30 [illegible]

Crepis paludosa	---	---	4 ---	3 ---	4 ---	---	14 ---	8 ---	30 31.4
Geranium palustre	---	---	---	---	---	---	---	---	26 40.7
Lathyrus laevigatus	---	---	---	---	---	---	---	---	19 41.0
Diagnostic species common for two or more associations									
Colchicum autumnale	83 41.5	12 ---	38 ---	13 ---	2 ---	57 20.9	60 23.4	2 ---	---
Campanula glomerata agg.	100 47.5	2 ---	5 ---	27 ---	12 ---	14 ---	33 ---	80 32.7	48 ---
Trisetum flavescens	85 22.4	98 30.9	40 ---	34 ---	8 ---	32 ---	80 18.4	28 ---	81 19.4
Centaurea phrygia agg.	71 31.4	23 ---	28 ---	13 ---	7 ---	41 ---	60 23.1	25 ---	4 ---
Plantago media	56 23.0	19 ---	31 ---	6 ---	6 ---	78 40.8	37 ---	12 ---	---
Linum catharticum	48 22.9	5 ---	13 ---	2 ---	---	62 33.4	37 13.6	25 ---	---
Cirsium erisithales	42 21.6	2 ---	12 ---	17 ---	4 ---	22 ---	44 24.0	20 ---	---
Rumex acetosa	58 ---	91 32.8	74 20.7	17 ---	10 ---	59 ---	67 16.1	25 ---	---
Campanula patula	40 ---	77 30.2	76 29.6	13 ---	12 ---	41 ---	37 ---	28 ---	---
Crepis biennis	27 ---	42 21.5	8 ---	1 ---	---	11 ---	34 14.6	42 22.1	---
Deschampsia cespitosa	4 ---	21 ---	46 ---	76 24.2	100 41.2	32 ---	10 ---	18 ---	74 ---
Rumex arifolius	10 ---	7 ---	17 ---	65 33.0	49 22.5	5 ---	17 ---	12 ---	26 ---
Jacobaea subalpina	2 ---	30 ---	21 ---	64 37.5	50 25.1	19 ---	3 ---	---	---
Lathyrus pratensis	60 16.1	37 ---	39 ---	32 ---	10 ---	14 ---	11 ---	70 23.1	70 23.3
Tanacetum corymbosum	44 14.5	---	18 ---	22 ---	7 ---	19 ---	7 ---	65 29.4	70 33.5
*Dianthus *compactus*	---	---	---	---	2 ---	---	1 ---	32 35.7	26 26.5
Other abundant species with frequency ≥ 10% in at least one cluster									
Alchemilla spec. div.	83 ---	95 ---	95 ---	100 14.3	90 ---	84 ---	87 ---	42 ---	96 ---
Agrostis capillaris	73 ---	67 ---	100 20.4	80 ---	69 ---	59 ---	73 ---	82 ---	70 ---
Hypericum maculatum	71 ---	58 ---	89 13.6	90 13.6	74 ---	41 ---	80 ---	62 ---	85 ---
Achillea millefolium agg.	83 ---	70 ---	79 ---	55 ---	64 ---	84 ---	66 ---	65 ---	70 ---
Cruciata glabra	94 22.1	81 ---	91 20.3	63 ---	32 ---	51 ---	43 ---	65 ---	52 ---
Festuca rubra agg.	73 ---	49 ---	93 44.7	49 ---	56 ---	78 ---	73 ---	45 ---	41 ---
Veronica chamaedrys agg.	54 ---	88 21.6	81 16.4	49 ---	56 ---	68 ---	66 ---	38 ---	22 ---
Ranunculus acris	56 ---	88 24.1	95 20.6	27 ---	48 ---	84 20.6	70 ---	15 ---	7 ---
Primula elatior	67 ---	28 ---	64 ---	72 12.6	30 ---	86 22.9	46 ---	18 ---	78 ---
Lotus corniculatus agg.	83 26.5	40 ---	60 7.5	37 ---	4 ---	51 ---	74 19.4	65 12.1	4 ---
Taraxacum sect. *Ruderalia*	52 ---	81 33.4	31 ---	15 ---	24 ---	54 ---	56 24.5	8 ---	4 ---
Carlina acaulis	85 39.3	9 ---	45 8.7	19 ---	8 ---	51 ---	34 ---	42 ---	4 ---
Leucanthemum vulgare agg.	83 21.3	65 ---	81 19.4	28 ---	13 ---	59 ---	80 16.9	70 ---	---
Anthoxanthum odoratum agg.	69 ---	84 22.6	74 15.7	23 ---	37 ---	59 ---	70 13.0	45 ---	4 ---
Leontodon hispidus	92 20.4	72 ---	54 ---	42 ---	31 ---	84 [illegible]	54 ---	38 ---	---
Dactylis glomerata agg.	85 24.5	74 16.7	61 ---	36 ---	11 ---	68 ---	53 ---	65 ---	4 ---
Stellaria graminea	46 ---	56 ---	75 21.1	36 ---	30 ---	32 ---	67 15.6	62 ---	---
Trifolium repens	58 ---	86 25.6	68 13.4	15 ---	30 ---	86 23.9	74 17.3	30 ---	---
Briza media	81 23.9	30 ---	68 19.4	26 ---	8 ---	89 29.5	40 ---	52 ---	33 ---
Luzula luzuloides	33 ---	16 ---	62 17.6	45 ---	42 ---	19 ---	19 ---	30 ---	74 20.4
Vicia cracca agg.	69 21.7	51 ---	64 10.3	31 ---	6 ---	35 ---	54 ---	25 ---	15 ---
Potentilla aurea	25 ---	21 ---	43 ---	48 14.9	64 27.4	38 ---	14 ---	5 ---	4 ---
Schedonorus pratensis	62 17.0	47 ---	43 ---	19 ---	17 ---	57 ---	59 19.1	45 ---	4 ---
Rhinanthus minor	42 ---	40 ---	61 16.6	12 ---	4 ---	70 23.7	51 ---	60 10.4	---
Plantago lanceolata	65 20.6	44 ---	61 10.3	4 ---	3 ---	57 ---	61 10.3	32 ---	---
Carum carvi	52 ---	56 15.6	46 8.0	10 ---	18 ---	59 10.3	50 11.3	22 ---	---
Potentilla erecta	25 ---	21 ---	63 22.3	10 ---	11 ---	38 ---	30 ---	50 ---	52 ---
Prunella vulgaris	56 17.4	30 ---	39 ---	11 ---	11 ---	62 21.6	56 16.6	30 ---	4 ---
Cerastium fontanum agg.	38 ---	51 ---	38 ---	16 ---	30 ---	46 ---	40 ---	10 ---	---
Thymus pulegioides	62 24.9	14 ---	39 ---	14 ---	7 ---	51 ---	27 ---	52 17.2	4 ---

