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Plant communities of the montane mesophilous grasslands (*Polygono bistortae–Trisetion flavescentis* alliance) in central Europe: Formalized classification and syntaxonomical revision

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Abstract

The research conducted here presents a syntaxonomical revision of the montane mesophilous meadows of the *Polygono bistortae-Trisetion flavescentis* alliance in central Europe – the Slovak part of the western and eastern Carpathians. These typical semi-natural grasslands occur mainly as small islands over the calcareous bedrocks. Associations of this alliance have tight relationships to the *Arrhenatherion*, *Mesobromion* and *Nardo-Agrostion* alliances. Formal definitions based on combination of the species groups were used regarding the diversity and geographical range of the *Polygono bistortae-Trisetion flavescentis* alliance. Following the formal definitions from the eight associations reported previously for Slovakia, only four of them can be placed within the *Polygono bistortae-Trisetion flavescentis*: *Campanulo glomeratae-Geranietum sylvatici*, *Geranio sylvatici-Trisetetum*, *Crepido mollis-Agrostietum capillaries* and *Geranio-Alchemilletum crinitae*. A comparison of traditional and formalized classification, and the advantages/disadvantages of the formalized classification are discussed.

Keywords: *Classification, diversity, Ellenberg indicator values, formal definitions,* Polygono bistortae-Trisetion flavescentis, *syntaxonomical revision*

Introduction

The *Polygono bistortae-Trisetion flavescentis* alliance includes species-rich mesophilous montane meadows on nutrient-rich soils. These meadows occur in various mountain ranges of temperate Europe, becoming progressively more common in oceanic areas (Chytrý 2007). Their centre of distribution is located in the Alps (Ellmauer & Mucina 1993; Peter et al. 2008; Pierce et al. 2008). Due to changes in the traditional mode of land exploitation, they are restricted – in Italy – mostly to the Alpine sector (northern Italy, mountain-subalpine belt); nowadays the areas in which they occur are becoming less and less (Poldini and Oriolo 1994; Buffa et al. 1995; Sburlino et al. 1999; Mion 2005; Biondi et al. 2009). They also occur, though less frequently, in the western Carpathians (Kliment 1994; Ružičková 2002b) and eastern Carpathians in Romania (Sanda et al. 1999; Brinkmann & Reif 2006). Their occurrence is also expected in Ukraine, and, due to the particular climatic conditions, also in northern England (Rodwell 1992; Rodwell et al. 2007). Semi-natural species-rich meadow vegetation has been described also from various areas of Switzerland (Studer-Ehrensberger 2000).

As far as the territory of Slovakia concerns, these typical semi-natural grasslands dominated by medium-tall grasses (*Trisetum flavescens, Agrostis capillaris, Festuca rubra* agg.) and broad-leaved herbs (*Geranium sylvaticum, Alchemilla* spec. div., *Crepis mollis, Phyteuma spicatum, Pimpinella major*) occur only in islands over the calcareous bedrock on wetter and colder sites of saddles and slopes with mainly northern aspect, rarely on a non-carbonate substratum (Figures 2 and 3) at altitudes ranging from 600 to 1500 m a.s.l. (Ružičková 2002a; Hegedüšová & Ružičková 2007). Associations of this alliance have tight relationships with the *Arrhenatherion elatioris*, *Bromion erecti* and *Nardo strictae-Agrostion tenuis*

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alliances. Their occurrence is relatively rare and fragmentary (Figure 1) and is influenced not only by altitude but also by human activities.

The distribution of the alliance up to the present day was relatively unknown for the Slovak part of the central western Carpathians. Up to the late 1980s, only partial data were published from the Belianske Tatry (Hadač et al. 1969; Hadač 1981) and Západné Tatry mountains (Unar et al. 1984). The described meadows were only the fallowing stages of the montane mesophilous meadows with rich occurrence of the species of the *Nardo-Agrostion* and *Mulgedio-Aconitetea*. These associations, along with the associations described by Szafer et al. (1923, 1927) from the Polish Tatras mountains, are considerably different from the montane meadows of central and western Europe. They were described as the self-suballiance *Alchemillo-Trisetenion* (Dierschke 1981). A more detailed analysis was made by Kliment (1994). The *Geranio sylvatici-Trisetetum* association, described by Ružičková (1991, 2001, 2006) as the relict of an intense utilization of meadows, has intermediate character between the *Arrhenatherion* and *Polygono bistortae-Trisetion flavescentis* alliances. The association has a central European distribution restricted to western Germany, the northern foothills of the Alps (Dierschke 1997), Bohemian Massif (Blažková 2007) and the western Carpathians (Ružičková 1991, 2001, 2006l Kliment 1994). The centre of its occurrence is the Sudeten Massif. Its occurrence in Slovakia is conditioned by the specific local climate, long-term inversions and impermeable nutrient-rich soils. It was documented from the Spišská Magura mountains and the northern part of the Vel'ká Fatra mountains in the vicinity of the villages at altitudes ranging from 700 to 900 m (Kliment 1994; Ružičková 2001, Figure 1). Dierschke (1981) described this vegetation type within the *Lathyro linifolii-Trisetenion* suballiance. Ellmauer and Mucina (1993) considered this suballiance as a synonym of the *Phyteumo-Trisetion* alliance. Vegetation similar to that of the *Agrostietum vulgaris* from the Polish Tatra mountains were described by Szafer et al. (1923, 1927). The well-preserved meadows of the *Geranio-Alchemilletum crinitae* were described by Ružičková (1997) from the Belianske Tatry mountains, and by Kliment (1994) from the Vel'ká Fatra mountains. Because of the less humid climate, species of the *Polygono bistortae- Trisetion flavescentis* (*Bistorta major*, *Senecio subalpinus* and *Crepis mollis*) are more abundant in mountain ranges than in the wet *Calthion* and *Molinion* meadows or on the cold northern slopes with the fallowing stages. These species indicate

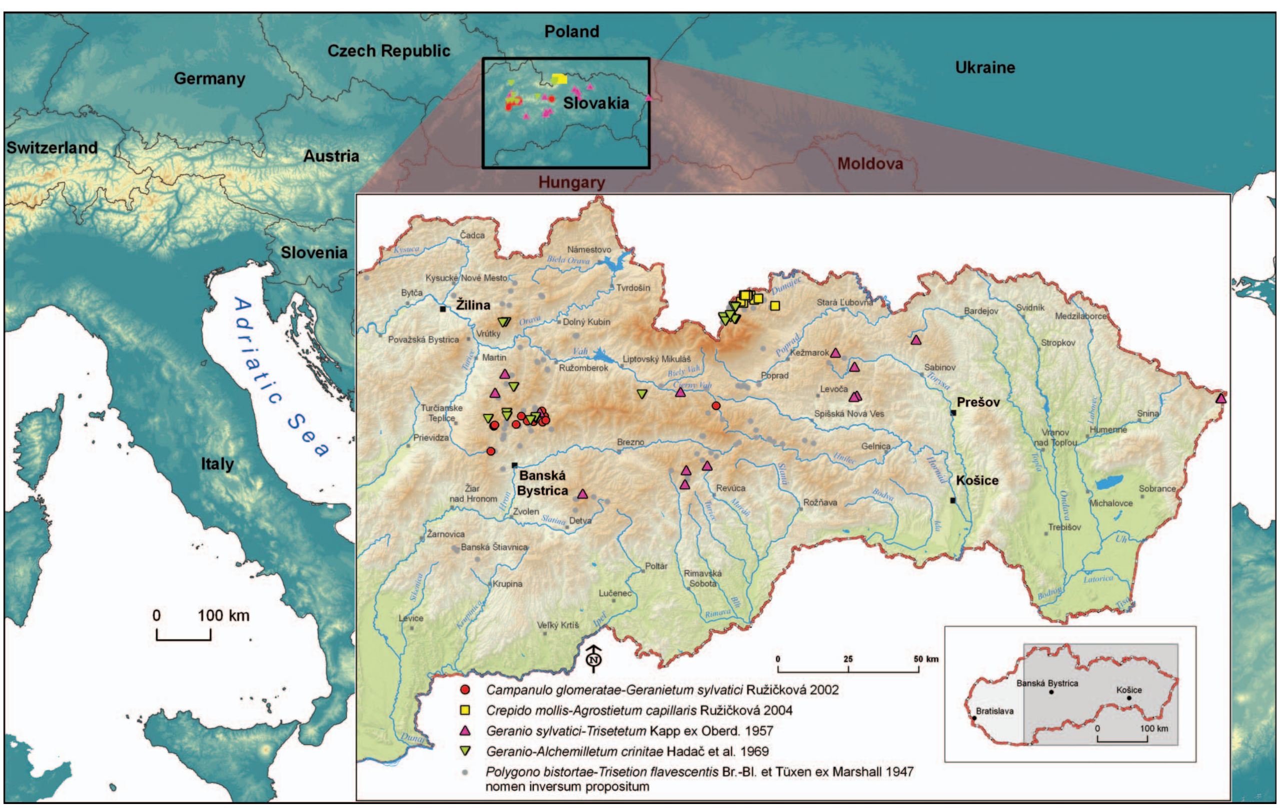

Figure 1. Distribution map of the *Polygono bistortae-Trisetion flavescentis* Br.-Bl. ex Marschall 1947 alliance in Slovakia. Gray points indicate relevés of the alliance before formalized classification. Different colours (red, blue, yellow and violet) display the relevés of associations after matching by the definitions.

