Subxerophilous and mesophilous grasslands of the White Carpathian Mts. in Slovakia.

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Introduction

The vegetation of meso- and subxerophilous grasslands of the White Carpathian Mts. in Slovakia are famous for their high species richness: sometimes, up to 80 species of vascular plants may occur in a plot of just 25 m2. Such incredible species diversity is a result of the long-term care of grasslands (regular mowing and grazing) and rather variable environmental conditions. In our research, we have focused on several environmental variables with the aim to find a degree they are responsible for species composition in studied plant communities.

Aims

Syntaxonomical classification of meso- and subxerophilous grassland vegetation

- Analysis of the main gradients of species composition
- Evaluation of the effect of environmental factors on species composition of grasslands

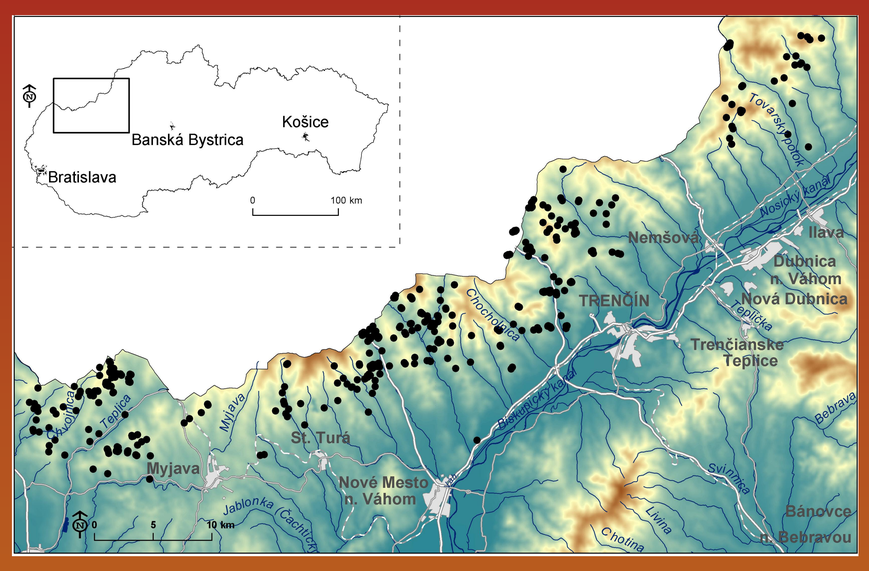
Methods

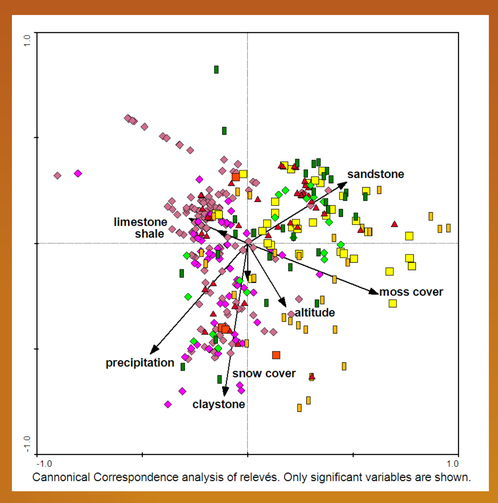
During the last 15 years we collected 343 phytosociological relevés from subxerophilous and mesophilous grasslands from the Slovak part of White Carpathian Mts. For the syntaxonomical analysis we used expert system for identification of grasslands in Slovakia (Janišová et al. 2007). Diagnostic species for the clusters were determined over the calculation of fidelity of each species to each cluster, using the phi coefficient of the association (Chytrý et al. 2002) in the program JUICE 6.5.54 (Tichý 2002). Threshold fidelity value for diagnostic species was set to 5 (species with phi>10 are printed in bold), threshold frequency value for constant species was set to 50 (species with frequency higher than 80 are printed bold) and the threshold frequency value for dominant species was up to 25.

The main gradients of species composition were analyzed by the detrended correspondence analysis (DCA) in the CANOCO 4.5 package (ter Braak & Šmilauer 2002). For the ecological interpretation of ordination axes, the average Ellenberg's indicator values (Ellenberg et al. 1992) for the relevés were plotted onto the DCA ordination diagram as the supplementary environmental data.