Poa pratensis agg.	62 [illegible]	19 ---	40 [illegible]	12 ---	24 ---	43 ---	29 ---	5 ---	---
Phleum pratense	21 ---	49 [illegible]	33 ---	9 ---	6 ---	30 ---	23 ---	60 [illegible]	---
Carex pallescens	23 ---	16 ---	40 $^{13.3}$	8 ---	8 ---	27 ---	23 ---	32 ---	41 ---
Vicia sepium	35 ---	44 [illegible]	32 ---	29 ---	10 ---	---	4 ---	2 ---	4 ---
Ranunculus polyanthemos	46 [illegible]	5 ---	31 [illegible]	8 ---	7 ---	14 ---	26 ---	42 [illegible]	---
Chaerophyllum hirsutum	4 ---	16 ---	16 ---	26 ---	24 ---	3 ---	20 ---	5 ---	33 ---
Gymnadenia conopsea	23 ---	9 ---	23 ---	6 ---	1 ---	30 ---	26 ---	40 [illegible]	4 ---
Nardus stricta	12 ---	12 ---	31 [illegible]	8 ---	20 ---	3 ---	7 ---	2 ---	---
Ajuga reptans	31 $^{19.3}$	9 ---	25 $^{12.3}$	6 ---	1 ---	16 ---	10 ---	10 ---	7 ---
Poa trivialis	4 ---	35 [illegible]	18 ---	9 ---	9 ---	11 ---	19 ---	---	---
Pimpinella saxifraga agg.	6 ---	14 ---	29 [illegible]	1 ---	---	16 ---	14 ---	28 ---	---
Galium pumilum agg.	33 [illegible]	5 ---	4 ---	15 ---	16 ---	30 ---	1 ---	---	---
Ranunculus auricomus agg.	10 ---	30 [illegible]	25 [illegible]	4 ---	---	38 [illegible]	4 ---	---	---
Rhinanthus angustifolius	21 ---	9 ---	18 ---	3 ---	1 ---	14 ---	26 [illegible]	---	11 ---
Cardamine pratensis agg.	10 ---	12 ---	11 ---	17 ---	13 ---	3 ---	4 ---	---	---
Avenula pubescens	21 ---	16 ---	19 [illegible]	7 ---	1 ---	16 ---	1 ---	15 ---	---
Ranunculus repens	---	19 ---	13 ---	8 ---	22 [illegible]	5 ---	10 ---	---	---
Euphrasia rostkoviana agg.	17 ---	5 ---	14 ---	1 ---	1 ---	14 ---	21 [illegible]	25 ---	---
Vaccinium myrtillus	2 ---	2 ---	10 ---	20 [illegible]	12 ---	---	3 ---	---	11 ---
Veronica officinalis	8 ---	7 ---	21 $^{18.8}$	4 ---	14 ---	14 ---	4 ---	---	---
Ligusticum mutellina	---	2 ---	1 ---	18 [illegible]	18 ---	19 ---	3 ---	---	---
Pilosella aurantiaca	2 ---	5 ---	8 ---	1 ---	20 [illegible]	8 ---	19 ---	8 ---	4 ---
Senecio nemorensis agg.	---	2 ---	1 ---	21 [illegible]	14 ---	---	1 ---	2 ---	15 ---
Traunsteinera globosa	8 ---	7 ---	15 ---	5 ---	1 ---	3 ---	14 ---	15 ---	---
Viola tricolor	23 [illegible]	9 ---	16 ---	1 ---	2 ---	11 ---	10 ---	2 ---	---
Phleum hirsutum	23 $^{25.8}$	---	3 ---	17 $^{18.4}$	8 ---	3 ---	---	---	---
Chaerophyllum aromaticum	6 ---	19 ---	10 ---	7 ---	7 ---	---	7 ---	5 ---	---
Helictochloa planiculmis	2 ---	---	1 ---	17 [illegible]	12 ---	3 ---	---	15 ---	---
Viola canina	19 ---	---	16 [illegible]	1 ---	---	8 ---	10 ---	12 ---	---
Luzula sylvatica	---	---	4 ---	17 [illegible]	12 ---	---	1 ---	2 ---	7 ---
Parnassia palustris	8 ---	2 ---	5 ---	7 ---	8 ---	8 ---	10 ---	12 ---	---
Neottia ovata	10 ---	9 ---	12 ---	2 ---	1 ---	14 ---	7 ---	12 ---	---
Medicago lupulina	27 [illegible]	9 ---	1 ---	---	---	16 ---	19 [illegible]	8 ---	---
Achillea distans agg.	2 ---	---	6 ---	12 ---	6 ---	3 ---	13 ---	---	---
Myosotis sylvatica agg.	4 ---	2 ---	4 ---	14 [illegible]	12 ---	---	---	---	---
Crepis conyzifolia	6 ---	2 ---	8 ---	8 ---	2 ---	---	1 ---	20 ---	15 ---
Phleum rhaeticum	2 ---	2 ---	1 ---	11 ---	16 $^{17.8}$	5 ---	6 ---	---	---
Avenella flexuosa	---	2 ---	14 [illegible]	8 ---	4 ---	3 ---	3 ---	---	---
Geranium phaeum	10 ---	12 ---	3 ---	9 ---	7 ---	---	---	5 ---	---
Calamagrostis arundinacea	---	---	2 ---	10 ---	9 ---	---	---	10 ---	19 ---
Scabiosa lucida	2 ---	---	5 ---	10 ---	3 ---	5 ---	4 ---	10 ---	---
Agrostis stolonifera agg.	2 ---	---	3 ---	15 [illegible]	7 ---	---	1 ---	---	---
Epilobium alpestre	---	2 ---	---	14 $^{20.1}$	11 ---	3 ---	1 ---	---	---
Taraxacum species	2 ---	5 ---	19 [illegible]	---	---	14 ---	3 ---	---	---
Campanula persicifolia	---	2 ---	15 [illegible]	4 ---	4 ---	5 ---	1 ---	2 ---	---
Homogyne alpina	---	---	1 ---	17 [illegible]	6 ---	3 ---	1 ---	---	---
Carex caryophyllea	12 ---	2 ---	11 ---	2 ---	---	14 ---	6 ---	---	---
Gladiolus imbricatus	6 ---	9 ---	11 ---	1 ---	---	8 ---	9 ---	2 ---	---
Pilosella officinarum	4 ---	2 ---	14 [illegible]	1 ---	2 ---	14 ---	4 ---	---	---
Botrychium lunaria	2 ---	2 ---	13 [illegible]	7 ---	1 ---	8 ---	---	---	---
Cirsium arvense	4 ---	7 ---	10 ---	3 ---	2 ---	5 ---	7 ---	2 ---	---