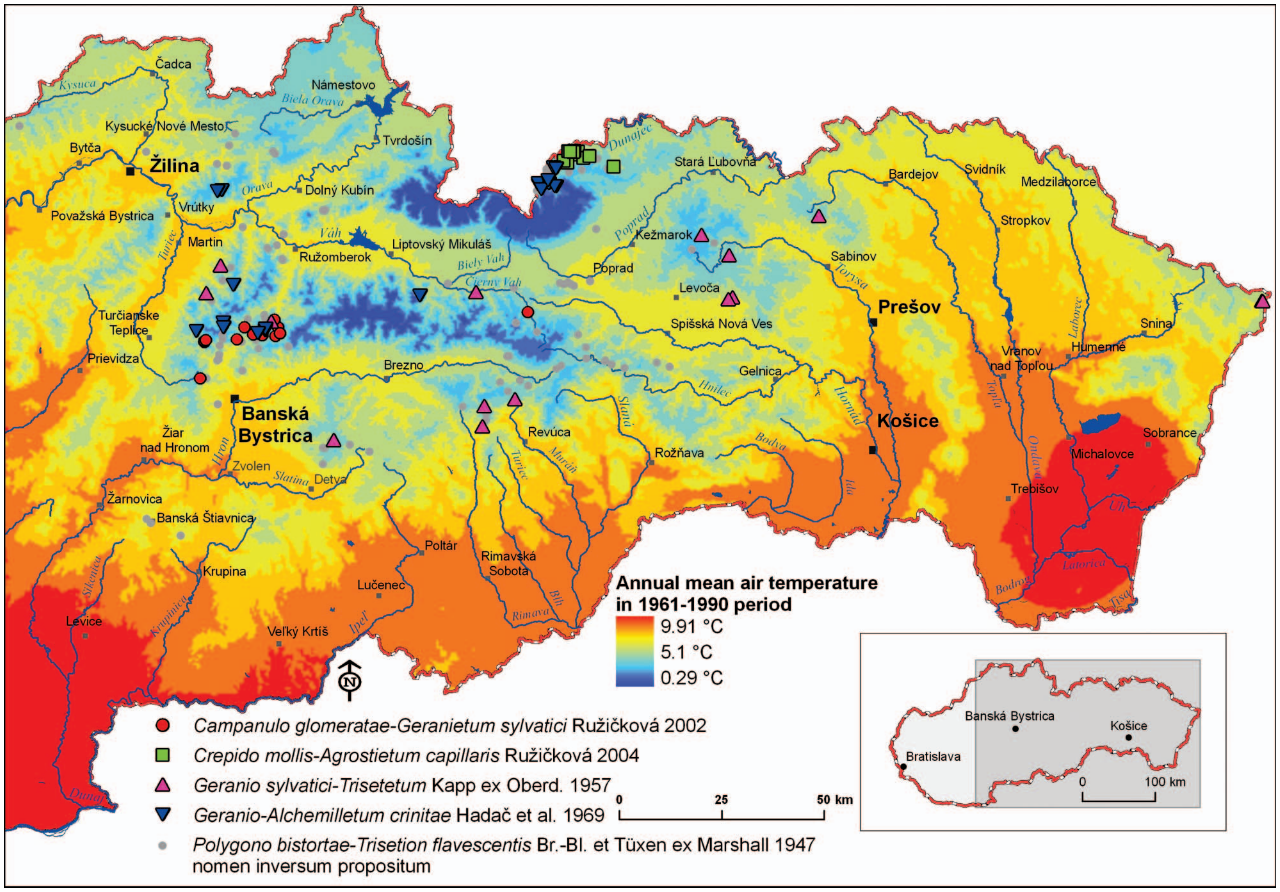

Figure 2. Annual mean air temperature in the 1961–1990 period.

long-lasting snow cover (November–May) and rich rainfall in the summer. At altitudes ranging from 600 to 1100 m, the *Campanulo glomeratae-Geranietum sylvatici* association encompasses the most species-rich montane meadows on the mineral-rich soils on carbonate bedrock and on some igneous rocks. The centre of its distribution is located in the Starohorské vrchy mountains (Ružičková 2002b), the southeastern part of the Vel'ká Fatra mountains and the Nízke Tatry mountains (Janišová 2007) (Figure 1). The montane meadows of the *Crepido mollis-Agrostietum* association are common on cool and humid sites at altitudes between 700 and 1200 m on the Nízke Tatry mountains, the Muránska planina plain, the Levočské vrchy hills, the Vel'ká Fatra mountains, the Bukovské vrchy hills, and the Slovenský raj (Slovak Paradise), Poľana and Čergov mountains (Figure 1). Ružičková (2004) considered these meadows to be a vicariant to the *Cardaminopsidi-Agrostietum* association, described from the Šumava mountains by Moravec (1965) as a replacement community of the acidic fir-beach forests.

The main objectives of this work were (1) to classify the mesophilous montane meadows on the basis of contemporary classification methods and formalized techniques that guarantee a better objectivity and explicitness of results, (2) to define diagnostic species for their identification, (3) to find the main environmental gradients responsible for variation in the floristic composition of the *Polygono bistortae Trisetion flavescentis* meadows in Slovakia and (4) to re-evaluate the traditional approach to the classification of the mesophilous montane meadows.

Materials and methods

The basis for the study and evaluation of the *Polygono bistortae-Trisetion flavescentis* alliance was the Central Phytosociological Database of Slovakia (CDF – http://ibot.sav.sk/cdf/, Hegedüšová 2007). All the phytosociological relevés were stored using the TURBOVEG database software (Hennekens 1996). All the analysed relevés were recorded according to the principles of the Zürich-Montpellier school (Braun–Blanquet 1921, 1928), frequently using the modified 9-degree Braun–Blanquet's sampling scale (Van Der Maarel 1979). The relevés with extreme size (<4 m^2 or >100 m^2) were deleted before the analyses. The relevés without a precise geographic location or without a syntaxonomic rank at least of the level of the classes were also excluded. The phytocoenological material (containing 32,729

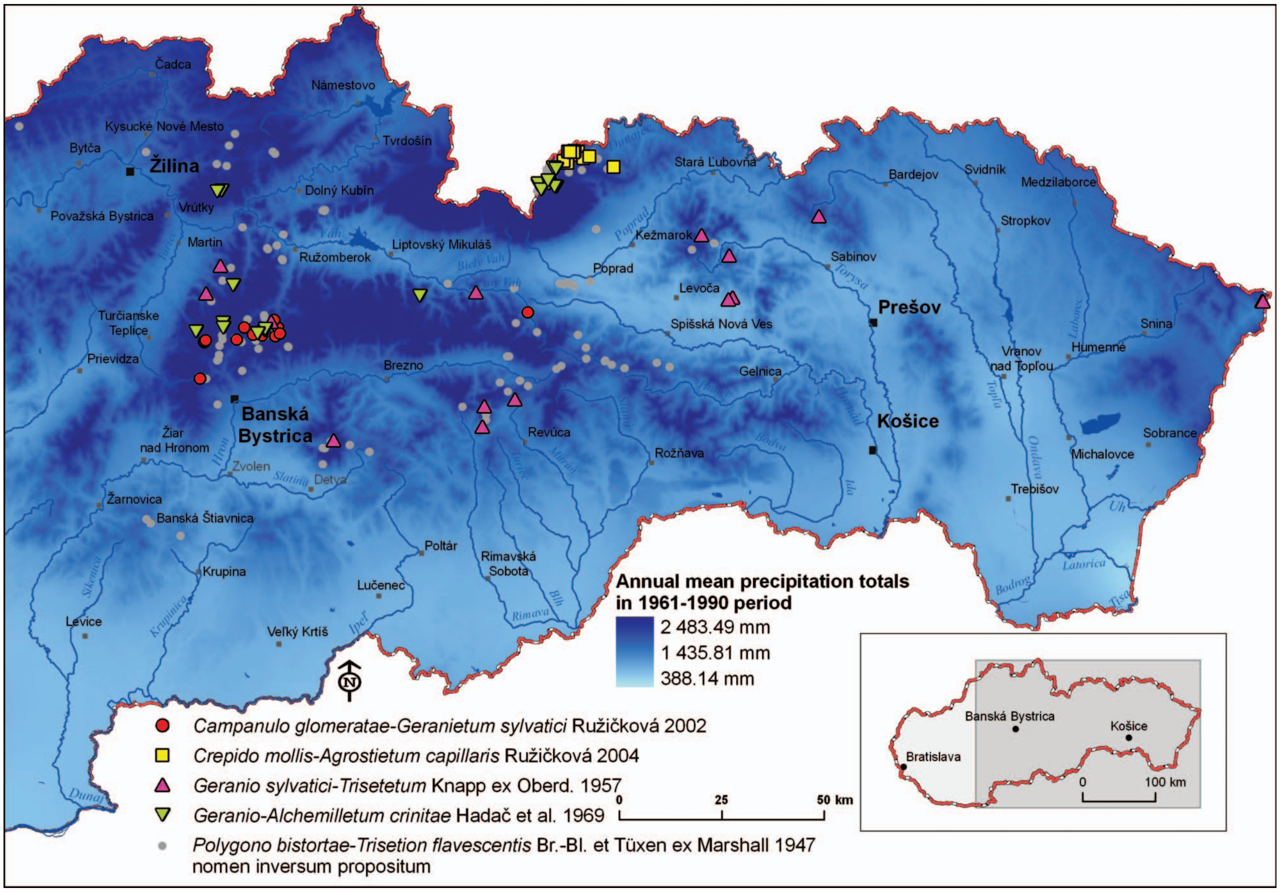

Figure 3. Annual mean precipitation totals in the 1961–1990 period.