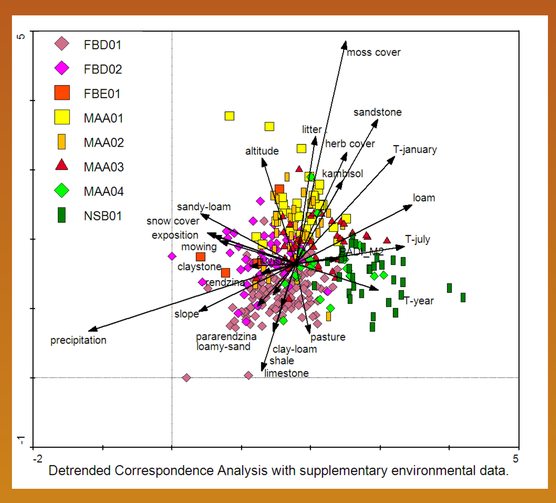
The relationship between species composition and defined environmental factors was analyzed over the canonical correspondence analysis (CCA) using the CANOCO 4.5 package (ter Braak & Šmilauer 2002). For each relevé the information on various ecological factors were determined and recorded - topographical factors, biological variables as well as the management. By means of geographical coordinates the additive data were obtained from the GIS digital layers for each relevé. A regular grid-based DEM of resolution relevant with respect to the research was generated from 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 GNU/GPL license. The DEM was used to calculate first derivations of elevation, slope angle and slope aspect in particular. Air temperature and vertical atmospheric precipitation were produced from rasters of mean annual precipitations for the years between 1961-1990. The source data were provided by the Slovak Hydro-meteorological Institute. Information on geological settings in 1:50 000 scale were acquired from State Geological Institute of Dionyz Stur. The Landscape Atlas of the Slovak Republic was the information source on soil types.

The correlation of all environmental variables was tested in the program Statistica for windows 5.5. 0All studied environmental factors were tested by the Monte Carlo permutation test with unrestricted permutations (999 permutations, P = 0.05). Finally, the pure effect (where the percentage variance is explained by the variable while the remaining significant variables were used as co-variables) was calculated. Pure variance is expressed as % of total inertia.





Cannonical Correspondence analysis of relevés. Only significant variables are shown.



Detrended Correspondence Analysis with supplementary environmental data.

Environmental variables used in the Canonical Correspondence Analysis:

management

- *mowing - three values 0 – non-mowed, 1 - irregularly mowed, 2 - regularly mowed*
- *grazing - 1 - grazed, 0 – non-grazed*

topographical factors

- *radiation - the potential annual direct irradiation (PADI) by McCune and Keon (2002) estimated over the slope, aspect and latitude*
- *inclination - slope inclination (°)*
- *altitude - m a.s.l*

biological variables

- *litter – cover of dead plant biomass (%)*
- *E1 - cover of herb layer (%)*
- *E0 - cover of moss layer (%)*

climatic factors

- *average annual precipitation*
- *average annual temperature*
- *average temperature in July*
- *average temperature in January*
- *average number of days with snow cover*

geology and soil factors

- *soil type (fluvisol, kambisol, pararendzina, rendzina)*
- *soil texture (loam, loamy-sand, clay-loam, sandy-loam)*
- *geological bedrock (limestone, sandstone, claystone, shale)*

Results

Expert system has identified 205 phytosociological relevés. Rest of relevés (138) was arranged to defined associations on the base of similarity indices (FPFI – Frequency-positive fidelity index).

Eight grassland communities were distinguished:

***Festuco-Brometea* Br.-Bl. et Tüxen ex Soó 1947**

***Bromion erecti* W. Koch 1926**

FBD01 *Brachypodio pinnati-Molinietum arundinacae* Klika 1939

FBD02 *Onobrychido viciifoliae-Brometum erecti* T. Müller 1966

***Cirsio-Brachypodion pinnati* Hadač et Klika ex Klika 1951**

FBE 01 *Scabioso ochroleucae-Brachypodietum pinnati* Klika 1933

***Molinio-Arrhenatheretea* Tüxen 1937**

***Arrhenatherion* Koch 1926**

MAA01 *Ranunculo bulbosi-Arrhenatheretum* Ellmauer 1993

MAA02 *Pastinaco sativae- Arrhenatheretum elatioris* Passarge 1964

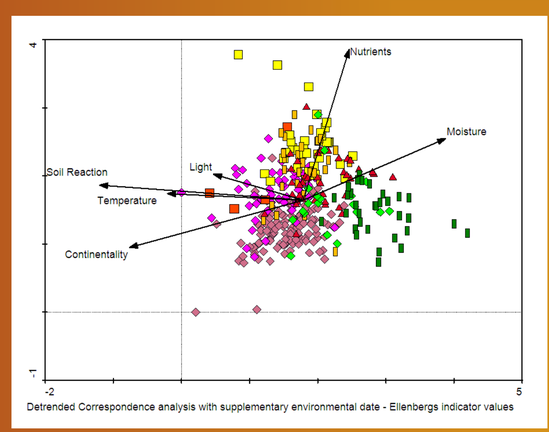
MAA03 *Poo-Trisetetum flavescentis* Knapp ex Oberdorfer 1957

