COMMUNITY ECOLOGY 9(Suppl): 115-123, 2008
1585-8553/$20.00 © Akadémiai Kiadó, Budapest
DOI: 10.1556/ComEc.9.2008.S.16

Semi-natural grasslands under impact of changing land use during last 30 years: *Trollio-Cirsietum* community in the Liptov region (N Slovakia)

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Keywords: Community structure changes, Fens, Intensification of agriculture, Mesophilous grasslands, Rural landscape, Trollio-Cirsietum, Wet meadow.

Abstract: Significant transformation of agriculture took place in Central Europe during the second half of the 20th century. The paper reviews the nature and consequences of this process in terms of grassland management and land use changes in the Liptov region (N Slovakia) and their impacts on plant communities of fen meadows (*Caricion davallianae, Caricion fuscae*), wet meadows (*Calthion*) and mesophilous grasslands (*Arrhenatherion, Cynosurion*). We studied in detail the changes in structure of the rare plant community *Trollio-Cirsietum* (Kühn 1937) Oberd. 1957 that occurred between the first period (1974-1983) and the second period (2002-2003). We recorded the decrease in abundance of species characteristic for permanently wet and fen meadows (alliances *Calthion* and *Caricion davallianae)* and the increase in abundance of characteristic species of seasonally dried, mesophilous and thermophilous meadows and mesophilous fringes (classes *Molinio-Arrhenatheretea, Festuco-Brometea* and alliances *Molinion caeruleae, Bromion erecti* and *Trifolion medii*). In the second studied period, a large group of mesophilous and thermophilous species appeared as new in this wet-meadow community. A cumulative impact of different factors, especially drainage and intensification of surrounding grasslands as well as abandonment of the community can represent reasons responsible for observed changes. Regardless identified changes, the community still maintains its typical character in significant proportion of the studied sites and hosts a high number of threatened plant species.

Abbreviations: T-C – *Trollio-Cirsietum* (Kühn 1937) Oberd. 1957.

Nomenclature: Marhold (1998).

Introduction

The agriculture in Central Europe underwent significant transformation during the second half of the 20th century. Extensive agriculture providing occupation for a significant part of the population, minimal extent of recultivation measures and the use of grasslands for hay-making and grazing of domestic animals were typical for the first half of the 20th century. After the World War II, from 1950's to 1970's, a strong intensification of agriculture was typical for the whole Europe (Rabingee and van Diepen 2000, Robinson and Sutherland 2002, Hopkins and Holz 2006, Young et al. 2007). In addition, the intensification was in most of the Central and Eastern European Countries (apart from Poland and Slovenia) connected with the breakdown of traditional farming and the replacement of small- and medium-sized private farms with larger-scale state or collective farms.

Intensification of agriculture was accompanied by broad land use changes leading to homogenisation of landscape and fragmentation of natural and semi-natural habitats (Alard and Poudevigne 1999, Jongman 2002). The environmental consequences included the increased use of fertilizers and biocides, land draining, irrigation, and the loss of many biodiversity-rich landscape features (Young et al. 2007). Intensification of agriculture was followed by abandonment of less productive or remote areas (e.g., MacDonald et al. 2000) and later by polarisation of agricultural land use - both intensive utilisation of some sites and abandonment of other ones in the same region. Impacts of these processes to grassland communities are documented by numerous studies (e.g., Rosenthal and Müller 1988, Kornaś and Dubiel 1991, Linusson et al. 1998, Vos and Meekes 1999, Alard and Poudevigne 1999, Pärtel et al. 2005, Gustavsson et al. 2007), they include conversion to other vegetation types and loss of the area, changes in the species composition, in dominance and constancy of species, simplification of the community structure, reduction of both biodiversity and conservation value. Besides the common features and principles of the community response to intensification and abandonment, there are also regional peculiarities; therefore the regional studies are needed.

This paper deals with grassland changes induced by land use changes in the Liptov region (N Slovakia) during the last

30 years. Because of harsh environmental conditions for agriculture, grasslands represented the main part of agricultural land in the past (up to 80% in cadastres of some mountain villages). High variability of both natural conditions and grassland management resulted in the occurrence of a rich mosaic of plant communities from fen meadows to mesophilous meadows. Rich, fertilised meadows were usually located in the vicinity of villages while more remote, badly accessible sites hosted grasslands where rotation of mowing and grazing (meaning also fertilisation) was applied. Wet and fen meadows with low hay quality were mown as well; the hay was used for production of bedding and manure.

Similar to other parts of Europe, intensification of agriculture took place also in the Liptov region in the 60-ties and the 70-ties of the 20th century. The establishment of the Tatra Mts. National Park in 1948 influenced the upper Liptov region. To compensate the loss of the stopped utilization of grasslands included to the National Park, affected villages received increased subsidies for intensification of agriculture and land recultivation. Therefore the intensification was stronger there than in other regions and it has remarkable consequences. Especially the change of the dimensions of landscape patches is striking: the former mosaic of small and narrow patches of land was replaced by large areas of arable land and intensive grasslands. Large homogenous, uniformly utilised patches totally changed the visual aspect of the former diverse sub-mountain landscape. This change in the studied region was connected with collectivisation of agriculture during the communist period.

Land use changes brought direct destruction of semi-natural grasslands of the region through their conversion to other land use type (mainly arable land), intensification and extensive drainage of wet sites (Ružičková 2004, Válkovcová and Ružičková 2007). Large areas of grasslands were recultivated by means of terrain adjustment, ploughing, sowing of more productive varieties of grasses and clovers, intensive fertilisation, large drainage and destruction of spring areas. In this way intensive grasslands were established, being harvested several times in a year or grazed by big herds of cattle and sheep. Grasslands in more fertile sites were transformed to arable land that became intensively used. On the other hand, mowing and later also grazing of badly accessible and less fertile grasslands were stopped and many sites gradually overgrew with forest. Besides the direct changes, some stands were influenced by changes of the use in neighbouring sites, often accompanied by infiltration of species from neighbouring habitats. This increases the species richness of the community, but it definitely cannot be understood as an increase of biological value of the community.