Hypochaeris uniflora	4 ---	---	10 ---	3 ---	2 ---	---	---	15 ---	15 ---
Scorzoneroides autumnalis	---	9 ---	4 ---	1 ---	8 ---	16 ---	9 ---	2 ---	---
Carex sempervirens	---	---	1 ---	9 ---	6 ---	16 ---	3 ---	8 ---	---
Helianthemum nummularium agg.	10 ---	2 ---	7 ---	7 ---	1 ---	11 ---	---	---	---
Rhinanthus alpinus	4 ---	7 ---	3 ---	13 [illegible]	2 ---	3 ---	1 ---	---	---
Laserpitium latifolium	21 [illegible]	---	1 ---	1 ---	---	3 ---	1 ---	18 [illegible]	15 ---
Viola lutea	15 ---	---	6 ---	6 ---	---	5 ---	1 ---	---	---
Gentianella lutescens	4 ---	---	4 ---	1 ---	1 ---	16 ---	13 [illegible]	---	---
Vicia sylvatica	8 ---	---	1 ---	10 [12.0]	---	3 ---	---	10 ---	---
Podospermum roseum	4 ---	---	---	---	8 ---	---	9 ---	20 [illegible]	---
Cirsium rivulare	---	9 ---	7 ---	2 ---	---	11 ---	4 ---	2 ---	---
Euphorbia amygdaloides	---	---	---	11 [illegible]	8 ---	---	---	---	---
Hypericum perforatum	17 [illegible]	5 ---	2 ---	3 ---	1 ---	3 ---	1 ---	5 ---	---
Solidago virgaurea	4 ---	---	1 ---	6 ---	4 ---	---	3 ---	2 ---	11 ---
Urtica dioica	---	7 ---	2 ---	4 ---	10 ---	---	---	5 ---	---
Scabiosa columbaria	---	2 ---	2 ---	1 ---	---	5 ---	17 [illegible]	10 ---	---
Holcus lanatus	---	---	3 ---	1 ---	---	---	16 [illegible]	18 [illegible]	---
Carex panicea	2 ---	---	9 ---	---	---	16 [illegible]	3 ---	---	7 ---
Geum montanum	---	---	2 ---	5 ---	12 [illegible]	3 ---	---	---	---
Polygonatum verticillatum	8 ---	---	4 ---	---	1 ---	3 ---	7 ---	10 ---	---
Anemone nemorosa	10 ---	2 ---	6 ---	1 ---	4 ---	---	3 ---	---	---
*Sesleria *tatrae*	---	---	---	10 [illegible]	2 ---	5 ---	1 ---	---	---
Medicago falcata	12 ---	---	2 ---	1 ---	---	14 ---	4 ---	---	---
Thesium alpinum	17 [illegible]	---	---	3 ---	---	---	1 ---	8 ---	---
Clinopodium vulgare	12 [illegible]	---	1 ---	1 ---	1 ---	---	1 ---	15 [illegible]	---
Luzula sudetica	---	---	---	---	4 ---	16 [22.2]	---	15 [20.0]	---
Primula veris	12 [illegible]	7 ---	2 ---	---	---	8 ---	1 ---	---	---
Equisetum arvense	---	12 ---	4 ---	1 ---	1 ---	---	3 ---	---	4 ---
Leucanthemum rotundifolium	---	---	---	1 ---	10 [illegible]	11 ---	---	---	---
Cuscuta species	---	---	---	---	---	---	10 [illegible]	20 [illegible]	---
Geranium pratense	2 ---	---	2 ---	---	1 ---	3 ---	10 [16.9]	5 ---	---
Salvia verticillata	10 ---	2 ---	---	---	---	3 ---	9 ---	---	---
Ranunculus lanuginosus	2 ---	2 ---	---	2 ---	2 ---	---	---	15 [illegible]	---
Brachypodium pinnatum	10 ---	---	2 ---	1 ---	---	5 ---	1 ---	---	---
Viola hirta	12 [illegible]	2 ---	---	---	---	---	---	12 [illegible]	---
Origanum vulgare	8 ---	---	---	1 ---	---	---	---	18 [illegible]	---
Euphorbia carniolica	2 ---	2 ---	---	---	---	---	7 ---	12 [21.5]	---
Securigera varia	15 [illegible]	5 ---	2 ---	---	---	---	---	---	---
Thalictrum aquilegiifolium	2 ---	---	1 ---	1 ---	---	5 ---	---	12 [illegible]	---
Poa nemoralis	2 ---	---	---	1 ---	---	---	---	20 [illegible]	---
Euphrasia stricta agg.	2 ---	---	2 ---	---	---	---	4 ---	12 [illegible]	---
Campanula rapunculoides	---	---	1 ---	1 ---	1 ---	3 ---	10 [illegible]	---	---
Dianthus superbus	---	---	---	4 ---	---	---	1 ---	10 ---	---
Lilium martagon	2 ---	---	2 ---	1 ---	---	---	1 ---	10 ---	4 ---
Digitalis grandiflora	10 [illegible]	2 ---	---	---	---	---	---	8 ---	---
Taraxacum sect. *Alpestria*	---	---	---	---	2 ---	16 [illegible]	---	---	---
Bromus monocladus	10 [illegible]	---	1 ---	---	---	3 ---	---	---	---
Carduus glaucinus	10 [24.7]	---	---	---	---	3 ---	1 ---	---	---
Succisa pratensis	---	---	1 ---	---	---	---	1 ---	12 [illegible]	---
Festuca carpatica	---	---	---	1 ---	---	---	---	12 [illegible]	---
Pedicularis verticillata	---	---	---	1 ---	1 ---	14 [illegible]	---	---	---

Hieracium prenanthoides	---	---	---	2 ---	---	--	1 -	--	11 ---
Ononis arvensis	---	2 ---	---	---	---	---	1 ---	10 [illegible]	---
*Hieracium *flagellare*	---	---	---	---	---	16 [38.3]	---	---	---
Phyteuma tetramerum	---	---	---	---	---	---	---	15 [illegible]	---
Aconitum anthora	---	---	---	---	---	---	---	15 [illegible]	---
Arenaria serpyllifolia agg.	---	---	1 ---	---	---	11 [illegible]	---	---	---
Aconitum moldavicum	---	---	---	---	1 ---	---	---	10 [illegible]	---
Pedicularis exaltata	---	---	---	---	---	---	---	12 [illegible]	---
Euphorbia illirica	---	---	---	---	---	---	---	---	11 [31.8]
Abundant bryophytes (E0)	---	---	---	---	---	---	---	---	---
Rhytidiadelphus squarrosus	---	---	---	---	1 ---	---	19 [illegible]	---	4 ---
Climacium dendroides	2 ---	---	8 ---	1 ---	3 ---	8 ---	19 [illegible]	---	4 ---
Brachythecium mildeanum	---	---	1 ---	---	1 ---	16 [illegible]	1 ---	---	---
Plagiomnium cuspidatum	---	---	---	1 ---	1 ---	14 [illegible]	---	---	---
Abietinella abietina	---	---	---	---	---	11 [31.2]	---	---	---
Hypnum lindbergii	---	---	2 ---	---	---	11 [illegible]	1 ---	---	---
Plagiomnium undulatum	---	---	1 ---	1 ---	1 ---	---	10 [illegible]	---	---
Calliergonella cuspidata	---	---	2 ---	1 ---	2 ---	---	10 [illegible]	---	---
Pleurozium schreberi	2 ---	---	7 ---	3 ---	4 ---	3 ---	13 ---	2 ---	4 ---
Plagiomnium affine agg.	4 ---	---	6 ---	8 ---	10 ---	11 ---	4 ---	---	4 ---
Brachythecium albicans	---	---	1 ---	---	4 ---	11 ---	---	---	---

Table 3: Phytosociological relevés of *Violo declinatae-Agrostietum capillaris* ass. nova. Nomenclatural type: relevé nr.20 is on a grey background. 1 – variant typicum (1-30), 2 – variant with *Cirsium erisithales* (31-40). *Dianthus barbatus* subsp. *compactus – Dianthus *compactus, Ranunculus polyanthemos* subsp. *nemorosus – Ranunculus *nemorosus*.