relevés, 11,552 of which belonged to the grassland communities originally ordered to the *Molinio-Arrhenatheretea*, *Festuco-Brometea* and *Nardetea strictae*, respectively) was stratified geographically using the program JUICE (Tichý 2002). Only a single relevé of each syntaxon (according to the original author's assignment) per grid square of 1.25 longitudinal × 0.75 latitudinal minute (ca., 1.5 × 1.4 km) was selected. If two or more relevés of the same syntaxon were found in the same grid square, the relevés with a record of a moss layer and more recent relevés were preferred. In the resulting data-set, the records of juvenile trees and shrubs were deleted, because all authors did not record them. For numerical analyses, some taxonomically problematic species that were not distinguished in several relevés were classified within higher or broadly defined taxa. The species aggregates (agg.) follow Marhold and Hindák (1998); the abbreviation "s. l." indicates groups of few species, which are difficult to distinguish or were not distinguished within the group of all relevés or their taxonomy is not convincingly solved (Table I). The stratified data-set, containing 16,640 phytosociological relevés belonging to all syntaxa recorded in Slovakia, was stored in the CDF. From the resulting data-set, 162 relevés of the *Polygono bistortae-Trisetion flavescentis* order by their authors was compiled. The sociological species groups were generated subjectively by the Coctail method (Bruelheide 2000) from the entire stratified data-set. The first species characteristic of the target vegetation unit was chosen and then the programme calculated which of the other species occur most frequently together with the chosen species. The degree of the co-occurrence was calculated for each species using the *phi* coefficient of association (Sokal & Rohlf 1995; Chytrý et al. 2002). The sociological species groups, together with dominance of important species, were used to formulate the definitions of associations using the logical operators AND, OR, NOT and different kinds of brackets (Bruelheide 1997; Kočí et al. 2003; Lososová 2004). Strong dominance of some species was also used as a character in some cases. The definitions have been tested on the data-set from the updated Central Phytosociological Database with new recorded and older unpublished relevés, which contained 43,222 relevés. This data-set was prepared by Jarolímek and Šibík (2008) focussing on statistical estimation of diagnostic species for all syntaxa of the Slovak vegetation. Diagnostic, constant and dominant species for the alliances and associations in the

Table I. List of species merged to aggregates (agg.) or broadly defined taxa (s. lat., sect.)

Taxon name	Included taxa
Achillea millefolium agg.	*A. millefolium*, *A. collina*, *A. pannonica*
Agrostis stolonifera s. lat.	*A. stolonifera*, *A. gigantea*
Alchemilla spec. div.	all species of genus *Alchemilla*
Anthoxanthum odoratum agg.	*A. odoratum*, *A. alpinum*
Campanula rotundifolia agg.	*C. rotundifolia*, *C. moravica*
Dianthus carthusianorum agg.	*D. carthusianorum*, *D. latifolius*
Euphrasia rostkoviana agg.	*E. kerneri*, *E. officinalis*, *E. picta*, *E. rostkoviana*
Festuca rubra agg.	*F. rubra*, *F. diffusa*, *F. nigrescens*
Galium mollugo agg.	*G. album*, *G. mollugo*
Galium pumilum agg	*G. austriacum*, *G. pumilum*, *G. anisophyllon*, *G. fatrense*
Galium verum agg.	*G. verum*, *G. wirtgenii*
Helianthemum nummularium agg.	*H. ovatum*, *H. grandiflorum*, *H. nummularium*
Hylotelephium maximum agg.	*H. maximum*, *H. argutum*
Jacea phrygia agg.	*J. phrygia*, *J. stenolepis*, *J. pseudophrygia*
Leucanthemum vulgare agg.	*L. vulgare*, *L. ircutianum*
Lotus corniculatus agg.	*L. corniculatus*, *L. alpinus*, *L. borbasii*, *L. pedunculatus*, *L. tenuis*
Luzula campestris s. lat.	*L. campestris*, *L. divulgata*, *L. multiflora*
Myosotis scorpioides agg.	*M. palustris*, *M. scorpioides*, *M. laxiflora*, *M. nemorosa*
Myosotis sylvatica agg.	*M. sylvatica*, *M. stenophylla*
Pimpinella saxifraga agg.	*P. saxifraga*, *P. nigra*
Plagiomnium affine agg.	*P. affine*, *P. elatum*, *P. ellipticum*, *P. medium*, *P. rostratum*
Poa pratensis agg.	*P. pratensis*, *P. angustifolia*, *P. humilis*
Polygala amara agg.	*P. amara*, *P. amarella*
Veronica chamaedrys agg.	*V. chamaedrys*, *V. vindobonensis*

synoptic table were calculated by JUICE (Tichý 2002). Diagnostic species were statistically determined on the basis of fidelity concept (Bruelheide 1995; Chytrý et al. 2002, 2006; Chytrý & Tichý 2003; Chytrý 2007). It is ordered according to the value of the *phi* coefficient whose critical value was set to 0.20. Fisher's exact test ($p < 0.001$) was used to eliminate the fidelity value of the species with a non-significant pattern of occurrence. Species fidelities were calculated on the basis of comparison of the relevés of each association with all the other relevés in the data-set of 16,640 relevés. Constant species include the species present in over 40% of relevés ordered according to their frequency. Dominant species were ordered according to the percentage of relevés in which they reach a cover of more than 25%. The internal variation within the associations was assessed by cluster analysis of the relevés, using the PC-ORD 4 program (Mccune & Mefford 1999), with the relative Euclidean distance as a resemblance measure, and Ward's method with logarithmic transformation $b = \log\ (X_{i,j} + 1)$. The optimal number of the clusters was determined by the crispness method using the JUICE software (Tichý 2002). The main environmental gradients in the species composition of the montane meadows based on the Coctail method were analysed using Detrended Correspondence Analysis (DCA) from the CANOCO 4.5 package (ter Braak and Šmilauer 2002). Average Ellenberg indication values (Ellenberg et al. 1992) for relevés were plotted onto a DCA ordination diagram as a supplementary environmental data. For comparative purposes, the clusters of the *Polygono bistortae-Trisetion flavescentis* alliance through the Ellenberg indicator values, Box and Whisker Plots in the STATISTICA 5.5 program, Break down and one-way analysis of variance and Tukey's HSD for unequal N test with α level for critical ranges 0.05 (StatSoft Inc. 2006) were used. The nomenclature follows Marhold and Hindák (1998) for both vascular plants and bryophytes. The nomenclature of syntaxa has been unified according to Jarolímek and Šibík (2008). Nomenclatural revision is according to Weber et al. (2000). The analysis of nomenclature is published by Hegedüšová and Ružičková (2007a). A regular grid-based DEM (digital elevation model) of resolution relevant with respect to the research was generated from the contour lines and height points vectorized from 1:50,000 raster maps. DEM generation was carried out using non-commercial open-source GRASS GIS v6.3 released under the GNU/GPL license. The DEM was used to calculate first derivations of elevation, slope angle and slope aspect in particular (GRASS Development Team 2009). The air temperature and vertical atmospheric precipitation were produced from the raster data-set of mean annual precipitations for the years 1961–1990 (Mikulová et al. 2006; Pecho et al. 2006). The Slovak Hydro-Meteorological Institute provided these data. This long-term average allowed us to calculate the vertical gradient increase (0.6°C

100 m^{-1}) of the mean. The Landscape Atlas of the Slovak Republic was used to generate the map of potential natural vegetation (Maglocký 2002).

Results

According to the formal definitions, four associations can be recognized within this alliance: *Campanulo glomeratae-Geranietum sylvatici*, *Geranio sylvatici-Trisetetum*, *Crepido mollis-Agrostietum capillaris*, *Geranio-Alchemilletum crinitae*. The Coctail method (Table II) was used to create 13 species groups for the formal definitions. The synoptic table reveals the differences in the floristic composition between the associations on the basis of diagnostic, constant and dominant species (Table III). The distribution map of the alliance and associations (Figure 1) shows the relevés before the formalized classification and after matching it to the definitions. The relationship between the defined associations and the environmental factors, together with the Shannon–Wiener diversity index, is shown in Figure 4.

Table II. The sociological species groups created by the Coctail method using a large data-set from the Slovak Phytosociological Database (CDF).