Grasslands of semi-natural character persisted till today only in small extent; they are located mainly in the periphery of villages, in old gardens, in stream floodplains and spring areas, in forest cleanings and badly accessible sites. Their area is in continuous decline – only small owners mow them individually, being out of interest for big farms.

In this paper, we characterize the land use changes in the Liptov region during the last 30 years and their impact to individual grassland types. We studied in detail the wet meadows of the association *Trollio-Cirsietum* (Kühn 1937) Oberd. 1957. This rare plant community is distributed in Slovakia only in cadastres of few villages in the Liptov region and in one site in the adjacent Poprad River basin. These meadows (as all grasslands of the *Molinion* alliance in Central Europe) were not fertilised and were mown once a year at the end of summer. The low-quality hay was used for bedding and as the fodder for horses. *Trollio-Cirsietum* has a significant conservation value; it is typical by very high proportion of threatened and rare species. It is included in the Annex I of the Habitats Directive (92/43/EEC), within the unit 6410 - "*Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)".

Material

Study area

The Liptov region is located in the northern part of Slovakia in a basin between the highest mountains of the Western Carpathians: the High Tatra Mts., the Low Tatra Mts., the Veľká Fatra Mts. and the Chočské vrchy Mts. (Hreško and Boltižiar 2001). The basin-bound climate of the continental character is typical for this region. It lies in the rain shadow of the High Tatra Mts; the mountain range of the Low Tatra Mts. hinders the access of warm air from the south. The studied eastern part of the basin belongs to the region of the cold climate with the annual average temperature of 5.1 °C, the annual precipitation of 754 mm and with up to 170 days of the snow cover per year (Ružičková 1986). The bed of the basin is built by thick flysch layers covered by the Quaternary sediments. Abundant springs determined formation of hygrophilous vegetation. The area belongs to the region of Western-Carpathian flora (*Carpaticum occidentale*); spruce- and fir-spruce forests (*Vaccinio-Piceenion, Piceion)* represent the natural vegetation.

Methods

Sampling

The field research of meadows of the association *Trollio-Cirsietum* (Kühn 1937) Oberd. 1957 was performed in two periods: 1974–1983 (the first period; 11 records) and 2002–2003 (the second period; 47 records). Because the sites of vegetation records were not permanently marked in the field during the first period (their location was drawn to maps of the scale 1:25.000 only), in the second period we sampled more records in the vicinity of 11 first-period records and the recorded sites were located by GPS. A digital point-layer was created in the software ArcView using the coordinates. The studied sites are represented on the map in Fig. 1 and their list in Appendix 1.

Phytosociological records were taken using standard phytosociological methods (Braun-Blanquet 1951). The 7-

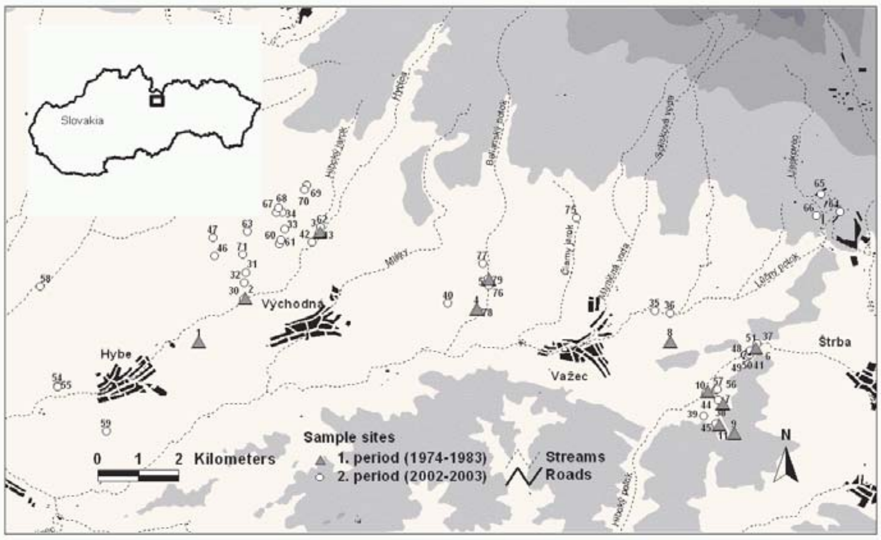

Figure 1. Location of sample sites.

degree Braun-Blanquet scale or its enlarged 9-degree version (Westhoff and van der Maarel 1978) were used, the size of sampled area was 25 m^2. The records were processed using the software TURBOVEG (Hennekens and Schaminee 2001) and JUICE (Tichý 2002). Phytosociological records of the first period were published by Ružičková (1986), of the second period by Ružičková et al. (2005).

Data analysis

A change of species richness (number of species per releveé) was tested by standard t-test of independent samples. Random subset of 11 records from the second period was selected for this purpose. All the statistical assumptions were checked in advance.

The records were analysed by multivariate methods using the software CANOCO 4.5, the graphic outputs were prepared in the program CanoDraw (ter Braak and Šmilauer 2002). In the species matrix (58 records, 143 species), the semi-quantitative Braun-Blanquet scale was transformed to ordinal scale (van der Maarel 1979). We analysed all 58 records using the detrended correspondence analysis (DCA). The DCA showed the maximal length of the gradient of 1,712. Because the gradient is short and thus indicates a linear response, we used one of the linear methods – principal component analysis (PCA) and the redundancy analysis (RDA) for a later gradient analysis.