Variant	1	2
Relevé number	111111111122222222223	3333333334
	123456789012345678901234567890	1234567890
***Violo declinatae-Agrostietum capillaris* ass. nova**		
Angelica sylvestris	+a11..r1+a.+.1++++++111++....a	++.r.r....
Lotus ucrainicus	.1+....1.11.a111+1++11.+...+.+	...+rrr...
Trifolium alpestre	+11.ar....1+1+1aaaaaaaa+...a.a	a.........
Stachys officinalis	++.++r+1aa.....+++a1..1+..+1..	a.........
Hieracium umbellatum	...+1r...1.....+1.+++++++.....	++.......r
Trifolium pannonicum	.+....r.+.+1+++11aa1......++..	....
Galium verum agg.	.+....r1.a+++11.....111...11..	....
Stachys alpina	....r..............+...+....a.	11...+rrrr
Cyanus mollis	.....+.1+...........m11....b1.	....r+....
Achillea carpatica	....................1....+.+1.	..11a+a...
Viola declinata	.....r...a.........++++.......	...r.rr...
variant typicum		
Phleum pratense	11++++r11a11.111a+11++.....1+4	....
Leucanthemum vulgare agg.	+1++1+ra111+a1a11+1+..+a.+++r.	+.+.......
Centaurea jacea	...+1.r1a3aaa1a11aaa......1..a	....
Anthoxanthum odoratum agg.	..1.a.a1++131a1a++.a++.+......	....
Schedonorus pratensis	.1aa1ar.a.+..111..a3...+.11a.+	....
variant with *Cirsium erisithales*		
Cirsium erisithales	....	41a..ar444
Laserpitium latifolium	....	..+aa.1aaa
Centaurea kotschyana	....	.11a3ar...
Aconitum anthora	....	.++rrrr...
Festuca carpatica	....	.++....aaa
Polygono-Trisetion		
Astrantia major	++11aa11+a...++a11+111a1a++11a	a11a3aaaaa
Trollius europaeus	+11+aa111++++++11a11111.1+11aa	.1+1.a1+++
Campanula serrata	+++...r+.11+++++++1+++++1+....	+++1+r1rr+
Alchemilla spec. div.	a+1..r1+..1a11....1.+++a......	..ar......
Pimpinella major	+.+.+r....++......1+++.1a.++1.	....
Geranium sylvaticum	...1....+..........+aaa111.a.4	....
Knautia dipsacifolia = maxima	.......+...........+...++.....	......raaa
Centaurea phrygia agg.	1a1..................+a+.+....	...r.+a...
Phyteuma tetramerum	....................++++.+.+..	....
Molino-Arrhenatheretea		
Lathyrus pratensis	.11..ar.+a++++.+++.++++++.++r.	.+.r.rrrr.
Rhinanthus minor	1+.....3+aa+111.+1a1++++......	.++ra+...r
Plantago lanceolata	+.....r.+1++1++.++1+..........	....
Myosotis scorpioides agg.	.++..r.++.+++.......++...+++..	....
Trifolium repens	.....+r1+a..++....++...+......	..+..r....
Prunella vulgaris	.....r.1+...1..+.......+++....	....+..rrr
Cynosurus cristatus	+.....r1.+...111.1...+.......3	....
Rumex acetosa	.....+.1+.+..++...+.....++....	.........r
Filipendula ulmaria	.....r..............++...+.+a.	...r...rrr
Trifolium pratense	.....r.a.a1.111...........+..1	....
Carum carvi	.++....++....++.11.+..........	....
Holcus lanatus	.........3.1.111+1............	....
Succisa pratensis	...+............a...++........	+.........
Ranunculus acris	......r.+.......++..++........	....
Cirsium oleraceum	.+......1.....................	....
Festuco-Brometea		
Campanula glomerata agg.	.+.++rr.+.++.+1++++++++++++..+	+1+rrr.rrr
Ranunculus polyanthemos	..+.+.r..+++1+++..++..1+....r.	...r.r....
Pimpinella saxifraga agg.	+.....r.+1+.+++.+++...........	....
Linum catharticum	......r.+...+++....+..........	+..r+.r...
Plantago media	.+.....1.....++..+............	....
Anthyllis vulneraria	..........1.....1+.a..........	....
Tragopogon pratensis agg.	.......1..+......+.....+......	....
Trifolium montanum	.......+.+........11..........	....

Medicago lupulina	.........+....1a...............	....
Nardetea strictae		
Potentilla erecta	+..+1rr111.1++..1+1.+++1......	..1..r....
Carex pallescens	.+....r...++.+.1..11...1..++..	...r..+...
Luzula luzuloides	...+a1a........1.1..++.+1...r.	......1...
Luzula campestris agg.	.....1..+....++m....+++.......	...rr.....
Hypochaeris uniflora	..................+++++.+......	....
Viola canina	...+.......+..+.+.+...........	....
Polygala vulgaris	+....rr.....+..........+......	....
Poa chaixii	.....ar........................	..1.......
Potentilla aurea	.....r....................+...	....
Mulgedio-Aconitetea		
Rumex arifolius	.++.......................+r.	......+...
Calamagrostis arundinacea	...................1..........	a......11.
Cerastium fontanum agg.	......r.....+++................	....
Silene dioica	.....r......................r.	..+.......
Delphinium elatum	....	.11.......
Calamagrostis villosa	...11.........................	....
Chaerophyllum hirsutum	........................+....	..+.......
Other species		
Agrostis capillaris	41415aa443443a13.a4aaaa3a111a.	..+ra+a...
Heracleum sphondylium	+11+.rr++.++++++....++.+1+.111	+++r.rraar
Dactylis glomerata agg.	+11+++r+1.+11a1...1.+++.153.3.	1......++r
Cruciata glabra	+.+++rr.+1.+++++..+++++++.+.r.	...r...rrr
Achillea millefolium agg.	++1+1++1+a++1+++++11.1..1.....	11.....rr.
Tanacetum corymbosum	.++++r1.++.+..++a1+11111a..1..	a..1r+r...
Stellaria graminea	++++.rr++11++1++++++++...+...+	.....rr...
Hypericum maculatum	.+..1..1+a++++.+...++++..11+..	+11a+aa..+
Thymus pulegioides	+....r..+.11+1.1++a1...11.....	.1aaa+.rr.
Briza media	+++.1++131+1.11.++.111.11.....	1.........
Festuca rubra agg.	..a..+a.3.a11111....aaa44.....	.+.ra.....
Carlina acaulis	+.....r.+.+1....+111....+..+..	1..rr.rrr.
Crepis biennis	.1+..1r1+.+.++++.+++11...+....	....
Gymnadenia conopsea	+....rr...++.++++++++++.......	...r......
Veronica chamaedrys agg.	+....rr.+1.++.++..++...+.+....	.....rr...
Leontodon hispidus	.+...rr1..b+1+.+..1.+++++.....	....
*Dianthus *compactus*	....................++.++.+r.	..+aaarrr.
Trisetum flavescens	+1..a.a.+4.aa341...............	....
Campanula patula	+...+..++++.+++.++............	....
Vicia cracca agg.	.+.....1+a++.++...........+..3	....
Euphrasia rostkoviana agg.	..+..rr......++..+..........r.	1...a.r...
Poa nemoralis	...............1...1..1.+1..+.	1.+.......
Crepis conyzifolia	...+..r..........1.+++1...+..	....
Podospermum roseum	..................+.+++++++...	....
Primula elatior	.....r..+............+++.....	..+...r...
Deschampsia cespitosa	11.a...+...............a4+..	....
Origanum vulgare	.....+.....................+.	1+a..rr...
Knautia arvensis agg.	...++r.1..+.....11............	....
Cuscuta europaea	..........+++.++..++..........	....
Helictochloa planiculmis	1.........1.113.........1.....	....
Avenula pubescens	....1...........aa............	....++a...
Traunsteinera globosa	......r...+.........++++......	....
Clinopodium vulgare	...+.....+...................+.	1.a.r.....
Luzula sudetica	..+...+...++......1...+......	....
Ranunculus lanuginosus	++............................	.1....rrr
Fragaria vesca	......................+.....	.+1r...rr.
Euphrasia stricta agg.	.......a....+.........++......	.+........
Pedicularis exaltata	.1+..................1++......	....
Neottia ovata	...........+.+........+.......	.......rr.
Viola hirta	......r......+++...+..........	....
Parnassia palustris	........+....+...........+....	....1.r...
Thalictrum aquilegiifolium	...................+....+.....	..+....rr.
Euphorbia carniolica	......................+.......	......rrrr
Vicia sylvatica	.....................1.1..a+.	....
Scabiosa lucida	....	.1ar.a....
Dianthus superbus	....	...1a+r...
Polygonatum verticillatum	........+...................a.	.++.......