MAA04*Anthoxantho-Agrostietum tenius* Sillinger 1933

***Nardetea strictae Rivas Goday et Borja Carbonell* 1961**

***Violion caninae* Schwickerath 1944**

NSB01 *Festuco capillatae-Nardetum strictae* Klika et Šmarda 1944



Detrended Correspondence analysis with supplementary environmental date - Ellenbergs indicator values

Axes	1	2	3	4	Total inertia
Eigenvalues	0.077	0.048	0.04	0.026	8.056
Species-environment correlations	0.573	0.467	0.56	0.507	
Cumulative percentage variance					
of species data	1	1.6	2	2.4	
of species-environment relation	33.8	54.9	72.3	83.8	
Sum of all eigenvalues					8.056
Sum of all canonical eigenvalues					0.228

CCA - variance explaned by variables						
Environmental variable	Conditional effect (selection order)	%	Marginal effect	%	Pure effect	%
moss cover	0.050	0.62	0.051	0.63	0.049	0.61
precipitation	0.045	0.56	0.046	0.57	0.043	0.53
altitude	0.036	0.45	0.026	0.32	0.026	0.32
claystone	0.035	0.43	0.036	0.45	0.016	0.20
aver. year temp.	0.034	0.42	0.037	0.46	0.015	0.19
snow cover	0.033	0.41	0.025	0.31	0.015	0.19
sandstone	0.027	0.34	0.014	0.17	0.014	0.17
limestone	0.025	0.31	0.031	0.38	0.036	0.45
shale	0.018	0.22	0.029	0.36	0.032	0.40

Conditional effect - additional variance explaned by the variable at the time it was included in the forward selectin. **Marginal effect -** variance explaned by the variable while used as the only constraining variable. **Pure effect** - variance explaned by the variable after all other significant variables were used as covariables

As some climatic factors were correlated with altitude, two factors with the smallest effect to the species variability were excluded from the analysis (average temperature in July and in January). The first CCA axis produced 1 % variance of the species data and 33.8 % of the species–environment relationship.

The results of direct gradient analysis (CCA) show that all the 27 environmental variables explained 7.83 % of the variability of the species data. The 9 factors which were significant in the Monte Carlo permutation test explained 3.77 % of the whole variability and 3.31 % when other environmental variables were put into CCA analysis as covariables.

The effect of selected factors is smaller that we have expected. It is probably caused by the fact that the composition of vegetation depends on complex influence of many environmental variables. As lot of environmental variables was not significant in Monte Carlo permutation test, all factors were used also in DCA analysis as supplementary data.

The DCA analysis of relevés with Ellenberg's indicator values as supplementary data demonstrated, that the firs axes is negatively correlated with soil reaction and temperature, the second axes with nutrients.

Brachypodio pinnati-Molinietum arundinacae (J. Škodová)

***Brachypodio pinnati-Molinietum arundinacae* Klika 1939** (131 relevés)

Diagnostic species: ***Cirsium pannonicum, Lathyrus latifolius, Carex montana, Betonica officinalis, Tanacetum corymbosum, Chamaecytisus supinus, Hypochaeris maculata, Melampyrum cristatum, Filipendula vulgaris, Thesium linophyllon, Brachypodium pinnatum, Trifolium rubens, Prunella grandiflora, Traunsteinera globosa, Campanula glomerata, Inula salicina, Peucedanum cervaria, Trifolium montanum, Helianthemum ovatum, Potentilla alba, Campanula persicifolia, Scorzonera purpurea, Clematis recta, Trifolium alpestre, Polygala major, Ranunculus polyanthemos, Centaurea jacea, Primula veris, Gymnadenia conopsea, Cruciata glabra, Tragopogon orientalis, Serratula tinctoria, Geranium sanguineum, Koeleria pyramidata agg., Salvia pratensis, Carlina acaulis, Lathyrus niger, Genista tinctoria, Knautia arvensis, Viola canina, Anthericum ramosum, Vicia tenuifolia, Avenula pubescens, Centaurea scabiosa, Galium verum, Valeriana stolonifera ssp. angustifolia, Ranunculus auricomus, Agrostis capillaris, Aquilegia vulgaris, Ajuga reptans, Viola hirta, Ononis spinosa, Medicago falcata, Veronica teucrium, Euphorbia cyparissias, Dactylis glomerata, Potentilla heptaphylla***