As we did not know exact locations of the first-period relevés, we adjusted our sample set in the way as recommended by Herben and Münzbergová (2003). For each of 11 records from the first period we found in its geographical vicinity (usually a valley) the most similar and the most dissimilar records using the Euclidean distance as the similarity measure. In this way we obtained the subset of 22 "most similar" records and the subset of 22 "most dissimilar" records. Both sets were analysed by means of a direct gradient analysis using the RDA method and the only environmental variable – the time of recording. We tested the importance of the time factor for the species composition change using the Monte Carlo permutation test. The test permuted and randomly resampled the original data set in order to simulate the distribution of test statistics, which is a multivariate counterpart of the ordinary F-ratio and has similar meaning as the F-value in ANOVA of the regression model (Lepš and Šmilauer, 2003). Significance level was identified by determining the proportion of values greater than or equal to test statistics of the original data (F_0) among all values (F_0, F_1, ..., F_K) of the resampled data sets divided by the total number of permutations (ter Braak and Šmilauer 2002).

Characteristic species of phytosociological units are used according to Ružičková et al. (2005), their list being in Appendix 2. For quantification of changes we used the average value of the coverage interval for the respective category of abundance scale (Jurko 1990). Indicator values of plant species (Ellenberg 1974, Jurko 1990) were also used for the analysis of relationship between the community composition and site conditions.

Results and discussion

Changes in species composition of grassland vegetation types

We summarise changes in the utilisation and composition of individual grassland types on the basis of own, mostly unpublished records and papers of Ružičková (1986) and Válkovcová and Ružičková (2007).

Fen meadows (*Caricion davallianae, Caricion fuscae*). Almost all characteristic species of fen meadows (*Carex davalliana, C. flava, C. nigra, C. hostiana, Eleocharis quinqueflora, Parnassia palustris, Pinquicula vulgaris, Primula farinosa*) retreated from drained sites, the abundance of species of wet fallows (*Angelica sylvestris, Filipendula ulmaria, Geranium palustre, Galium rivale*) increased, reeds (*Phragmites australis*) spreads in many sites. If the cattle pass through the fens, species of mesophilous meadows (e.g., *Lathyrus pratensis, Festuca pratensis, Trifolium hybridum*) increase. Within a drained fen meadow we recorded the disappearance of 7 fen species and appearance of 21 species of mesophilous meadows. In the acid transition fens of the *Caricion fuscae* alliance, their characteristic species - sensitive to eutrophication - disappear among the first ones and the species of nutrient-rich wet meadows dominate.

Wet meadows (*Calthion*). Changes in species composition arise as a result of drainage, fertilisation of surrounding meadows, grazing or abandonment. If the meadows had not been ploughed and sown and had been mown regularly, the number of fresh meadow species raised and the species richness increased in some sites from 30 to 50. More important changes result from abandonment. Species of mown meadows disappear completely and those of nutrient-rich sites (*Aegopodium podagraria, Angelica sylvestris, Cirsium arvense, Calystegia sepium, Filipendula ulmaria, Galium aparine, Phragmites australis, Symphytum officinale, Urtica dioica* and other) gradually dominate. Similar changes in the species composition of wet as well as fresh meadows were recorded in long-term studies also from other countries (Rosenthal and Muller 1988; Kornaś and Dubiel 1991, Falińska 2003). The study of changes in the *Trollio-Cirsietum* association is provided in detail in this paper.

Mesophilous meadows (*Arrhenatherion, Cynosurion*). They underwent the biggest changes of species composition, especially because of their radical renewal: ploughing and sowing of cultivars of grasses and clovers. Later on, they were intensively fertilised and frequently mown or grazed by large herds of domestic animals. The extensively and semi-intensively utilised semi-natural grasslands disappeared from the landscape almost completely and poor pastures remained only in the periphery of intensive pastures (Válkovcová and Ružičková 2007).

During the last 15 years, intensity of utilisation of these meadows decreased significantly. Their species composition was stabilised during the process of not planned extensification: weedy species, indicating a high level of fertilisation (e.g., *Cirsium arvenese, Rumex crispus, Chaerophyllum aromaticum)* disappeared and some species of semi-natural meadows came back. After this change the average number of species increased up to 37. However, there exists a group of species of the former meadows that does not come back. Besides the low-competitive species of poor and warm sites (e.g., *Briza media, Potentilla erecta, Thymus pulegioides, Linum catharticum)* there belong also *Primula veris, P. elatior, Campanula glomerata, Knautia kitaibelii, Filipendula vulgaris, Leontodon hispidus, Tragopogon orientalis, Colchicum autumnale* and other. The comeback of these species will probably take a longer time (decades). Changes in the utilisation intensity of these meadows are at best reflected in the changes of dominance of grasses with different nutrient requirements: instead of sown species (*Dactylis glomerata, Festuca pratensis, Phleum pratense)* grasses of lower nutrient demand (*Festuca rubra, Agrostis capillaris*) currently dominate there. It seems that the comeback of native species is quicker in communities that were only fertilised and not subject to a radical renewal and sowing. This can be documented through the example of a poor meadow (*Anthoxantho-Agrostietum)* that in certain period was fertilised but after ceasing of fertilisation 26 out of 39 former species appeared again. The species like *Nardus stricta, Viola canina, Polygala vulgaris, Veronica officinalis*, *Plantago media* did not come back and the species of mesophilous meadows appeared.

Species composition of abandoned (not utilised) mesophilous grasslands cannot be classified in a single scheme. Besides the site conditions, it reflects both the ancient and recent history of grassland utilisation and in several cases the species number temporarily increases.