Scabiosa columbaria	........+........+.....++.....	....
Lotus corniculatus agg.	+.....r.......................	.1+.......
Aconitum moldavicum	...............+...1........r.	1.........
Ononis arvensis	.......1+....++...............	....
Lilium martagon	...................+....+.....	...r..r...
Ajuga reptans	......r.......................	.1.....rr.
Pteridium aquilinum	...5...a.......1..............	....
Carex sempervirens	....	...aaa....
Elymus caninus	............................a.	.1a.......
Melampyrum saxosum	........................+.....	.11.......
Helictochloa praeusta	...................a..1.....+.	....
Digitalis grandiflora	...................+....+.....	+.........
Crepis paludosa	....................++.....+..	....
Carex umbrosa	...................1++........	....
*Ranunculus *nemorosus*	.......1..................++..	....
Taraxacum sect. *Ruderalia*	......r.+....+................	....
Pilosella aurantiaca	.....r....+...........+.......	....
Polygala comosa	........+.........++..........	....
Silene vulgaris	...................+..........	....+.r...
Silene nutans	..................++..........	...r......
Thesium alpinum	....	...ra.r...
Poa pratensis agg.	..............3..............3	....
Holcus mollis	..........a.a.................	....
Carex montana	..................11..........	....
Chaerophyllum aromaticum	......1.....................a.	....
Elytrigia repens	..............11..............	....
Trifolium medium agg.	1.....1.......................	....
Mercurialis perennis	....	.1+.......
Cyanus montanus	....	.++.......
Carex sylvatica	....	.1+.......
Danthonia decumbens	.........a.......+............	....
Trifolium hybridum	..+...........+...............	....
Bunias orientalis	........+...+.................	....
Ranunculus breyninus	....	..+...r...
Urtica dioica	...+........................r.	....
Hypericum perforatum	...+.r........................	....
Pilosella cymosa	......r....+..................	....
Geranium pratense	..+..r........................	....
Geranium phaeum	.....r......................1.	....
Arnica montana	1.....r.......................	....
Rhinanthus alectorolophus agg.	.....r......................r.	....
Silene nemoralis	....	.......rr.
Aposeris foetida	....	.......rr.
Acer pseudoplatanus	....	.1+.......
Picea abies	......r.......................	......r...

Species occurring in less than four relevés

E_1: *Acinos alpinus* 36: r; *Alopecurus pratensis* 2: 1; *Arabidopsis halleri* 32: +; *Aquilegia species* 31: a; *Bistorta officinalis* 23: +; *Bromus hordeaceus* 10: 1; *Calamagrostis epigejos* 25: 1; *Campanula persicifolia* 26: +; *Carduus kerneri* 35: +; *Carex flava* agg. 2: +; *Cirsium arvense* 2: +; *C. palustre* 29: +; *C. rivulare* 2: +; *Colchicum autumnale* 27: +; *Cuscuta species* 7: r; *Dactylorhiza maculata* 12: +; *D. majalis* 23: +; *Daucus carota* 13: +; *Dianthus carthusianorum* agg. 6: r; *D. deltoides* 21: +; *Dryopteris filix-mas* 33: +; *Epilobium angustifolium* 4: +; *Equisetum pratense* 30: 1; *E. sylvaticum* 24: +; *Festuca ovina* agg. 1: +; *F. stricta* subsp. *saxatilis* 37: 3; *Galeopsis tetrahit* 10: 1; *Gentiana asclepiadea* 1: +; *G. cruciata* 6: r; *Gentianella amarella* 24: +; *Geum rivale* 33: +; *Gladiolus imbricatus* 16: 1; *Glechoma hederacea* agg. 33: +; *Heracleum carpaticum* 35: +; *Hypericum hirsutum* 18: +; *Leontodon autumnalis* 6: 1; *Luzula sylvatica* 26: +; *Lysimachia vulgaris* 26: +; *Molinia caerulea* 10: +; *Myosotis arvensis* 1: +; *M. ramosissima* 7: r; *Myosoton aquaticum* 29: r; *Nardus stricta* 1: +; *Neotinea ustulata* 14: +; *Ononis spinosa* 1: +; *Pedicularis hacquetii* 21: 1; *Phleum alpinum* 37: r; *Phyteuma orbiculare* 37: r; *Polystichum aculeatum* 32: +; *P. lonchitis* 32: +; *Pulmonaria mollis* 25: +; *Rubus idaeus* 4: +; *Scorzoneroides autumnalis* 1: +; *Senecio nemorensis* agg. 29: +; *Silene flos-cuculi* 2: +; *Sisyrinchium montanum* 1: +; *Solidago virgaurea* 25: +; *Spiraea chamaedrifolia* 25: +; *Stachys sylvatica* 6: r; *Stellaria nemorum* 26: +; *Thymus alpestris* 37: 1; *Vaccinium vitis-idaea* 1: +; *Verbascum lanatum* 35: r; *Veronica urticifolia* 25: +; *Vicia sepium* 40: r; *Viola arvensis* 13: +; *V. tricolor* 1: +. – E_0: *Pleurozium schreberi* 1: a.

Table 4: Ecological characteristics of associations.