Constant species: ***Filipendula vulgaris, Dactylis glomerata, Carex montana, Achillea millefolium agg., Primula veris, Salvia pratensis, Brachypodium pinnatum, Cruciata glabra, Plantago lanceolata, Cirsium pannonicum, Campanula glomerata, Briza media, Trifolium montanum, Ranunculus polyanthemos, Anthoxanthum odoratum agg., Leontodon hispidus,*** *Tragopogon orientalis, Centaurea jacea, Lotus corniculatus, Bromus erectus, Leucanthemum vulgare agg., Betonica officinalis, Viola hirta, Trisetum flavescens, Arrhenatherum elatius, Lathyrus latifolius, Galium verum, Carlina acaulis, Plantago media, Luzula campestris agg., Festuca rubra agg., Rumex acetosa, Prunella vulgaris, Agrostis capillaris, Festuca pratensis, Pimpinella saxifraga agg., Potentilla heptaphylla, Taraxacum sect. Ruderalia, Linum catharticum, Hypochaeris maculata, Helianthemum ovatum, Vicia cracca, Knautia arvensis, Festuca rupicola, Campanula patula, Alchemilla species, Trifolium pratense*

Dominant species: *Bromus erectus, Brachypodium pinnatum, Carex montana, Arrhenatherum elatius*

Onobrychido viciifoliae-Brometum erecti (M. Janišová)

***Onobrychido viciifoliae-Brometum erecti* T. Müller 1966** (51 relevés)

Diagnostic species: ***Bromus erectus, Salvia pratensis, Onobrychis viciifolia, Plantago media, Festuca rupicola, Salvia verticillata, Teucrium chamaedrys, Pimpinella saxifraga agg., Sanguisorba minor***

Constant species: ***Salvia pratensis, Bromus erectus, Pimpinella saxifraga agg., Plantago media, Achillea millefolium agg., Plantago lanceolata, Arrhenatherum elatius,*** *Leucanthemum vulgare agg., Lotus corniculatus, Briza media, Trisetum flavescens, Festuca rupicola, Dactylis glomerata, Trifolium montanum, Anthoxanthum odoratum agg., Primula veris, Viola hirta, Leontodon hispidus, Trifolium pratense, Centaurea jacea, Veronica chamaedrys, Linum catharticum, Vicia cracca, Potentilla heptaphylla, Galium verum, Campanula patula, Sanguisorba minor, Poa pratensis agg., Luzula campestris agg., Campanula glomerata, Tragopogon orientalis, Prunella vulgaris, Daucus carota, Rumex acetosa, Filipendula vulgaris*

Dominant species: ***Bromus erectus,*** *Cirsium pannonicum*

***Scabioso ochroleucae-Brachypodietum pinnati* Klika 1933** (4 relevés)

Diagnostic species: ***Prunella laciniata, Securigera varia, Agrimonia eupatoria***

Constant species: ***Viola hirta, Securigera varia, Sanguisorba minor, Potentilla heptaphylla, Poa pratensis agg., Lotus corniculatus, Leontodon hispidus, Knautia kitaibelii, Festuca rupicola, Euphorbia cyparissias, Dactylis glomerata, Brachypodium pinnatum, Agrimonia eupatoria,*** *Trisetum flavescens, Thymus pulegioides, Salvia pratensis, Prunella laciniata, Primula veris, Plantago media, Plantago lanceolata, Ononis spinosa, Linum catharticum, Leucanthemum vulgare agg., Hypericum perforatum, Galium verum, Fragaria viridis, Asperula cynanchica, Arrhenatherum elatius, Achillea millefolium agg.*

Dominant species: *Brachypodium pinnatum, Viola hirta, Teucrium chamaedrys, Arrhenatherum elatius*

Scabioso ochroleucae-Brachypodietum pinnati (J. Škodová)

***Poo-Trisetetum flavescentis* Knapp ex Oberdorfer 1957** (40 relevés)

Diagnostic species: ***Cirsium arvense, Stellaria graminea, Ranunculus acris, Carex pallescens***