Group name	List of species in groups
Agrostis capillaris	*Anthoxanthum odoratum* agg., *Festuca rubra* agg., *Agrostis capillaris*
Arrhenatherum elatius	*Arrhenatherum elatius, Tragopogon orientalis, Galium mollugo* agg.
Campanula glomerata	*Campanula glomerata* agg., *Aquilegia vulgaris, Lilium bulbiferum*
Cardaminopsis halleri	*Cardaminopsis halleri, Crocus discolor, Primula elatior*
Festuca carpatica	*Saxifraga rotundifolia, Corthusa matthioli, Festuca carpatica, Adenostyles alliariae*
Geranium sylvaticum	*Geranium sylvaticum, Crepis mollis, Phyteuma spicatum*
Heracleum sphondylium	*Heracleum sphondylium, Crepis biennis, Anthriscus sylvestris, Chaerophyllum aromaticum, Geranium pratense*
Trisetum flavescens	*Dactylis glomerata, Taraxacum sect. Ruderalia, Trisetum flavescens*
Pimpinella major	*Pimpinella major, Knautia maxima, Pyrethrum clusii*
Poa alpina	*Poa alpina, Phleum rhaeticum, Ligusticum mutellina*
Scabiosa lucida	*Scabiosa lucida, Phyteuma orbiculare, Thesium alpinum, Carduus glaucinus*
Senecio subalpinus	*Senecio subalpinus, Viola biflora, Acetosa arifolia*
Viola canina	*Viola canina, Polygala vulgaris, Luzula campestris* s.lat.

Table III. Combined synoptic table of the *Polygono bistortae-Trisetion flavescentis* associations defined formally with modified fidelity *phi* coefficient and percentage frequency.

Group No.	30	31	32	33
Association	CgGs	GsT	CmAc	GAc
No. of relevés	14	13	15	20
DS *Campanulo glomeratae-Geranietum sylvatici* Ružičková 2002				
Cirsium erisithales	$\mathbf{54.4}^{57}$	–	$–^{7}$	$–^{10}$
Lilium bulbiferum	$\mathbf{51.8}^{71}$	–	–	–
Campanula glomerata agg.	$\mathbf{41.7}^{\mathbf{100}}$	–	$–^{7}$	12.5^{35}
Silene vulgaris	34.8^{71}	–	$–^{13}$	–
Silene nemoralis	33.2^{29}	–	–	$–^{5}$
Pyrethrum corymbosum	31.9^{57}	–	$–^{7}$	$–^{5}$
Tragopogon orientalis	$31.8^{\mathbf{93}}$	$–^{8}$	14.1^{47}	$–^{10}$
Aquilegia vulgaris	31.2^{43}	–	$–^{7}$	–
Arrhenatherum elatius	$27.2^{\mathbf{93}}$	–	–	$–^{5}$
Knautia arvensis agg.	26.2^{64}	$–^{8}$	$–^{27}$	–
Trifolium montanum	25.6^{79}	–	$–^{27}$	$–^{5}$
Campanula serrata	24.9^{71}	–	$–^{27}$	16.3^{50}
Carlina acaulis	$22.3^{\mathbf{86}}$	–	16.3^{67}	$–^{10}$
Leontodon hispidus	$22.2^{\mathbf{100}}$	13.5^{69}	$–^{33}$	$–^{45}$
Polygala vulgaris	21.3^{57}	–	$–^{20}$	–
Colchicum autumnale	20.7^{64}	–	$–^{40}$	–
DS Geranio sylvatici-Trisetetum Knapp ex Oberd. 1957				
Crepis biennis	16.1^{36}	$\mathbf{49.7}^{\mathbf{100}}$	–	–
Anthriscus sylvestris	$–^{7}$	$\mathbf{48.8}^{\mathbf{85}}$	$–^{7}$	$–^{5}$
Vicia sepium	16.3^{36}	30.0^{62}	15.0^{33}	$–^{25}$
Phleum pratense	$–^{29}$	29.0^{69}	$–^{20}$	$–^{25}$
Chaerophyllum aromaticum	$–^{7}$	26.8^{38}	$–^{20}$	$–^{5}$

(*continued*)

Table III. (*Continued*).

Group No.	30	31	32	33
Association	CgGs	GsT	CmAc	GAc
No. of relevés	14	13	15	20
Dactylis glomerata	20.0^{93}	22.0^{100}	16.4^{80}	$–^{40}$
Lychnis flos-cuculi	–	21.8^{85}	$–^{7}$	$–^{25}$
Cruciata glabra	18.2^{93}	20.1^{100}	14.7^{80}	14.7^{80}
DS *Crepido mollis-Agrostietum capillaris Ružičková 2004*				
Poa chaixii	$–^{7}$	–	31.2^{73}	8.6^{25}
Traunsteinera globosa	$–^{7}$	–	28.2^{27}	–
Ranunculus polyanthemos	14.2^{43}	$–^{8}$	24.0^{67}	–
Trifolium medium agg.	$–^{7}$	$–^{8}$	23.3^{40}	–
Luzula luzuloides	$–^{36}$	$–^{8}$	24.4^{80}	$–^{20}$
Avenula pubescens	$–^{14}$	–	21.6^{40}	–
DS *Geranio-Alchemilletum crinitae Hadač et al. 1969*				
Rhinanthus pulcher	–	–	–	$\mathbf{43.4^{30}}$
Acetosa arifolia	–	$–^{13}$	–	$\mathbf{42.8^{90}}$
Conioselinum tataricum	–	–	–	31.3^{10}
Delphinium elatum	–	–	–	31.1^{10}
Knautia maxima	16.1^{21}	$–^{13}$	–	27.4^{35}
Trollius altissimus	–	–	17.1^{27}	26.5^{40}
Astrantia major	$–^{21}$	–	$–^{7}$	25.5^{35}
Dianthus superbus	–	–	–	22.7^{10}
Myosotis sylvatica agg.	$–^{7}$	–	$–^{20}$	21.2^{25}
DS common for three vegetation types				
Geranium sylvaticum	$\mathbf{46.9^{100}}$	$\mathbf{43.1^{92}}$	17.1^{40}	$\mathbf{44.4^{95}}$
Pimpinella major	34.1^{79}	29.7^{69}	$–^{27}$	23.0^{55}
Phyteuma spicatum	15.0^{36}	$\mathbf{47.1^{100}}$	$\mathbf{43.8^{93}}$	24.6^{55}
DS common for two vegetation types				
Crocus discolor	30.4^{43}	$\mathbf{50.2}^{69}$	13.2^{20}	–
Trisetum flavescens	28.4^{93}	30.9^{100}	$–^{27}$	15.1^{55}
Jacea phrygia agg.	29.0^{79}	–	24.1^{67}	$–^{20}$
Primula elatior	28.9^{79}	$–^{31}$	37.8^{100}	17.1^{50}
Cardaminopsis halleri	$–^{21}$	30.4^{54}	$\mathbf{50.3^{87}}$	$–^{15}$
Campanula patula	16.1^{64}	27.7^{100}	21.2^{80}	$–^{30}$
Heracleum sphondylium	19.5^{50}	38.7^{92}	15.0^{40}	24.0^{60}
Alchemilla vulgaris s.lat.	13.1^{71}	20.9^{100}	19.1^{93}	20.9^{100}
Crepis mollis	13.0^{29}	18.4^{38}	$\mathbf{44.5^{87}}$	$\mathbf{46.4^{90}}$
Other abundant species				
Agrostis capillaries	10.4^{64}	17.8^{92}	18.1^{93}	10.6^{65}
Acetosa pratensis	10.2^{71}	17.4^{100}	10.7^{73}	$–^{10}$
Ae *Trifolium pratense*	11.5^{71}	16.9^{92}	13.7^{80}	$–^{55}$
PT *Hypericum maculatum*	14.7^{71}	$–^{46}$	17.2^{80}	18.6^{85}
Rb-Ae *Veronica chamaedrys agg.*	$–^{36}$	16.4^{85}	15.2^{80}	12.5^{70}
Ae *Leucanthemum vulgare agg.*	13.8^{79}	13.4^{77}	12.4^{73}	$–^{50}$
Vicia cracca	19.4^{79}	$–^{46}$	15.7^{67}	$–^{35}$
C-Bp *Thymus pulegioides*	15.9^{64}	$–^{8}$	14.5^{60}	$–^{5}$
Ns *Stellaria graminea*	14.1^{64}	$–^{46}$	$–^{47}$	8.3^{45}
MA *Ranunculus acris*	$–^{71}$	15.9^{100}	14.3^{93}	$–^{40}$
MA *Trifolium repens*	$–^{50}$	15.9^{92}	9.4^{67}	$–^{25}$
Pt-Ap *Alopecurus pratensis*	–	17.6^{77}	$–^{13}$	8.1^{45}
Ns *Festuca rubra agg.*	$–^{57}$	$–^{15}$	19.1^{100}	10.0^{65}
PT *Potentilla aurea*	$–^{29}$	$–^{8}$	14.3^{47}	19.5^{60}
Deschampsia cespitosa	–	$–^{8}$	8.6^{53}	17.4^{85}
Be *Knautia kitaibelii*	19.8^{43}	–	$–^{7}$	–
Ns *Anthoxanthum odoratum agg.*	$–^{50}$	19.4^{100}	$–^{67}$	$–^{25}$
Taraxacum sect. Ruderalia	$–^{50}$	19.0^{100}	$–^{53}$	$–^{5}$
Viola tricolor	18.7^{29}	–	$–^{7}$	–
Ca-Bm *Dianthus carthusianorum agg.*	18.3^{64}	–	$–^{13}$	$–^{20}$
Ol-Ch *Anthyllis vulneraria*	18.3^{64}	$–^{8}$	$–^{20}$	$–^{5}$
Ae *Rhinanthus serotinus*	17.6^{29}	–	$–^{20}$	$–^{10}$
PT *Pilosella aurantiaca*	–	–	17.6^{27}	$–^{5}$
PT *Trommsdorfia uniflora*	–	–	17.5^{33}	$–^{10}$

(*continued*)

Table III. (*Continued*).