Name of association	**Slope**	**orientation**	**elevation m a.s.l.**	**soils**	locality
Campanulo glomeratae-Geranietum sylvatici	2 –65°	various	630–1200	semi-deep to deep soils with varying limestone skeleton content	Starohorské vrchy Mts and south-eastern part of the Veľká Fatra Mts, Wolosate, Chyvchyny Mts
Geranio sylvatici-Trisetetum flavescentis	35(45)º	various	730–1200	mineral rich, moist and deep brown soils	Spišská Magura Mts, Belianske Tatry Mts, Tatry Zachodnie Mts and Pogórze Spisko-Gubałowskie Hills
Crepido mollis-Agrostietum capillaris	2 –36°	mostly northern	650–1400	moderately deep, clay to loamy-clay soils	Slovakia and Poland
Geranio-Alchemilletum crinitae	5–45°	various	750–1670	shallow to moderately deep, well aerated rendzina and pararendzina	Veľká Fatra Mts, Malá Fatra Mts, Belianske Tatry Mts, Tatry Zachodnie Mts
Alchemillo-Deschampsietum caespitosae	up to 35°	various	1100–1600	medium heavy to heavy, medium deep to deep, freshly wet, loamy-clayey, neutral to weakly alkaline soils (rendzina)	Slovakia, Poland, Romania, Ukraine
Phyteumo (orbicularis)-Trifolietum pratensis	2–25°	various	800–1360	shallow, well drained, rocky soils	Polish Tatra Mts, Slovenský raj Mt., Veľká Fatra Mts, Muránska planina Mts and rarely Nízke Tatry Mts, Chočské vrchy Mts and Malá Fatra Mts
Astrantio-Trisetetum flavescentis	2–20(30)°	various	800–1100	rendzinas or brown soils	entire study area
***Violo declinatae-Agrostietum capillaris* ass. nova**	5–45°	various	800–1600	sod-brown soils with varying depth, brown mountain meadow soils of “polonynas” grasslands on the artificially deforested mountain ridges and the brown-grey soils in post-forest areas **lower altitudes** (800–1300 m a.s.l.) - slightly acidic to acidic soil reaction (pH 5.3–5.7) and low content of exchange bases mainly on the western and north-eastern slopes **higher altitudes** (1050–1600 m a.s.l.) - carbonate substrates on the dry north-eastern and eastern slopes with poorly developed, well-drained neutral or weakly alkaline soils with significant humus content in the upper horizon	Skybovy and Verkhovynsky Carpathians, Chyvchyny Mts
Trollio altissimi-Knautietum dipsacifoliae	5–25º	mostly sout-west	810–1450	Eutric-Gleyic Cambisols and Eutric Gleysols	Bieszczady Mts

Table 5: Correlation coefficients between the first two axes and environmental variables. Significant corelation coefficients are in bold.

Correlations (DCA_score_env_factors)
Marked correlations are significant at p < .00416
N=612 (Casewise deletion of missing data)

Variable	species NR	AMT	TAR	AP	Altitude	Light	Temperature	Moisture	Soil Reaction	Nutrients
DCA1	-.6491	-.5753	-.5527	.5957	.6591	-.4061	-.1670	.3489	.2097	.1355
	p=0.00	p=0.00	p=0.00	p=0.00	p=0.00	p=0.00	p=.000	p=.000	p=.000	p=.001
DCA2	.2047	.1867	.2018	-.1268	-.0569	.0311	.2216	-.3182	-.2847	-.4161
	p=.000	p=.000	p=.000	p=.002	p=.160	p=.443	p=.000	p=.000	p=.000	p=0.00

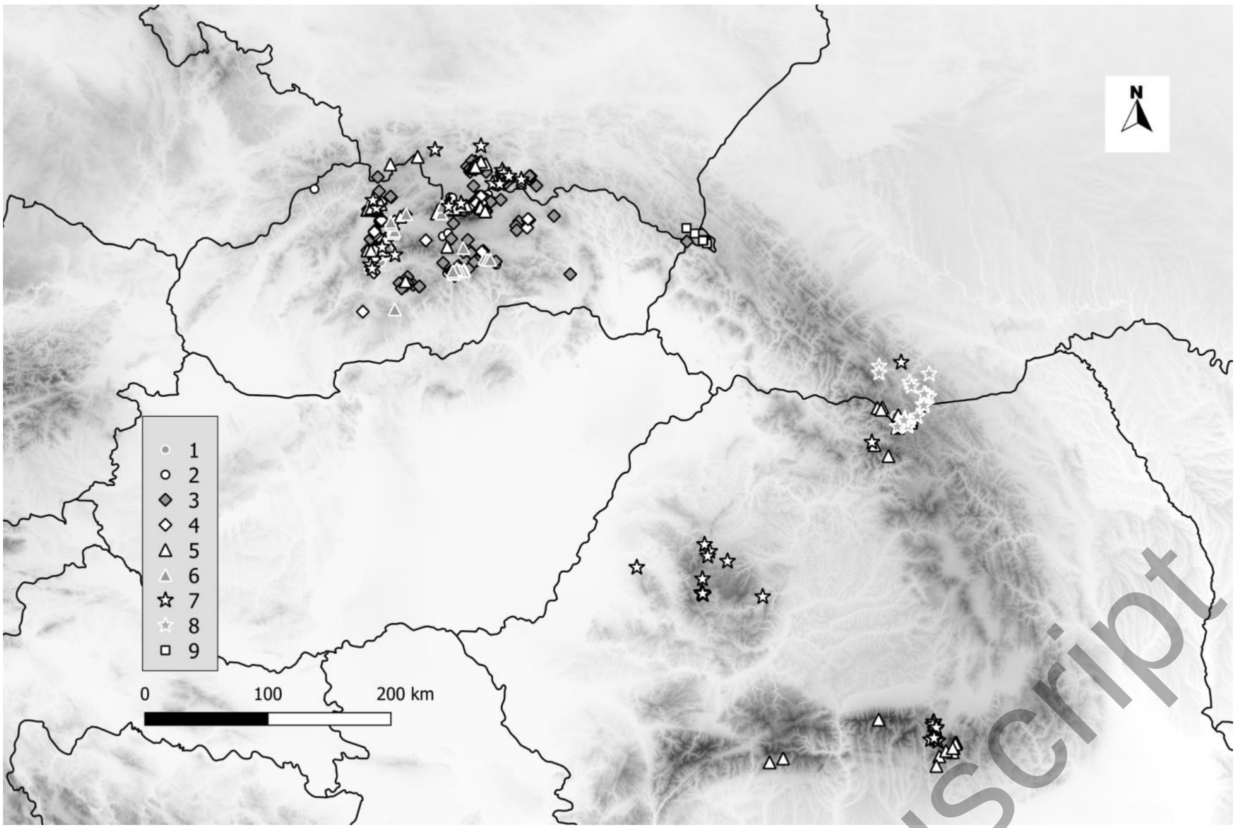

Figure 1. Distribution map of the *Triseto flavescentis-Polygonion bistortae* alliance in the Carpathians. 1 – *Campanulo glomeratae-Geranietum sylvatici*, 2 – *Geranio sylvatici-Trisetetum flavescentis*, 3 – *Crepido mollis-Agrostietum capillaris*, 4 – *Geranio-Alchemilletum crinitae*, 5 – *Alchemillo-Deschampsietum caespitosae*, 6 – *Phyteumo (orbicularis)-Trifolietum pratensis*, 7 – *Astrantio-Trisetetum flavescentis*, 8 – *Violo declinatae-Agrostietum capillaris* ass. nova, 9 – *Trollio altissimi-Knautietum dipsacifoliae*.