The Trollio-Cirsietum community and its changes

We recorded significant changes of the community since 70-ties of the 20th century. Its area decreased and the mowing of remaining not-dried sites stopped. The areas were reclaimed by ploughing and sowing to intensive meadows in cadastres of Hybe and Štrba villages. The community persisted in hardly drainable spring areas and stream floodplains, but the stands are not mown at present. Grazing of cattle represents the major management type in the community stands in cadastres of villages Východná and Dovalovo. The community disappeared in the places accessible for cattle; small fragments remained in not accessible sites. In surroundings of Tatranská Štrba village, the community occurs among recreational buildings. It has a typical structure, but it is not managed.

Community structure and variability

As regards the species composition, the *Trollio-Cirsietum* association lies in transition between the permanently wet meadows of the *Calthion* alliance and the seasonally dry meadows of the *Molinion* alliance. It is possible to consider the community to be the mountain vicariant of the *Molinia* sp. meadows (*Molinietum caerulae*). Typical stands of the *Trollio-Cirsietum* association are dominated by *Trollius altissimus* and *Cirsium rivulare*, while species of fen meadows of the *Caricion davallianae* alliance are locally abundant. The community structure is more similar to *Calthion* in sites located on the streams' floodplains where the water and nutrient supply is permanent and the soil is not dried up. In slopes and plateaus with the tendency to drying up it is more similar to *Molinion*. Ružičková (1978) classified the communities in the most drying-up sites as the sub-association *Trollio-Cirsietum scorzoneretosum humilis* with the differential species *Scorzonera humilis, Bistorta vivipara* and *Salix rosmarinifolia*.

We recorded occurrence of 19 species listed in the red list of Slovakia (Feráková et al., 2001) in 58 records that documents the exceptionally high conservation value of the community. The highest number of threatened species in one record was 13, the average being 5,62. The critically endangered (CR) *Dactylorhiza maculata* and several endangered (EN) species (*Carex hartmanii, Gentiana pneumonan-*

the, *Gymnadenia densiflora* and *Scorzonera humilis*) were found in the community as well.

Results of the indirect gradient analysis of all 58 records using the method PCA (Fig. 2) illustrate the community variability. Based on species distribution in relation to the ordination axes (Fig. 2b), it is possible to consider the first ordination axis as the moisture gradient and the second ordination axis should represent the gradient of soil nutrients. The hygrophilous species of alliances *Calthion* and *Caricion davallianae* are located in the left part of the graph; characteristic species of the sub-association T-C *scorzoneretosum* and of the class *Nardo-Callunetea* are situated at the bottom on the right. Species of mesophilous and thermophilous meadows and forest fringes of class *Festuco-Brometea* and alliances *Arrhenatherion*, *Bromion erecti* and *Trifolion medii* are typical for the right upper part of the graph. It is possible to distinguish 3 clusters of records in Fig. 2a. The cluster A is the typical association *Trolio-Cirsietum*, the cluster B is related to the sub-association T-C *scorzoneretosum* and cluster C represents transition to the mesophilous meadows of the class *Molinio-Arrhenatheretea*. The records from the second period are distributed in all parts of the graph, but some of them are located quite far from the "optimal" position of the typical community, the community variability increased and the number of outliers in transition to mesophilous meadows increased. It indicates certain drying and warming at least in part of the community sites.

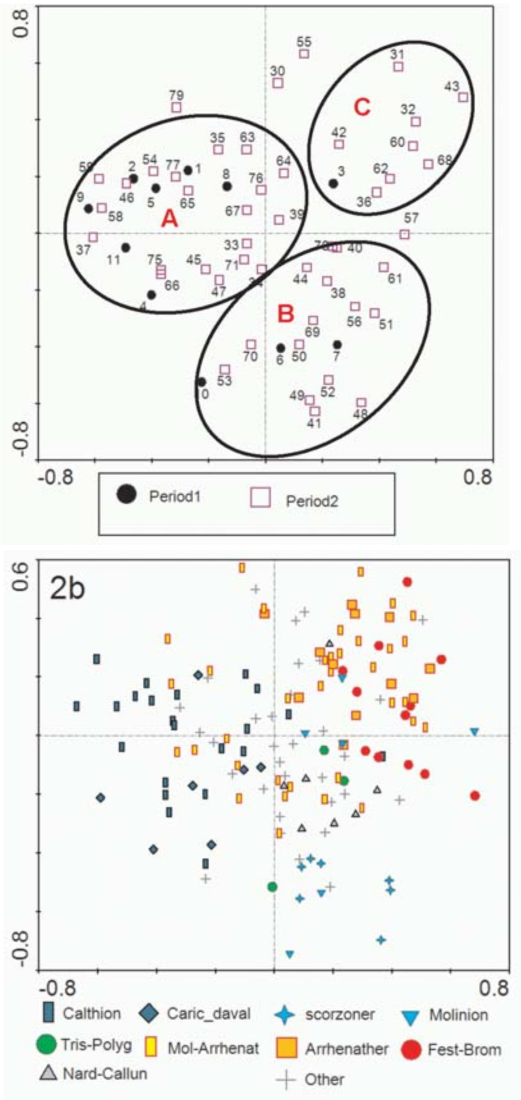

Figure 2. Indirect gradient analysis of records (2a) and species (2b) of both studied periods through PCA. Legend: Caric_daval: *Caricion davallianae*; scorzoner: *Trollio-Cirsietum scorzoneretosum*; Tris-Polyg: *Polygono-Trisetion*; Mol-Arrhenather: *Molinio-Arrhenatheretea*; Fest-Brom: *Festuco-Brometea*, *Bromion erecti*, *Trifolion medii*; Nard-Callun: *Nardo-Callunetea.*