Group No.	30	31	32	33
Association	CgGs	GsT	CmAc	GAc
No. of relevés	14	13	15	20
Ol-Ch *Potentilla heptaphylla*	17.4^{57}	–	$-^{7}$	–
Cc *Bellis perennis*	–	*17.4^{38}*	–	–
C-Bp *Linum catharticum*	*17.1^{57}*	$-^{8}$	–	$-^{5}$
Hu-Ns *Gymnadenia conopsea*	$-^{29}$	–	*17.1^{40}*	$-^{15}$
Briza media	$17.0^{\mathbf{86}}$	$-^{8}$	$-^{47}$	$-^{25}$
MA *Myosotis scorpioides agg.*	–	*15.8^{77}*	–	$-^{25}$
Hu-Ns *Achillea distans agg.*	–	–	*15.2^{20}*	–
Ns *Potentilla erecta*	$-^{14}$	$-^{8}$	*14.8^{73}*	–
Cerastium holosteoides	$-^{29}$	14.4^{69}	$-^{27}$	$-^{20}$
Ns *Gentiana asclepiadea*	–	$-^{8}$	*14.4^{33}*	$-^{20}$
Galium mollugo agg.	14.2^{57}	$-^{38}$	–	$-^{20}$
Ns *Crepis conyzifolia*	$-^{7}$	–	14.0^{27}	$-^{15}$
Ns *Ranunculus nemorosus*	–	–	$-^{25}$	*13.2^{25}*
Lotus corniculatus agg.	$13.0^{\mathbf{86}}$	$-^{46}$	$-^{60}$	$-^{25}$
Fv *Acinos arvensis*	12.9^{36}	–	–	–
Ns *Achillea millefolium agg.*	$11.6^{\mathbf{93}}$	$-^{62}$	$-^{67}$	$-^{45}$
Ol-Ch *Bromus monocladus*	11.1^{21}	–	–	–

The numbers given in the table are percentage values of species fidelity. Their upper indices are the frequency value of a species for a particular vegetation type; dashes mean negative *phi* values. Diagnostic species (DS) with *phi*-coefficient value higher than 0.20 (Fisher's exact test $p < 0.001$) are on a grey background, DS with *phi*-coefficient value higher than 0.40 are in bold. Constant species with frequency over 80 % are in bold.

Ae - *Arrhenatherion elatioris*, Ap - *Alopecurion pratensis*, Be - *Bromion erecti*, C-Bp - *Cirsio-Brachypodion pinnati*, Ca-Bm - *Carici albae-Brometum monocladi*, Cc - *Cynosurion cristati*, Fv - *Festucion valesiacae*, Hu-Ns - *Hypochaerido uniflorae-Nardetum strictae*, MA - *Molinio-Arrhenatheretea*, Ns - *Nardetea strictae*, Ol-Ch - *Orthantho luteae-Caricetum humilis*, Pa - *Poion alpinae*, Pt - *Polygono bistortae-Trisetion flavescentis*, Pt-Ap - *Poo trivialis-Alopecuretum pratensis*, Rb-Ae - *Ranunculo bulbosi-Arrhenatheretum elatioris* (according to Janišová 2007).

Polygono bistortae-Trisetion flavescentis *Br.-Bl. et Tüxen ex Marschall 1947*

Orig. (Marschall 1947): Triseto-Polygonion bistortae (Trisetum flavescens, Polygonum bistorta = Bistorta major).
Syn.: *Triseto-Polygonion bistortae* Br.-Bl. et R. Tx. 1943 (Art. 8), *Rumici-Trisetion* Passarge 1969 (Art. 29c), *Phyteumo-Trisetion* (Passarge 1969) Ellmauer and Mucina 1993 (Syntax. syn.).
Incl.: *Campanulo-Trisetenion* Dierschke 1981 (Art. 5), *Phyteumo-Trisetenion* Passarge 1969.

Campanulo glomeratae-Geranietum sylvatici Ružičková 2002 (Table III, column 1)

Orig. (Ružičková 2002a): Campanulo glomeratae-Geranietum sylvatici.
Formal definition: ((group Geranium sylvaticum or Geranium sylvaticumUP05) and group Campanula glomerata) not (Sanguisorba officinalisUP05 or Festuca rupicolaUP05).

The *Campanulo glomeratae-Geranietum sylvatici* is a two-/three-layer association with a large group of calcareous, rather thermophilous species (*Campanula glomerata agg., Carlina acaulis, Dianthus carthusianorum, Lilium bulbiferum, Plantago media, Silene vulgaris, Thymus pulegioides, Trifolium montanum*) indicating the basic and warm sites of the central western Carpathians, and also the close relationship with the *Arrhenatherion elatioris* alliance (Figure 4). The species *Geranium sylvaticum, Alchemilla* spec. div., *Hypericum maculatum* and graminoids (*Agrostis capillaries, Festuca rubra agg., Nardus stricta, Arrhenatherum elatius*) dominate in these communities. Numerous rare and endangered species occur here as well, and some of them have an endemic character (*Campanula serrata, Crocus discolour and Bromus monocladus*). A distinctive spring aspect is created by *Crocus discolour* and *Primula elatior*. The species *Nardus stricta* indicates the influence of grazing. Ružičková (2002b) described two subassociations, *typicum* and *brometosum*. On the basis of DCA and cluster analysis, two different variants of this vegetation were distinguished. In our opinion, the vegetation of the subassociation *brometosum erecti*that occurs on very steep northeastern, northwestern or southeastern and southwestern slopes should be considered only as a warmer variant due to its intermediate character and closer relationship with the *Arrhenatherion elatioris* alliance. Diagnostic species of this variant are *Aquilegia vulgaris, Securigera varia, Bromus monocladus, Salvia pratensis, Jacea phrygia agg., Pimpinella saxifraga agg., Medicago falcata, Carduus glaucinus, Anemone nemorosa* and *Salvia verticillata*. These meadows are never ploughed nor grazed because of the extreme relief conditions. A characteristic feature of the second variant with *Luzula luzuloides* is the high constancy and cover of the species from the *Polygono bistortae-Trisetion flavescentis*.

Diagnostic species of this variant are *Alchemilla* spec. div., *Rhinanthus minor, Luzula luzuloides, Crepis biennis, Potentilla aurea* and *Pimpinella major*.

The vegetation of the *Campanulo glomeratae-Geranietum sylvatici* association is considered to be a relic of the semi-intensive traditional agriculture in this region. This type of meadows was utilized in the same way for many generations; in many cases, they are considered relicts – semi-natural grasslands. Due to their restricted distribution and vulnerability to abandonment, these meadows need protection.

Fourteen relevés from the stratified data-set respect the conditions of the definition.

Geranio sylvatici-Trisetetum *Knapp ex Oberd. 1957 (nom. amb. rejic. propos.) (Table III, column 2)*

Orig. (Oberdorfer 1957): Geranio sylvatici-Trisetetum Knapp 1951.
Syn.: Agrostidetum vulgaris Szafer et al. 1923 (Art. 36, Syntax. syn.), Agrostidetum vulgaris Szafer et al. 1927 (Art. 31, Syntax. syn.), Trisetum flavescens-Geranium sylvaticum Knapp 1951 (Art. 3b), Melandrio-Trisetetum Moravec 1965 (Syntax. syn.), Cardaminopsio halleri-Agrostietum Moravec 1965 (Syntax. syn.).
Formal definition: Groups Agrostis capillaries, Geranium sylvaticum, Heracleum sphondylium Trisetum flavescens, not Arrhenatherum elatius.

Species-rich, floriferous, relatively homogeneous montane meadows dominated by species of mesophilous meadows of the *Arrhenatherion elatioris* alliance in combination with grasses (*Trisetum flavescens, Agrostis capillaries, Dactylis glomerata*), clovers (*Trifolium repens, T. pratense*) and the broad-leaved montane herb *Geranium sylvaticum*. Nitrophilous species, together with *Trisetum flavescens*, predominate in the fertilized meadows (Figure 4). The species *Agrostis capillaris* becomes dominant after reduction of farming activities or abandonment. The species *Heracleum sphondylium*, indicator of mineral rich soils, is considered to be a good diagnostic species. The historical grassland use is still maintained, involving manuring and mowing twice a year.