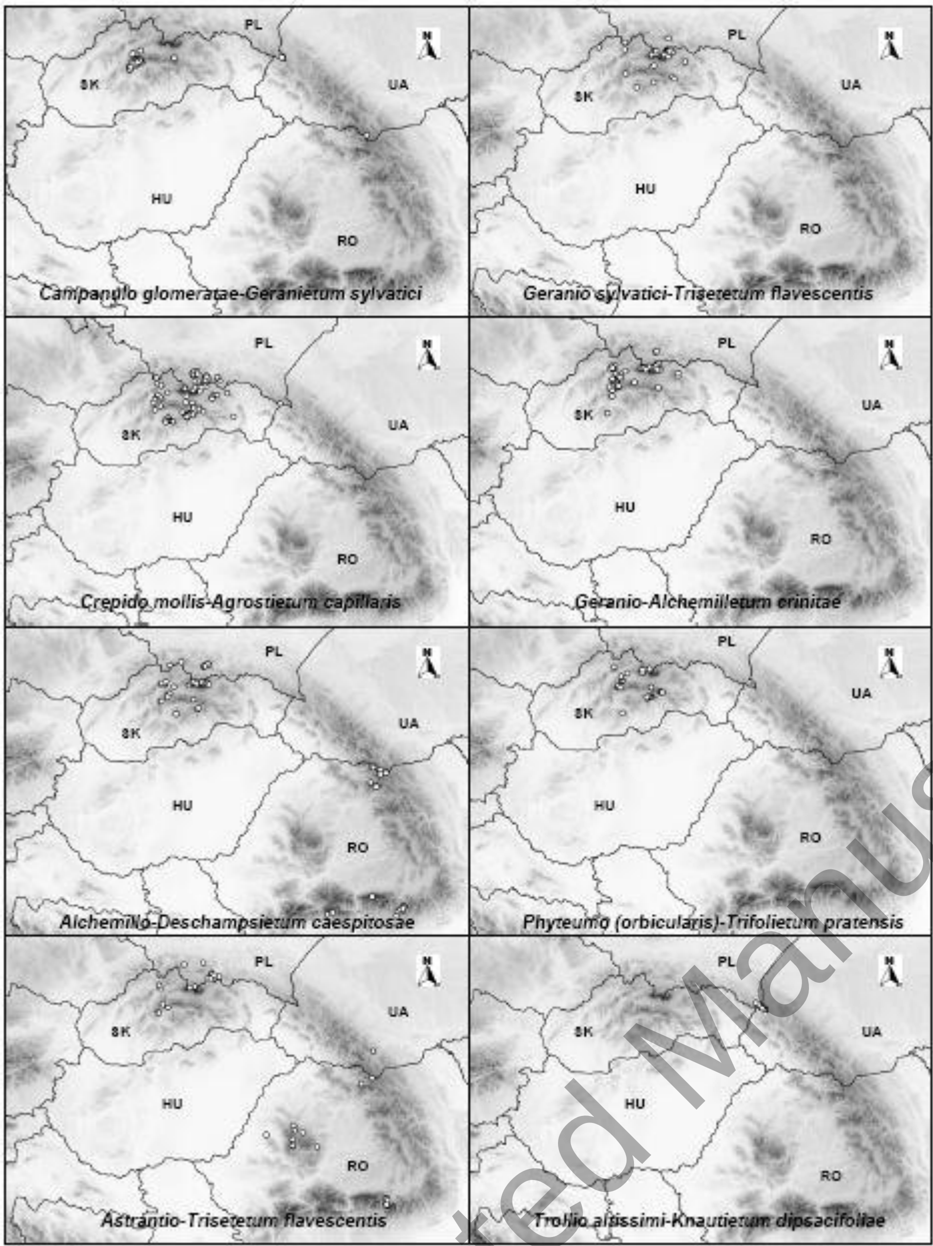

Figure 2. Distribution of clusters 1–7 and 9 in the study area.

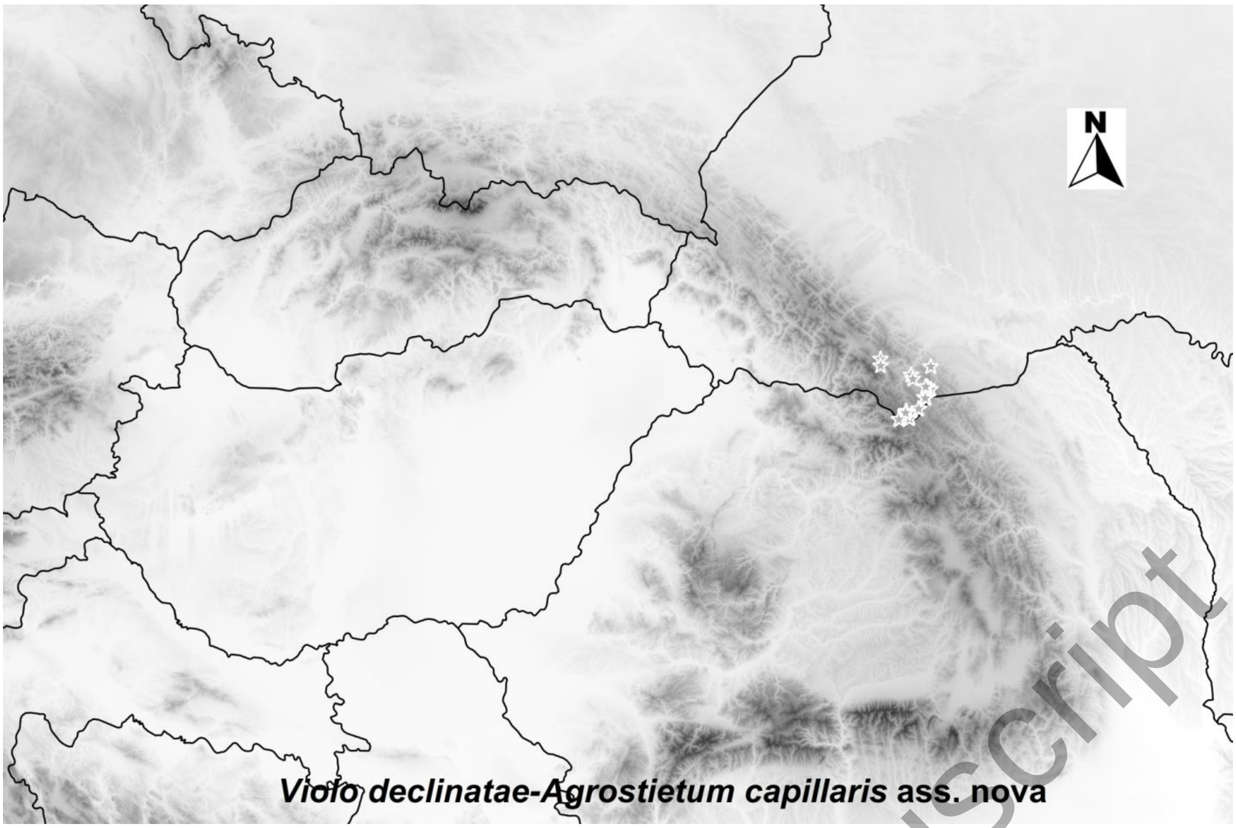

Figure 3. Distribution of *Violo declinatae-Agrostietum capillaris* ass. nova in the study area.