Community change

The increase of species number in the second studied period (2002-2003) represents the most remarkable feature of change. Out of the 143 totally registered taxa, 51 taxa are "new", not recorded in the first period (1974-1983). The average species richness increased from 35,64 (30-44) taxa per relevé in the first period to 52,15 (37-63) in the second period. A standard t-test of independent samples was done using the random subset of 11 samples from the second period. The mean difference was identified as significant ($p<0.001$) with its 95% confidence interval between 10 and 22 species per releveé. Among the species recorded only in the second period, following species were registered in the highest number of records: *Angelica sylvestris* (39 records), *Carex tomentosa* (35), *Gladiolus imbricatus* (19), *Carex hartmanii* (18), *Trifolium flexuosum* (18), *Equisetum palustre* (15), *Pimpinella saxifraga* (12), *Carex hirta* (11), *Dactylorhiza majalis* (10), *Pimpinella major* (10), *Trifolium repens* (10), *Helianthemum grandiflorum* (9), *Listera ovata* (9), *Trifolium hybridum* (9) and *Dactylis glomerata* (8). All mentioned species have low abundance (except for *Angelica sylvestris* in 3 records). Also some threatened species not recorded in the first period appeared: *Gladiolus imbricatus, Carex hartmanii, Dactylorhiza majalis, Listera ovata, Carex capillaris, Epipactis palustris, Gymnadenia conopsea, G. densiflora*. All species registered in the first period were recorded again in the second period, no one disappeared.

We intended to separate the spatial heterogeneity from the temporal change by correct selection of records, used for the test of significance for the influence of the time factor on community structure changes. The spatial heterogeneity can cause not correct interpretation of the temporal change of the vegetation (Berlin et al. 2000). We performed direct gradient analysis using the RDA method and the only environmental variable - the time of the recording (sampling date) on each subset of data. The time factor was found significant ($p<0.01$; using the permutation Monte Carlo test) both for the set of "most similar" and the set of "most dissimilar" records (see the methods). This enables us to state that during the studied period the real changes occurred in the structure of the community. Fig. 3 indicates that more species appeared or eventually increased their abundance (left part of the graph) than decreased it (right part). Especially species of the classes *Molinio-Arrhenatheretea, Festuco-Brometea* and alliances *Arrhenatherion, Bromion erecti* and *Trifolion medii* increased in number. We recorded the increase of individual species of other phytosociological units as well. Part of species characteristic for alliances *Calthion, Polygono-Trisetion, Caricion davallianae*, for the class *Nardo-Callunetea* and sub-association *Trollio-Cirsietum scorzoneretosum* are decreasing in number. This analysis indicates the increase in number of more xeric species and species of nutrient-rich sites on one hand and the decrease of hygrophilous and nutrient-poor-bound species.

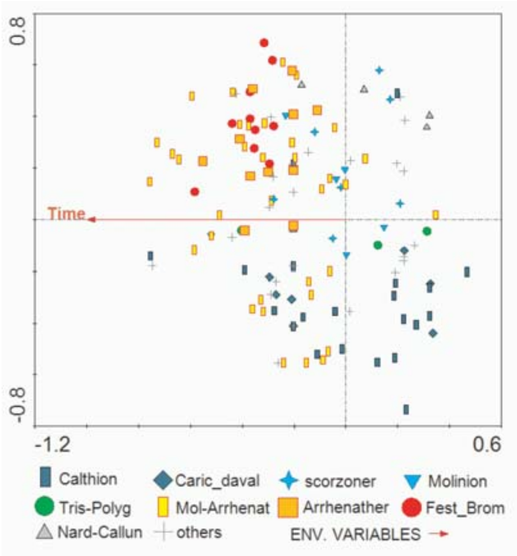

Figure 3. Direct gradient analysis (RDA) of „most dissimilar" records. Legend: Caric_daval: *Caricion davallianae*; scorzoner: *Trollio-Cirsietum scorzoneretosum*; Tris-Polyg: *Polygono-Trisetion*; Mol-Arrhenather: *Molinio-Arrhenatheretea*; Fest-Brom: *Festuco-Brometea*, *Bromion erecti*, *Trifolion medii*; Nard-Callun: *Nardo-Callunetea.*

Quantitative changes in abundance of characteristic species of individual phytosociological units are represented in Fig. 4. Significant differences in community structure between two studied periods are visible. Proportion of species characteristic for permanently wet meadows of the alliance *Calthion* decreased from 46,3% in the first period to 31,4% in the second period. On the other hand, the ratio of species of seasonally dried meadows of the alliance *Molinion caerulae* increased from 8.6% to 13.4%; characteristic species of the mesophilous meadows of the class *Molinio-Arrhenatheretea* from 18.2% to 26.1%; species of thermophilous grasslands and mesophilous fringes of class *Festuco-Brometea* and alliances *Bromion erecti* and *Trifolion medii* from 0.6% to 3.9% between the studied periods. It documents the above mentioned assumption on drying up of the community sites. The decrease in number of hygrophilous species is caused by lower abundance of typical species of the association *Trollio-Cirsietum*, namely *Trollius altissimus*, *Cirsium rivulare*, *Sanguisorba officinalis* and *Scorzonera humilis* recorded in the second period. Broader variety of species participated in the increased number of mesophilous and thermophilous species; quantitatively important are *Jacea pseudophrygia*, *Alchemilla* spp., *Cruciata glabra*, *Poa angustifolia*, *Melampyrum nemorosum*, *Veronica chamaedrys*, *Trifolium flexuosum*, T. montanum, *Stellaria graminea*, *Hypericum maculatum* and *Galium verum*.