Thirteen relevés from the stratified data-set respect the conditions of the definition.

Crepido mollis-Agrostietum capillaris Ružičková *2004 (Table III, column 3)*

Formal definition: Groups Agrostis capillaries, Cardaminopsis halleri, Geranium sylvaticum, not Arrhenatherum elatius, Poa alpine, Nardus stricta UP05, and Trisetum flavescens UP05.

These semi-natural grasslands are regularly mowed and occasionally fertilized. They have an

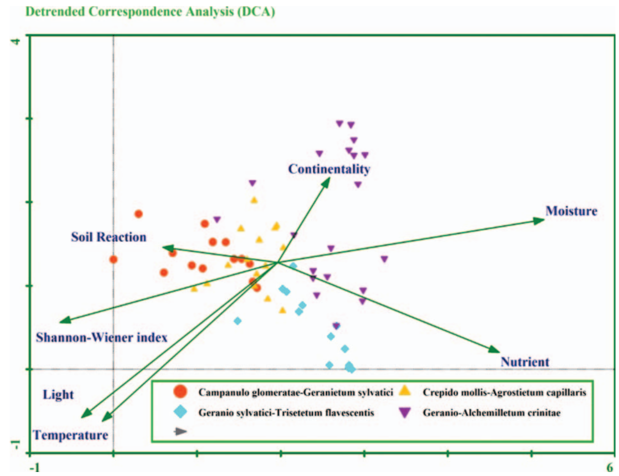

Figure 4. DCA of relevés matched by the association definitions. The average Ellenberg indicator values for relevés were used as supplementary environmental variables. The first and the second axes are shown ($Eig_1 = 0.4249$ and $Eig_2 = 0.3444$).

intermediate position between the *Geranio-Alchemilletum crinitae* (on drier substrata and less humid climate) and *Campanulo glomeratae-Geranietum sylvatici* (on wetter and more humid areas with longer lasting snow cover) (Figure 4) with close relationship to the *Arrhenatherion elatioris* and *Nardo strictae-Agrostion tenuis* alliances (Hadač et al. 1969; Kliment 1994; Ružičková 1997, 2004). The vegetation is rich in species of the *Arrhenatherion elatioris* alliance. They are usually dominated by medium-to-tall grasses of medium-fodder quality (*Agrostis capillaris* and *Festuca rubra* agg.) in combination with species of *Polygono bistortae-Trisetion flavescentis* (mainly *Phyteuma spicatum, Crepis mollis, Primula elatior, Cardaminopsis halleri* and *Geranium sylvaticum*). The geographical position, the microclimatic features and abandonment are the factors mainly affecting the floristic composition and the overall structure of these communities. The original species composition is preserved only if the grasslands are regularly mown or grazed and occasionally fertilized.

Fifteen relevés from the stratified data-set respect the conditions of the definition.

Geranio-Alchemilletum crinitae *Hadač et al. 1969 (Table III, column 4)*

Orig. (Hadač et al. 1969): Geranio-Alchemilletum crinitae (Geranium phaeum, G. sylvaticum).
Syn.: Alchemilleto-Deschampsietum caespitosae Bareš et Hadač 1958 (Art. 2b), Alchemilleto-Festucetum pratensis Bareš et Hadač 1958 (Art. 2b), Alchemillo-Deschampsietum caespitosae Hadač et Smola 1962 (Art. 2b), Alchemilleto-Festucetum pratensis Hadač et Smola 1962 (Art. 2b), Rhinantho-Alchemilletum monticolae Hadač et Smola. 1962 (Art. 2b), Geranio-Alchemilletum crinitae Hadač et Smola 1962 (Art. 2b), Rhinantho-Alchemilletum monticolae Hadač et al.

1969 (Art. 3b), Alchemillo-Deschampsietum caespitosae Hadač et al. 1969 (Art. 36, Syntax. syn.), Alchemillo-Festucetum pratensis Hadač et al. 1969 (Art. 36, Syntax. syn.), Geo-Dactylidetum slovenicae Hadač 1981 (Syntax. syn.), Hyperico-Deschampsietum caespitosae Hadač 1981 (Syntax. syn.), Rhinantho pulchri-Alchemilletum monticolae Hadač et al. ex Kliment 1994 (Syntax. syn.).

Pseud.: Alchemilletum pastoralis sensu Šmarda et al. 1963, 1971 p. p. non Szafer et al. 1927, Deschampsietum caespitosae sensu Unar et al. 1984 non Krajina 1933.

Syntaxonomic remark: Hadač et al. (1969) described the Geranio-Alchemilletum crinitae association without giving any indication of the species of the genus Geranium. Due to the occurrence of both Geranium sylvaticum and G. phaeum in the published relevés as well as in the type-relevé, we consider Geranio-Alchemilletum crinitae to be a valid name.

Formal definition: Group Geranium sylvaticum and (Pimpinella major or Senecio subalpinus or Bistorta major UP05) and Alchemilla spec div. UP05 not groups Arrhenatherum elatius, Cardaminopsis halleri, Festuca carpatica, Poa alpine, Scabiosa lucida, Viola canina and Festuca carpatica UP05.

These chionophilous, two-layer montane meadows occur at the higher altitudes (from 930 to 1500 m) with a long-lasting snow cover (Figures 1, 2, and 3). They contain broad-leaved species (e.g. *Geranium sylvaticum*, *Alchemilla* spec. div., *Crepis mollis*), grasses (*Festuca rubra* agg., *Deschampsia cespitosa*, *Trisetum flavescens*) and some species typical of higher altitudes, such as *Acetosa arifolia*, *Campanula serrata*, *Potentilla aurea*, *Senecio subalpinus* and *Viola biflora*. The species *Hypericum maculatum*, *Bistorta major*, *Astrantia major*, *Ligusticum mutellina*, *Soldanella carpatica* and in some places *Geranium phaeum* or *Trollius altissimus*, prevail sporadically indicating fallow land and leached soils. The species *Rhinanthus pulcher* indicates regular farming. It is considered as a good diagnostic species towards the *Arrhenatherion elatioris* alliance. These stands are often almost monodominant.

Following the DCA and cluster analysis, two variants were distinguished (Figure 4). The fallow land and succession stages of these meadows assign them to the *Pimpinella major* subsp. *rhodochlamys* variant, characterized by the occurrence of the diagnostic species *Campanula serrata, Primula elatior, Trollius altissimus, Knautia maxima, Pimpinella major* subsp. *rhodochlamys, Agrostis capillaris, Ranunculus nemorosus, Dianthus carthusianorum* agg., *Cardamine pratensis* agg. They are found in the Vel'ká Fatra Mts (Kliment 1994), the Malá Fatra Mts and the Nízke Tatry Mts (Unar et al. 1984) and were described by Kliment (1994) as the *avenochloetosum planiculmis* and *acetosetosum alpestris* subassociations (variant *Festuca pratensis*, variant *typicum*). Diagnostic species of the *Trisetum flavescens* variant are *Alopecurus pratensis, Trisetum flavescens, Phyteuma spicatum, Rhinanthus pulcher, Campanula patula, Bistorta major, Festuca rubra* agg., *Poa trivialis, Phleum pratense, Lychnis flos-cuculi, Anthoxanthum odoratum* agg., *Leontodon hispidus*, *Rhinanthus minor*, *Luzula campestris* s. lat. It can be found in Západné and Belianske Tatry Mts. Ružičková (1997) described this vegetation as the *Geranio-Alchemilletum crinitae T. flavescentis*. Its species composition is also very similar to the associations described by Hadač et al. (1969) from Belianske Tatry Mts, where the species *Geranium phaeum, Hypecicum montanum, Festuca pratensis, Deschampsia caespitose* and *Rhinanthus pulcher* prevail. Due to abandonment, these stands no longer exist. The *Alchemilla* spec. div. montane meadows 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 nonutilization. It is necessary to ensure their traditional use in order to maintain their diversity.

Ordination analysis – Main environmental gradients responsible for the variation in floristic composition of the studied vegetation

The scatter plot of the DCA (Figure 4) based on the individual relevés shows the distribution of particular vegetation types along the first and second ordination axis (the eigenvalues of the first two axes are 0.4249 and 0.3444). The average Ellenberg indicator values for relevés plotted onto an ordination diagram reveal that environmental factors are most important for variation of the species data. The main compositional gradient of the *Polygono bistortae-Trisetion flavescentis* montane meadows strongly positively correlates with moisture and nutrient availability and negatively with the Shannon–Wiener index and soil reaction. The second axis correlates positively with continentality. The distribution of relevés in the ordination diagram shows a continuous transition between the associations. The transitional type represents the *Crepido mollis-Agrostietum capillaris*, which is at the middle of the ordination diagram. This association occurs in the alluvium of streams and on a remote mountain ridges. Although meadows of the *Geranio sylvatici-Trisetetum flavescentis* occur in the nutrient-rich soils with intense utilization and fertilization (in the lower part of the scatter), they are also found in the middle part of the ordination diagram. This is due to its occurrence being conditioned by specific local climate, such as long-term inversions and impervious soils and also by the presence of mesophilous species of the *Arrhenatherion elatioris*. It represents the most productive nutrient-demanding vegetation type. The relevés of the *Geranio-Alchemilletum* *crinitae* are situated on the opposite end of the ordination diagram; they prefer the coldest places with a humid climate, and a long-lasting snow cover in the mountain areas. There are remarkable differences between the two variants, confirming both methods (cluster analysis and DCA). The *Pimpinella major* subsp. *rhodochlamys* variant is more continental and occurs on the unutilized sites where species from the *Arrhenatherion elatioris* are absent. The *Trisetum flavescens* variant occurs on more nutrient-rich sites with grasses of higher fodder quality indicative of mowing and exploitation. This variant has an intermediate character. The occurrence of the *Campanulo glomeratae-Geranietum sylvatici* is positively correlated with soil reaction. It is also reflected in the accepted syntaxonomical classification. These associations occur on alkaline soils at higher altitudes with a large group of species typical for mesophilous meadows and warmer sites.