Constant species: ***Plantago lanceolata, Anthoxanthum odoratum agg., Dactylis glomerata, Achillea millefolium agg., Rumex acetosa, Leontodon hispidus, Veronica chamaedrys, Trifolium pratense, Pimpinella saxifraga agg., Luzula campestris agg., Lotus corniculatus,*** *Arrhenatherum elatius, Taraxacum sect. Ruderalia, Festuca rubra agg., Briza media, Ranunculus acris, Cruciata glabra, Campanula patula, Trisetum flavescens, Leucanthemum vulgare agg., Alchemilla species, Trifolium repens, Tragopogon orientalis, Festuca pratensis, Cerastium holosteoides, Primula veris, Vicia cracca, Bromus erectus, Carex pallescens, Stellaria graminea, Filipendula vulgaris, Ranunculus polyanthemos, Colchicum autumnale, Agrostis capillaris*

Dominant species: *Bromus erectus, Arrhenatherum elatius, Anthoxanthum odoratum agg., Festuca rubra agg., Trifolium medium, Holcus lanatus, Festuca rupicola, Cruciata glabra, Brachypodium pinnatum, Agrostis capillaris*

***Festuco capillatae-Nardetum strictae* Klika et Šmarda 1944** (32 relevés)

Diagnostic species: ***Nardus stricta, Polygala vulgaris, Betula pendula, Luzula luzuloides, Veronica officinalis, Hypochaeris radicata, Danthonia decumbens, Salix cinerea (juv.), Hieracium murorum, Picea abies, Hypericum maculatum, Populus tremula (juv.), Agrostis capillaris, Potentilla erecta, Hieracium pilosella, Stellaria graminea, Calluna vulgaris, Holcus lanatus, Luzula campestris agg., Ranunculus acris, Rumex acetosa, Thymus pulegioides***

Constant species: ***Plantago lanceolata, Anthoxanthum odoratum agg., Achillea millefolium agg., Rumex acetosa, Polygala vulgaris, Pimpinella saxifraga agg., Luzula campestris agg., Lotus corniculatus, Leontodon hispidus, Briza media, Agrostis capillaris, Potentilla erecta, Cruciata glabra, Alchemilla species,*** *Ranunculus acris, Campanula patula, Leucanthemum vulgare agg., Veronica officinalis, Festuca rubra agg., Thymus pulegioides, Stellaria graminea, Prunella vulgaris, Hypericum maculatum, Veronica chamaedrys, Nardus stricta, Carlina acaulis, Trifolium repens, Holcus lanatus, Carex pallescens, Trifolium medium, Danthonia decumbens, Centaurea jacea, Trifolium pratense*

Dominant species: *Leontodon hispidus, Nardus stricta, Festuca rubra agg., Carex montana, Festuca rupicola*

***Ranunculo bulbosi-Arrhenatheretum* Ellmauer 1993** (30 relevés)

Diagnostic species: ***Daucus carota, Ranunculus bulbosus, Polygala comosa, Plantago media, Medicago lupulina, Fragaria viridis, Trifolium repens***

Constant species: ***Plantago lanceolata, Arrhenatherum elatius, Anthoxanthum odoratum agg., Plantago media, Leontodon hispidus, Briza media, Achillea millefolium agg., Veronica chamaedrys, Lotus corniculatus, Leucanthemum vulgare agg., Trifolium pratense, Pimpinella saxifraga agg., Daucus carota,*** *Trisetum flavescens, Salvia pratensis, Dactylis glomerata, Trifolium repens, Festuca rupicola, Campanula patula, Luzula campestris agg., Bromus erectus, Rumex acetosa, Festuca rubra agg., Taraxacum sect. Ruderalia, Vicia cracca, Primula veris, Tragopogon orientalis, Thymus pulegioides, Rhinanthus minor, Poa pratensis agg., Linum catharticum, Galium verum, Festuca pratensis, Cerastium holosteoides, Ranunculus polyanthemos, Ranunculus acris, Prunella vulgaris, Polygala comosa, Trifolium montanum, Sanguisorba minor, Medicago lupulina, Fragaria viridis, Alchemilla species*

Dominant species: *Arrhenatherum elatius, Vicia cracca, Rhinanthus minor, Carex montana, Bromus erectus, Briza media, Brachypodium pinnatum*