The observed increase of the community species richness is produced mostly by the increase in species, typical for other communities and this fact cannot be assessed positively. If this process will continue, probably the area of stands with typical community structure will decrease and the area of transitional stands will increase – as a component of the grassland homogenisation process within the study region.

We tested if the changes in the community structure are reflected also by changing spectrum of species indicator values. We calculated the spectra for soil moisture, soil nutrients, pH value, light and temperature requirements using

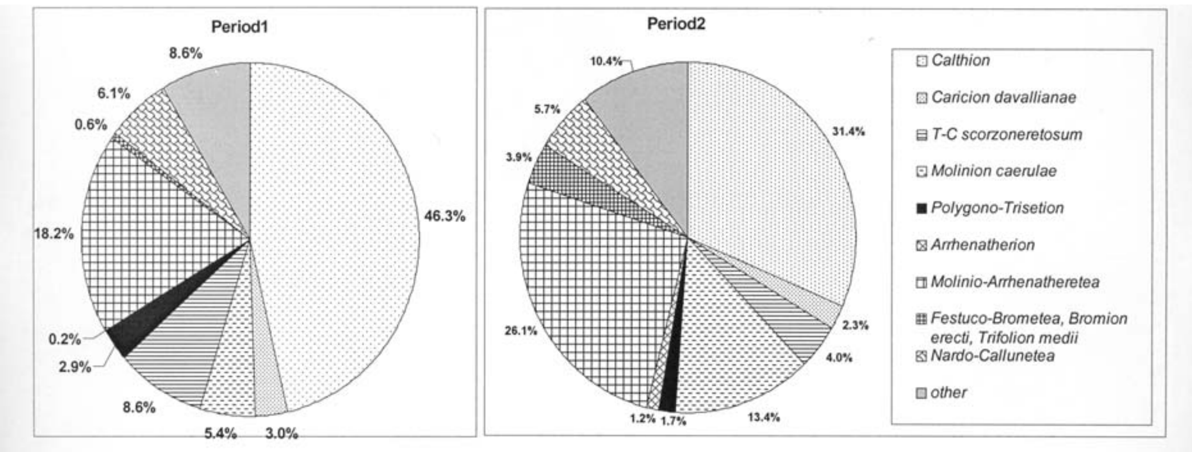

Figure 4. Proportion of species, characteristic for individual phytosociological units in the first (1974-1982) and the second (2002-2003) periods. Legend: T-C scorzoneretosum: *Trollio-Cirsietum scorzoneretosum.*

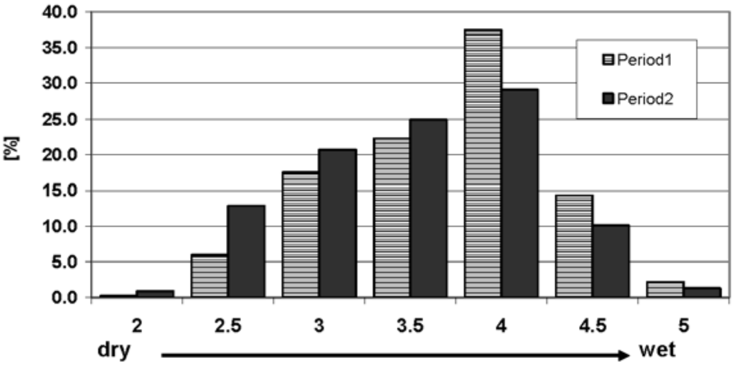

Figure 5. Proportion of species, indicating individual categories of the soil moisture (Jurko 1990). Legend: 2 - dry soils (value 3 of Ellenberg´s scale), 3 - fresh soils (Ell. 5), 4 - moist soils (Ell. 7), 5 - wet soils (Ell. 9).

both Ellenberg (1974) and Jurko (1990) values. Differences between studied periods were confirmed for soil moisture only, both using Ellenberg and Jurko values. Since the species indicator values published by Jurko (1990) were available for almost all species, we used these results in Fig. 5. Percentage of species typical for wet sites (categories 4-5) was lower in the second period than in the first one while the percentage of species of dry sites (categories 2-3.5) was higher in the same period. The results correspond to the above-mentioned results that were achieved by means of other methods.

Our results indicate the influence of soil moisture changes to the species structure of a community. The moisture gradient together with the gradient of intensity of management is considered to be the main factors influencing the grassland biodiversity and the species composition of the community (Alard et al. 1994, Linusson et al. 1998). We observed decrease in species of permanently wet habitats and increase in species of seasonally dry stands as well as of mesophilous and thermophilous grasslands. Drainage of surrounding plots and of the overall landscape, impact of global warming and accumulation of biomass in abandoned grasslands belong to the possible explanations.

Fertilisation of surrounding grasslands probably did not influence significantly the species composition of the *Trollio-Cirsietum* community; our analysis did not confirm remarkable increase in species of nutrient-rich habitats. Utilisation of nutrients by vegetation in a discontinuous zone of different width (kind of a buffering zone) that we observed in some sites represents one possible explanation. Nitrophilous species like *Urtica dioica, Cirsium arvense, Elytrigia repens, Bromus inermis* and *Chaerophyllum aromaticum* grow in this zone. In this way the central part of the community is protected against the increased input of nutrients from the surroundings.

Plant succession after the abandonment is remarkable especially in sites close to the forest or in the vicinity of streams. Willows, aspen and birch are invading the community, also the number of species of wet and mesophilous fallows (*Filipendula ulmaria, Polemonium caeruleum, Angelica sylvestris, Valeriana officinalis, Galium rivale)* is increasing and species of the fens (*Carex davalliana, C. hostiana, C. flava*) and species of *Molinion* meadows are decreasing. The abundance of species in this region typical for fallows on alternately wet and dry sites (*Betonica officinalis, Carex umbrosa, C. tomentosa, Bistorta vivipara, Galium boreale*) and species of mountain meadows (*Crepis mollis, Primula elatior*) considerably increased in number as well.