The relationship of the defined associations to individual environmental factors is shown in Figure 5. Tukey's HSD for unequal N test was significant for all Ellenberg indicator values ($P < 0.05$). A comparison of clusters (Figure 5) shows that cluster 4 (*Geranio-Alchemilletum crinitae*) includes the moistest stands with the lowest nutrient and light requirements and the occurrence on the coldest localities; cluster 1 (*Campanulo glomeratae-Geranietum sylvatici*) includes the driest types of stands with the highest light and the lowest nutrient requirements. Cluster 2 (*Geranio sylvatici-Trisetetum flavescentis*) includes stands with the highest nutrient requirements.

Discussion and conclusions

Re-evaluation of the traditional approach to classification

The main aim of this study was to re-evaluate the traditional approach to the classification of mesophilous montane meadows and to perform a syntaxonomical revision. The traditional phytosociological approaches to vegetation description and classification are frequently criticized (Roleček 2007). The results of formalized classification

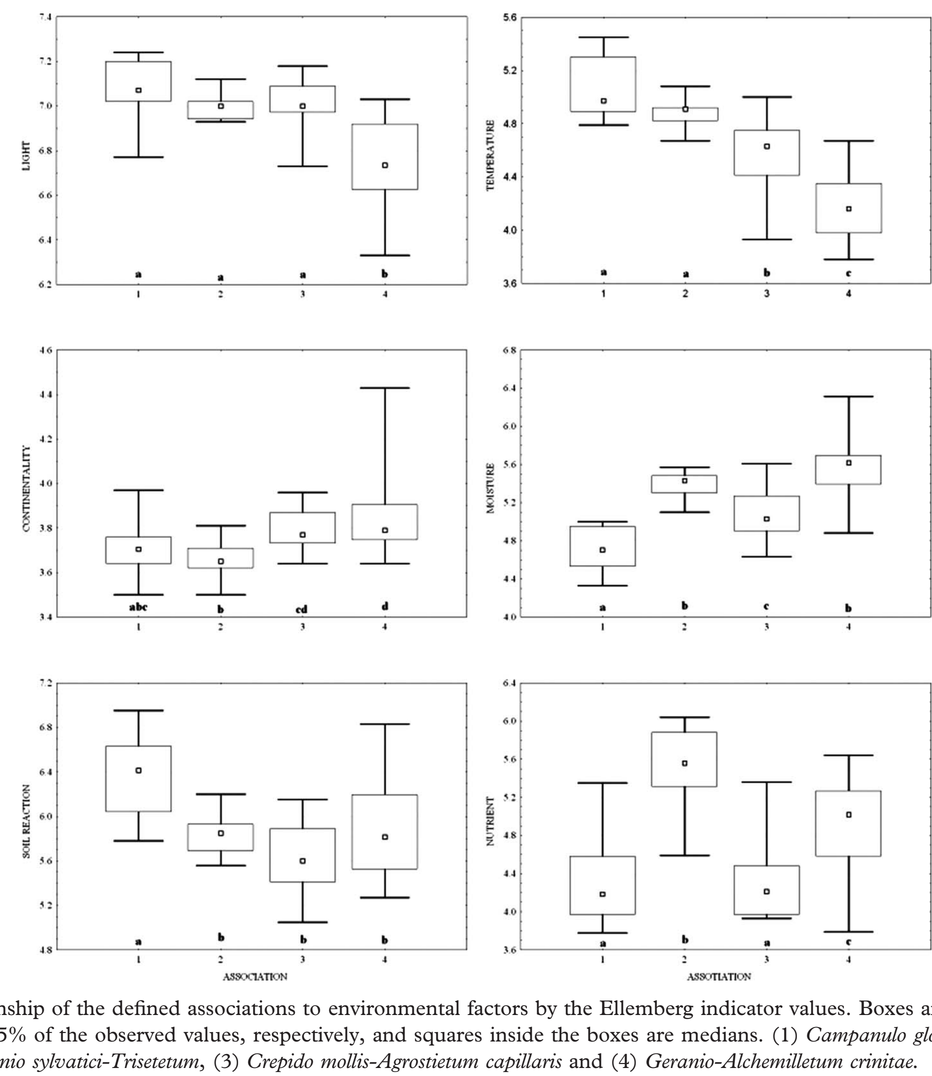

Figure 5. Relationship of the defined associations to environmental factors by the Ellenberg indicator values. Boxes and whiskers include 25–75% and 5–95% of the observed values, respectively, and squares inside the boxes are medians. (1) *Campanulo glomeratae-Geranietum sylvatici*, (2) *Geranio sylvatici-Trisetetum*, (3) *Crepido mollis-Agrostietum capillaris* and (4) *Geranio-Alchemilletum crinitae.*

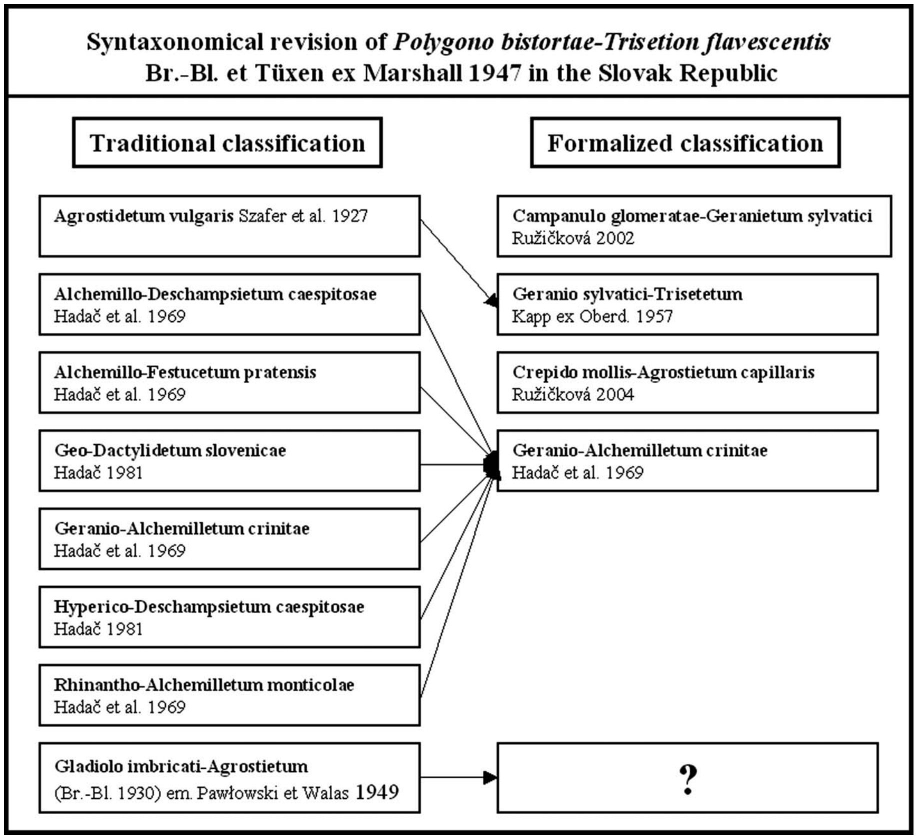

Figure 6. Comparison between traditional and formalized classifications.

pointed out that the Coctail method can be used to reproduce the traditional phytosociological classification. This is in accord with the results of Kočí et al. (2003), Hájková et al. (2005, 2006), Havlová (2006), Lososová (2004), Dítě et al. (2007), Janišová (2007) and Douda (2008) who showed that the method can reproduce the traditional classification of vegetation. On the other hand, traditional classification offers an overview to local variability, peculiarity and diversity of the vegetation. Hence, in the first step of the classification, the traditional classification was confronted with the results of several numerical analyses of the data-set (ordinations and cluster analysis) to check the validity of the traditional associations (Hegedüšová & Ružičková 2007). The Formal Coctail definitions were formulated only for those associations that were found to be meaningful (i.e. mainly ecologically interpretable, unique and broad enough).

What does the syntaxonomical revision of the classification bring?