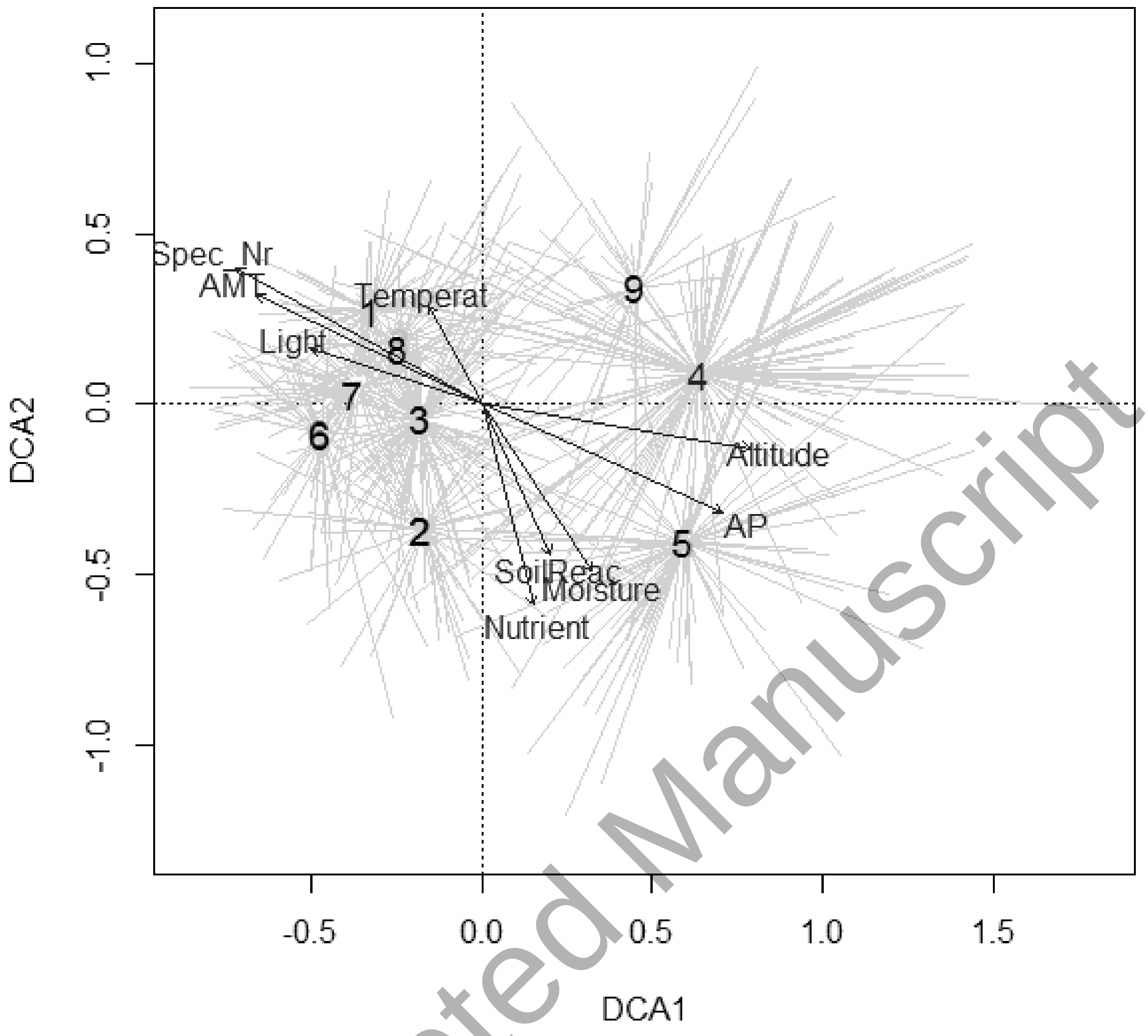

Figure 4. The DCA ordination diagram based on logarithmic transformed data of the Carpathians mountain hay meadows (length of gradient 2.9903; eigenvalues of the first two axes are 0.2731 and 0.1708). Selected indicator values for relevés (temperature, moisture, light, soil reaction and nutrients), altitude, climatic variables (annual precipitation – AP, annual mean temperature – AMT) and the number of vascular plant species for the relevés of individual clusters 1–9 were used as supplementary variables. 1 – *Campanulo glomeratae-Geranietum sylvatici*, 2 – *Geranio sylvatici-Trisetetum flavescentis*, 3 – *Crepido mollis-Agrostietum capillaris*, 4 – *Geranio-Alchemilletum crinitae*, 5 – *Alchemillo-Deschampsietum caespitosae*, 6 – *Phyteumo (orbicularis)-Trifolietum pratensis*, 7 – *Astrantio-Trisetetum flavescentis*, 8 – *Violo declinatae-Agrostietum capillaris* ass. nova, 9 – *Trollio altissimi-Knautietum dipsacifoliae*.

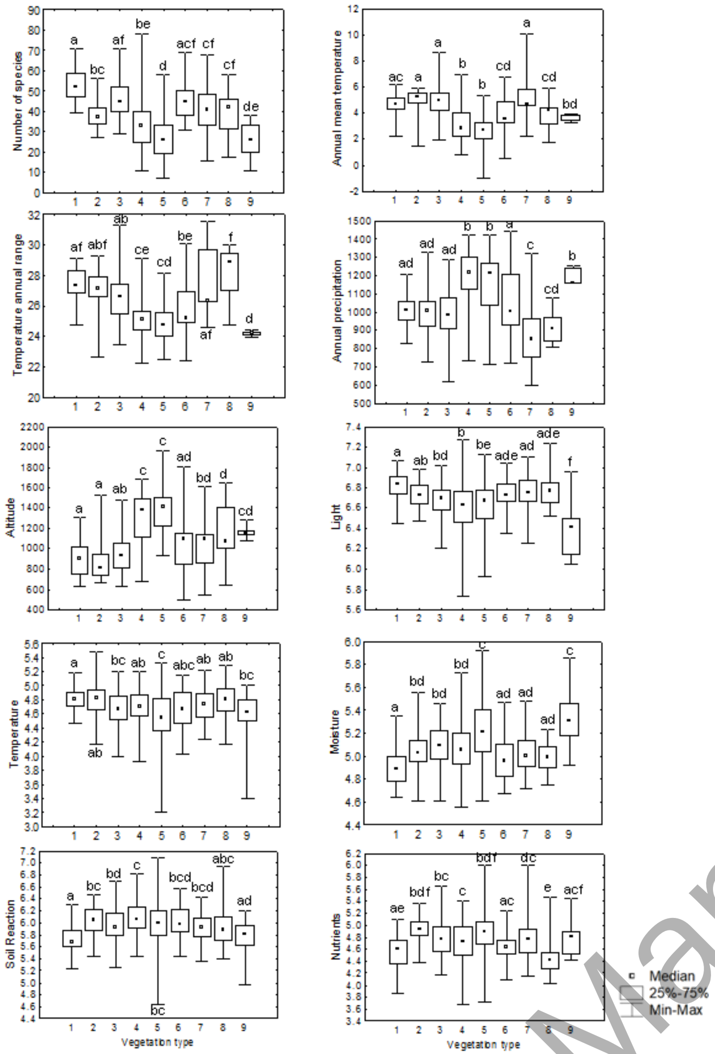

Figure 5. Box and Whisker plots of selected indicator values for relevés (temperature, moisture, light, soil reaction and nutrients), altitude, climatic variables (annual precipitation – AP, annual mean temperature – AMT) and number of vascular plant species for relevés in individual clusters 1–9. The boxes show medians and upper and lower quartiles and the whiskers indicate minimum and maximum values. Significant differences between clusters (Kruskal-Wallis ANOVA and multiple comparison tests of the mean ranks, $P < 0.05$) are marked by labels (a-f). The same letters indicate associations that did not differ significantly in a specifc parameter. 1 – *Campanulo glomeratae-Geranietum sylvatici*, 2 – *Geranio sylvatici-Trisetetum flavescentis*, 3 – *Crepido mollis-Agrostietum capillaris*, 4 – *Geranio-Alchemilletum crinitae*, 5 – *Alchemillo-Deschampsietum caespitosae*, 6 – *Phyteumo (orbicularis)-Trifolietum pratensis*, 7 – *Astrantio-Trisetetum flavescentis*, 8 – *Violo declinatae-Agrostietum capillaris* ass. nova, 9 – *Trollio altissimi-Knautietum dipsacifoliae*.