Regardless observed changes, the community still maintains its typical character in significant portion of the studied sites and hosts a high number of threatened plant species. The succession changes of the *Trollio-Cirsietum* community after its abandonment seem to be slower than those in other meadows, mown in the past. The reason can be drawn from the former way of utilisation of this community: very extensive management, mowing in late summer or early autumn, probably not every year. It may explain why it persists in relatively good conditions without any management for a certain period. But it is plausible that this status can be held only for a limited time, later followed by a sudden break and rapid changes in the community structure.

The community of the *Trollio-Cirsietum* gradually recovers after the ceased fertilisation (being currently the case quite often) on sites with formerly intensified grasslands that were not ploughed and drained. Among the first ones there appear species of the *Molinion* meadows like *Sanguisorba officinalis, Galium boreale, Molinia caerulea* and *Succisa pratensis* together with species of fen meadows, e.g., *Carex davalliana* and *C. hostiana* (Ružičková et al. 2005).

Conclusion

Despite forests represent the largest areas of natural vegetation in Central Europe, a considerable part of the plant and animal richness is linked with natural and semi-natural grasslands managed by man. Intensification of agriculture between the 50's and the 70's of the 20th century had a significant impact on the distribution and structure of grasslands in the studied region - it is possible to speak about homogenisation of their structure and about landscape homogenisation. We recorded significant reduction of the area of semi-natural grasslands connected with decrease in numbers of livestock. Usually there is no interest in utilisation of remnants of semi-natural meadows in badly accessible sites, in gardens, field margins and road verges. Mowing of fen and wet meadows (including *Trollio-Cirsietum*) was stopped completely. This is the main reason for significant changes in the community structure during the last 30 years that we recorded for *Trollio-Cirsietum*.

A comprehensive approach to the conservation of semi-natural grasslands is highly needed. Examples of the most important communities can be preserved in nature reserves, but maintenance of the whole spectrum of semi-natural grasslands in larger spatial extent cannot be ensured by nature conservation – grasslands require continuous agricultural management. Measures of the EU Common Agricultural Policy (CAP) focused to non-production functions of agriculture - especially through agro-environmental programmes launched in Slovakia in 2004 - represent for the semi-natural meadows of the studied region a chance to be saved. However, currently in Slovakia there is supported rather the effort (the way of management) than the result (species diversity of certain grassland). The present generation has to decide if to invest money in order to maintain at least some of the semi-natural grassland types for future generations.

Acknowledgements: This paper was prepared under financial contribution of the grant agency VEGA, grant No. 2/0166/08. The authors wish to express thanks to A. Bača for linguistic correction of the text.

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Appendix 1

Location of samples.

Appendix 2

Characteristic species of phytosociological units.

The appendices may be downloaded from the web site of the publisher at www.akademiai.com.

Received January 19, 2008
Revised October 15, 2008
Accepted November 22, 2008

Appendix 1. Location of samples.

ID	Cadastre (village)	Date	Altitude [m]	Period	X-coord	Y-coord
1	Važec	15.07.1976	760	1	19.85374	49.05509
2	Hybe	22.06.1981	730	1	19.86837	49.06532
3	Hybe	27.06.1977	765	1	19.89207	49.08106
4	Važec	03.09.1976	780	1	19.94598	49.06626
5	Važec	11.07.1978	780	1	19.94942	49.07297
6	Štrba	13.09.1974	900	1	20.04015	49.06169
7	Štrba	13.09.1974	905	1	20.03026	49.04887
8	Važec	21.07.1975	880	1	20.01141	49.06186
9	Štrba	28.06.1977	900	1	20.03479	49.04248
10	Važec	14.07.1978	880	1	20.02499	49.05145
11	Važec	23.08.1983	900	1	20.02960	49.04423
30	Hybe	03.07.2002	728	2	19.86787	49.06524
31	Hybe	03.07.2002	740	2	19.86810	49.07116
32	Hybe	03.07.2002	737	2	19.86768	49.06883
33	Hybe	03.07.2002	770	2	19.88019	49.08114
34	Hybe	03.07.2002	780	2	19.87915	49.08482
35	Važec	04.07.2002	815	2	20.00560	49.06837
36	Važec	04.07.2002	810	2	20.01081	49.06814
37	Važec	05.07.2002	908	2	20.04059	49.06260
38	Štrba	05.07.2002	900	2	20.02876	49.04965
39	Štrba	06.07.2002	890	2	20.02407	49.04601
40	Východná	09.07.2002	815	2	19.93629	49.06727
41	Važec	05.07.2002	900	2	20.03893	49.06099
42	Hybe	07.07.2002	764	2	19.88962	49.07869
43	Hybe	07.07.2002	765	2	19.89167	49.08086
44	Štrba	05.07.2002	886	2	20.02459	49.05097
45	Štrba	06.07.2002	900	2	20.02853	49.04452
46	Hybe	07.07.2002	790	2	19.85728	49.07430
47	Hybe	07.07.2002	815	2	19.85622	49.07827
48	Štrba	08.07.2003	900	2	20.03662	49.06000
49	Štrba	08.07.2003	900	2	20.03691	49.05997
50	Štrba	08.07.2003	902	2	20.03768	49.05972
51	Štrba	08.07.2003	908	2	20.03825	49.06009
52	Štrba	08.07.2003	900	2	20.03810	49.06091
53	Štrba	08.07.2003	901	2	20.03837	49.06111
54	Hybe	07.07.2003	690	2	19.80746	49.04356
55	Hybe	07.07.2003	690	2	19.80739	49.04314
56	Štrba	09.07.2003	890	2	20.02773	49.05178
57	Štrba	09.07.2003	880	2	20.02814	49.05200
58	Dovalovo	10.07.2003	710	2	19.79936	49.06504
59	Hybe	10.07.2003	748	2	19.82468	49.03414
60	Hybe	11.07.2003	777	2	19.87879	49.07803
61	Hybe	11.07.2003	775	2	19.87909	49.07876
62	Hybe	11.07.2003	775	2	19.89219	49.08224
63	Hybe	11.07.2003	787	2	19.86775	49.08021
64	Štrba	22.07.2003	930	2	20.06569	49.09277
65	Tatranská Štrba	22.07.2003	970	2	20.05888	49.09642
66	Tatranská Štrba	22.07.2003	930	2	20.05768	49.09164