Our syntaxonomical revision led to a substantial simplification of the classification system of the *Polygono bistortae-Trisetion flavescentis* alliance. Four major and ecologically well-defined associations were distinguished for Slovakia: (1) *Campanulo glomeratae-Geranietum sylvatici*, (2) *Geranio sylvatici-Trisetetum*, (3) *Crepido mollis-Agrostietum capillaries* and (4) *Geranio-Alchemilletum crinitae*. Apart from these discussed associations, seven more associations of the study alliance were distinguished in a List of Vegetation Units of Slovakia (Mucina & Maglocký 1985). Vegetation classification reflects environmental and phytogeographical gradients that influence species composition (Knollová & Chytrý 2004). As the significance of gradient depends on the size of the studied area, it is no wonder that various similar vegetation units have been described in the past,

Table IV. Annual mean air temperature (°C) and annual mean precipitation (mm) in the 1961–1990 period.

Polygono bistortae-Trisetion flavescentis Br.-Bl. et Tüxen ex Marschall 1947		
Syntaxa	Annual mean air temperature in 1961–1990 period (°C)	Annual mean precipitation in 1961–1990 period (mm)
Geranio-Alchemilletum crinitae	3.05	1177.98
Geranio sylvatici-Trisetetum	4.46	1027.83
Campanulo glomeratae-Geranietum sylvatici	4.82	1161.96
Crepido mollis-Agrostietum capillaris	4.96	946.21

differing from each other mainly by the presence or absence of regionally specific taxa (Šibík et al. 2008). The associations *Alchemillo-Deschampsietum caespitosae*, *Alchemillo-Festucetum pratensis*, *Geo-Dactylidetum slovenicae*, *Hyperico-Deschampsietum caespitosae* and *Rhinantho-Alchemilletum monticolae* were described by Hadač et al. (1969, Hadač 1981) on the basis of high cover of some dominant species and some of them on the basis of few relevés. It had to be decided whether the associations, which could have been defined primarily on the basis of dominance, could be defined and accepted. Due to the impossibility to formally define them, and according to the classification, these units should not be considered as separate syntaxa,

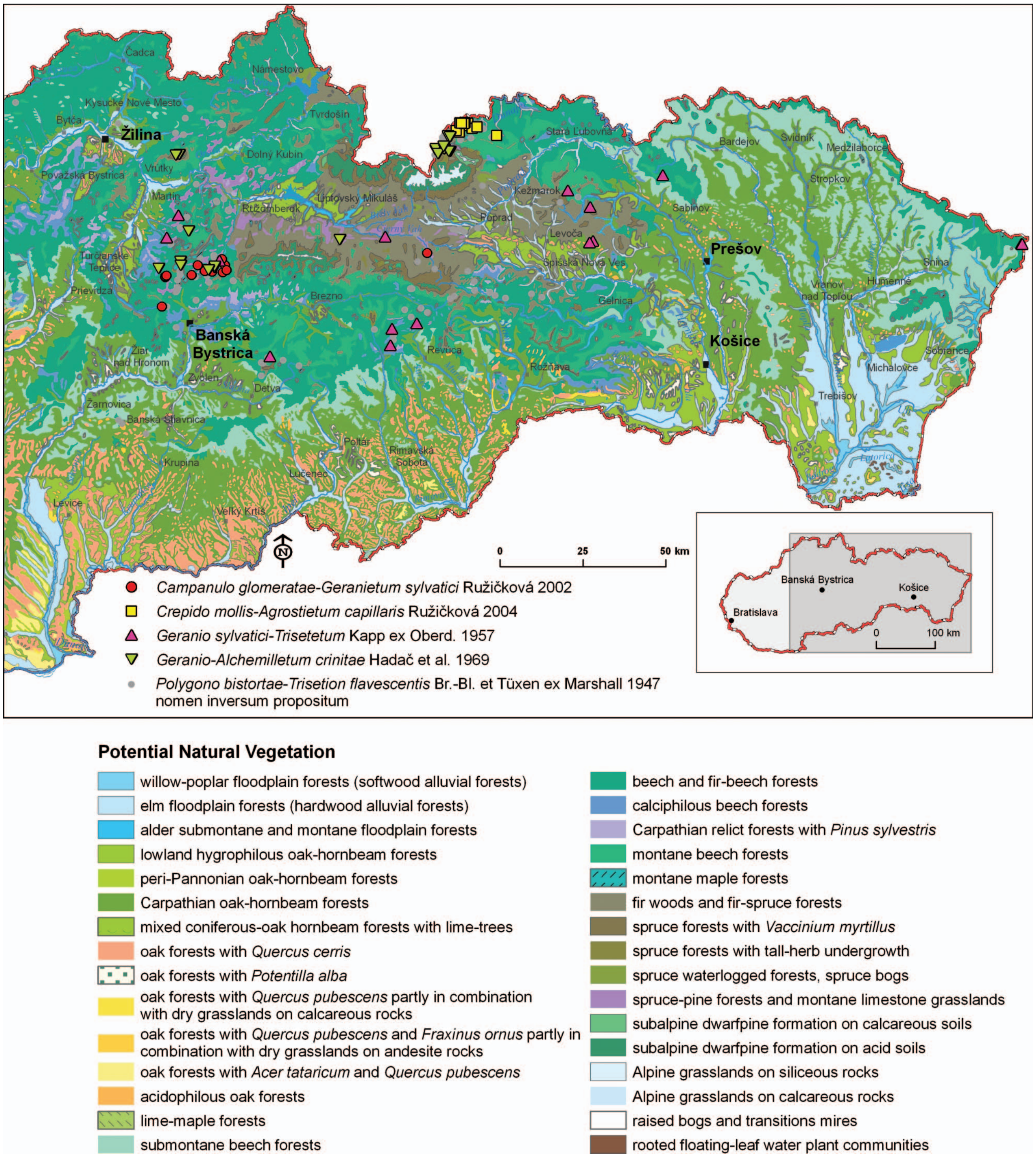

Figure 7. Map of contemporary potential natural vegetation of Slovakia.

Table V. Correlation between the *Polygono bistortae-Trisetion flavescentis* associations and the potential natural vegetation.

Polygono bistortae-Trisetion flavescentis Br.-Bl. et Tüxen ex Marschall 1947	
Syntaxa	Potential natural vegetation
Campanulo glomeratae-Geranietum sylvatici	Montane beech forests
	Alder submontane and montane floodplain forests
	Beech and fir-beech forests
	Spruce-pine forests and montane limestone grasslands
Crepido mollis-Agrostietum capillaris	Beech and fir-beech forests
	Alder submontane and montane floodplain forests
	Beech and fir-beech forests
	Calciphilous beech forests
	Carpathian oak-hornbeam forests
	Fir woods and fir-spruce forests
	Montane beech forests
	Oak forests with Quercus cerris
	Spruce-pine forests and montane limestone grasslands
Geranio sylvatici-Trisetetum	Beech and fir-beech forests
	Fir woods and fir-spruce forests
	Montane beech forests
Geranio-Alchemilletum crinitae	Beech and fir-beech forests
	Fir woods and fir-spruce forests
	Spruce forests with tall-herb undergrowth
	Montane beech forests
	Spruce waterlogged forests, spruce bogs
	Fir woods and fir-spruce forests

and their assignment to one association, namely *Geranio-Alchemilletum crinitae* Hadač et al. 1969, is proposed. We considered them as synonyms also because all characteristics of this vegetation fit the definition of the *Geranio-Alchemilletum crinitae* (obvious from the Figure 6). They do not have their own diagnostic species and represent only successional stages. The *Gladiolo imbricati-Agrostietum* association described by Pawłowski et al. (1960) does not exist in Slovakia. Some characteristic species, such as *Centaurea jacea* subsp. *oxylepis*, *Alchemilla walasii*, *Euphrasia stricta* and *Viola saxatilis*, are absent here as well.

Advantages and disadvantages of the formalized classification

From the entire stratified data-set, only 62 relevés were assigned by Coctail definitions to the *Polygono bistortae-Trisetion flavescentis*, which covered 38% of the 162 relevés assigned to the alliance (Figure 1). Common conclusions are that formalized classification by sociological species groups can be a valid instrument to record ecologically interpretable, clear vegetation types without successional stages or marginal vegetation types. A possible drawback of this method, however, is that only 38% could be assigned to the alliance. The positive and negative aspects of this method, as well as the problem with definitions, are also found in Roleček (2007).

The most important environmental factors

Based on Ellenberg indicator values, there are three major environmental gradients in the species composition of the montane mesophilous meadows. The first is connected with moisture, the second with nutrients and the third with light conditions (Figures 4 and 5, Table IV). Another significant factor is temperature as related to the geographic location as well as altitude. Climatic differences are shown by continentality (Figures 2, 3, and 4).

Vulnerability

In the past, the meadows of the *Polygono bistortae-Trisetion flavescentis* were cut twice a year in combination with occasional grazing. Recently, the majority of these meadows are not cut, and are seriously endangered by succession, afforestation or by conversion to downhill courses, not only in central Europe but also in the whole European context. The map of contemporary Potential Natural Vegetation of Slovakia shows the vegetation type that would develop nowadays under the climatic, soil and hydrologic conditions of the studied area if the influence of human activities were to cease. The potential vegetation is constructed with reference to present-day climatic and natural conditions (Figure 7, Table V).

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