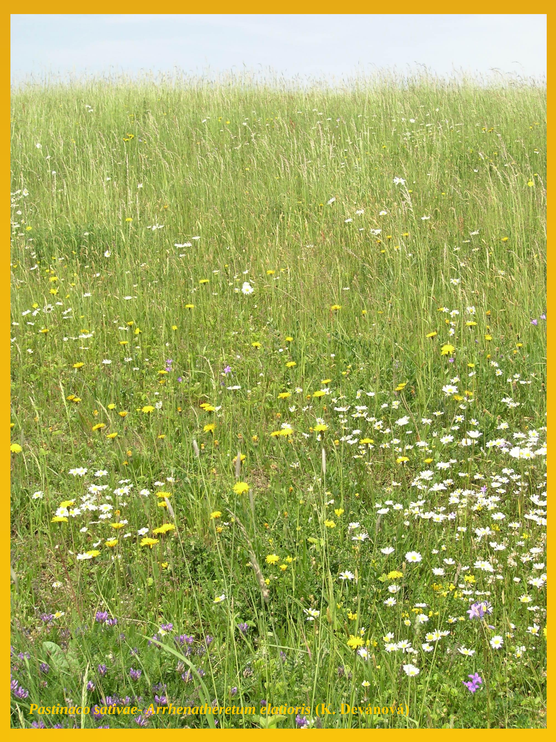
***Anthoxantho-Agrostietum tenius* Sillinger 1933** (19 relevés)

Diagnostic species: ***Polygala vulgaris, Viola canina, Potentilla erecta***

Constant species: ***Dactylis glomerata, Anthoxanthum odoratum agg., Plantago lanceolata, Briza media, Alchemilla species, Trisetum flavescens, Rumex acetosa, Leucanthemum vulgare agg., Leontodon hispidus, Achillea millefolium agg.,*** *Veronica chamaedrys, Polygala vulgaris, Festuca rubra agg., Viola canina, Trifolium pratense, Ranunculus polyanthemos, Potentilla erecta, Pimpinella saxifraga agg., Lotus corniculatus, Campanula patula, Agrostis capillaris, Plantago media, Luzula campestris agg., Filipendula vulgaris, Festuca pratensis, Cruciata glabra, Carex pallescens, Trifolium montanum, Thymus pulegioides, Cerastium holosteoides, Centaurea jacea, Carlina acaulis, Primula veris, Potentilla heptaphylla, Linum catharticum, Knautia kitaibelii, Arrhenatherum elatius, Vicia cracca, Trifolium repens, Tragopogon orientalis, Salvia pratensis, Ranunculus acris, Prunella vulgaris*

Dominant species: *Bromus erectus, Trisetum flavescens, Trifolium montanum, Plantago lanceolata, Festuca rubra agg., Carex montana, Brachypodium pinnatum, Arrhenatherum elatius*

Brachypodio pinnati-Molinietum arundinacae (J. Kostál)



Pastinaco sativae- Arrhenatheretum elatioris (K. Devánová)

***Pastinaco sativae- Arrhenatheretum elatioris* Passarge 1964** (36 relevés)

Diagnostic species: ***Glechoma hederacea, Lysimachia nummularia, Medicago sativa, Anthriscus sylvestris, Crepis biennis, Medicago lupulina, Poa trivialis, Pastinaca sativa, Campanula rapunculoides, Alopecurus pratensis, Taraxacum sect. Ruderalia, Convolvulus arvensis, Arrhenatherum elatius, Veronica arvensis, Galium mollugo agg., Veronica chamaedrys, Trifolium repens, Campanula patula***

Constant species: ***Arrhenatherum elatius, Veronica chamaedrys, Plantago lanceolata, Achillea millefolium agg., Leontodon hispidus, Dactylis glomerata, Campanula patula, Trifolium pratense, Leucanthemum vulgare agg., Taraxacum sect. Ruderalia, Lotus corniculatus, Trifolium repens, Rumex acetosa,*** *Anthoxanthum odoratum agg., Tragopogon orientalis, Festuca pratensis, Crepis biennis, Trisetum flavescens, Salvia pratensis, Poa pratensis agg., Prunella vulgaris, Primula veris, Medicago lupulina, Lysimachia nummularia, Daucus carota, Pimpinella saxifraga agg., Luzula campestris agg., Cerastium holosteoides, Briza media, Plantago media, Glechoma hederacea, Vicia cracca, Ranunculus polyanthemos, Bromus erectus, Ranunculus acris, Campanula rapunculoides*

Dominant species: *Arrhenatherum elatius, Plantago lanceolata, Anthoxanthum odoratum agg., Bromus erectus, Trisetum flavescens, Lotus corniculatus, Taraxacum sect. Ruderalia, Cruciata glabra*

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