ID	Cadastre (village)	Date	Altitude [m]	Period	X-coord	Y-coord
67	Hybe	23.07.2003	803	2	19.87710	49.08485
68	Hybe	23.07.2003	805	2	19.87758	49.08577
69	Hybe	23.07.2003	831	2	19.88653	49.09123
70	Hybe	23.07.2003	827	2	19.88586	49.09022
71	Hybe	23.07.2003	753	2	19.86661	49.07504
75	Važec	24.07.2002	840	2	19.97738	49.08785
76	Važec	24.07.2002	786	2	19.94953	49.07170
77	Važec	23.07.2002	805	2	19.94702	49.07649
78	Važec	23.07.2002	772	2	19.94647	49.06599
79	Važec	24.07.2002	788	2	19.94927	49.07326

Appendix 2. Characteristic species of phytosociological units.

Calthion*:** *Angelica sylvestris, Caltha palustris, Carex hartmanii, Carex nigra, Cirsium palustre, Cirsium rivulare, Crepis paludosa, Dactylorhiza maculata, Dactylorhiza majalis, Filipendula ulmaria, Galium rivale, Galium uliginosum, Geum rivale, Juncus conglomeratus, Lysimachia vulgaris, Mentha aquatica, Myosotis scorpioides, Bistorta major, Polemonium caeruleum, Ranunculus auricomus agg., Sanguisorba officinalis, Trollius altissimus, Valeriana officinalis.* ***Caricion davallianae*:** *Blysmus compressus, Carex davalliana, Carex flava, Carex hostiana, Epipactis palustris, Equisetum palustre, Valeriana simplicifolia.* ***Trollio-Cirsietum scorzoneretosum: *Carex flacca, Galium boreale, Listera ovata, Bistorta vivipara, Salix repens ssp. rosmarinifolia,Scorzonera humilis, Selinum carvifolia.* ***Molinion*:** *Betonica officinalis, Carex umbrosa, Gladiolus imbricatus, Molinia caerulea,Serratula tinctoria, Succisa pratensis.* ***Polygono-Tristetion:*** *Crepis mollis, Primula elatior, Trifolium spadiceum.* ***Molinio-Arrhenatheretea*:** *Agrostis capillaris, Achillea millefolium, Alchemilla spp., Alopecurus pratensis, Avenula pubescens, Carex pallescens, Carum carvi, Jacea pratensis, J. pseudophrygia, Cerastium holosteoides, Colchicum autumnale, Deschampsia cespitosa, Festuca pratensis, F. rubra, Lathyrus pratensis, Leontodon hispidus* subsp. *danubialis, Lotus corniculatus, Luzula campestris, Lychnis flos-cuculi, Phleum pratense, Pimpinella major, Plantago lanceolata, Poa angustifolia, P. pratensis, P. trivialis, Prunella vulgaris, Ranunculus acris, Rhinanthus minor, Acetosa pratensis, Stellaria graminea, Trifolium hybridum, Trifolium pratense, Trifolium repens, Veronica chamaedrys, Vicia cracca.* ***Arrhenatherion*:** *Arrhenatherum elatius, Campanula patula, Dactylis glomerata, Galium mollugo, Heracleum sphondylium, Leontodon hispidus, Leucanthemum vulgare, Plantago media, Ranunculus polyanthemos, Taraxacum sect. Ruderalia, Tragopogon orientalis, Trisetum flavescens.* ***Festuco-Brometea, Bromion erecti, Trifolion medii*:** *Anthyllis vulneraria, Dianthus carthusianorum, Filipendula vulgaris, Galium verum, Helianthemum grandiflorum* subsp. *grandiflorum , Hypericum perforatum, Knautia kitaibelii, Melampyrum nemorosum, Pimpinella saxifraga, Thymus pulegioides, Trifolium flexuosum, T. montanum.* ***Nardo-Callunetea*:** *Calluna vulgaris, Danthonia decumbens, Genista tinctoria, Nardus stricta, Polygala vulgaris, Potentilla erecta, Viola canina.* **Others:** *Agrostis canina, Anthoxanthum odoratum, Astrantia major, Avenula planiculmis, Briza media, Carex capillaris, C. hirta, C. ovalis, C. panicea, C. tomentosa, Cirsium arvense, Cruciata glabra, Cynosurus cristatus, Equisetum arvense, Equisetum fluviatile, Gentiana pneumonanthe, Geranium palustre, Gymnadenia conopsea, G. densiflora, Hypericum maculatum, Juncus articulatus, J. effusus, J. inflexus, Linum catharticum, Lysimachia nummularia, Ononis arvensis, Ranunculus repens, Salix aurita, S. cinerea, S. pentandra, Veronica officinalis.*