Theses of PhD dissertation

Studies on the floristic composition and quality attributes of Hungarian semi-dry grasslands

Eszter Illyés

Eötvös Loránd University
Biology PhD School
Ecology, Conservation Biology and Systematics Program
Leader of the PhD school: Anna Erdei (PhD, D.Sc., corresponding member of the Hungarian Academy of Sciences)
Leader of the program: János Podani (PhD, D.Sc.)
Supervisor: Sándor Bartha (PhD, Dr. Habil.)

2010

1. Introduction, scientific background, aims of the thesis

The most species-rich plant communities in the world at small scale (< $10m^2$) are temperate grassland communities. They are central object of syntaxonomical and ecological research and of European nature conservation (e.g. the EU Habitats Directive and Natura2000 network) because of their high species richness and the occurrence of many rare or endangered species. My thesis presents analyses of floristic patterns of semi-dry grassland vegetation of central Europe and of Hungary and ecological analyses of the factors affecting the quality of Hungarian semi-dry grasslands at two spatial scales.

Historically, phytosociological studies of semi-dry grasslands were run independently in different countries, which resulted in a set of national classifications with only limited international compatibility. So far, no comparative analysis has been performed that would establish clear links between corresponding semi-dry grassland types of different countries. Therefore, in the frames of an international cooperation we compiled a relevé database of semi-dry grasslands of Hungary, Czech Republic, Slovak Republic, east-Austria, Germany and Romanian Transylvania. We analysed the relevé data with recently elaborated numerical techniques. We intended to describe the main types of semi-dry grasslands and show their relations to associations mentioned in the relevant literature. In Hungary, despite the many scattered previous studies completed in separate parts of the country in semi-dry grasslands, a country-level computer-aided synthesis had not been available, neither a comprehensive syntaxonomical study of semi-dry grasslands. We compiled a relevé database of Hungarian semi-dry grasslands geographically and ecologically representative for this community type. We used similar numerical techniques to analyse the floristic patterns at country scale as in the central European analysis.

Effective conservation of (semi-)natural grasslands requires not only knowledge of where the vegetation occurs, but also upon the naturalness, the actual quality of a habitat or vegetation patch, and the factors affecting it. We used a hypothesis generating and testing method and linear modelling on data from the MÉTA database of (semi-)natural vegetation of Hungary in order to reveal the factors affecting the naturalness of semi-dry grasslands on landscape scale. Since previous studies showed that both local or patch variables (e.g. size of a patch, vegetation cover in the patch), and landscape or matrix variables (e.g. proportion of different habitat types in the surroundings) influence the quality of habitats, I included both types of variables. Although, the MÉTA data has an advantage of country-level coverage, the resolution of the data is rather coarse and many important characteristics of semi-dry grassland stands were not feasible to document in the frames of the MÉTA survey. Therefore we run a new analysis to identify the factors which affect the quality of a semi-dry grassland patch on stand level. For estimating quality on stand level

I chose the following indicators: species richness, diversity, cover of dominant grasses, and presence of valuable species and proportion of rough physiognomical forms (graminoids, forbs, shrubs and trees). Prior to this analysis, there was very little known on the factors affecting species richness of Hungarian semi-dry grasslands.

Thus the central object of the thesis is semi-dry grassland vegetation. The questions formulated and posed to answer by our analyses were:

A.1. What major vegetation types of central European semi-dry grasslands can be revealed by a large-scale numerical analysis?

A.2. Is there a difference in geographical range and climatic attributes of this major vegetation types (clusters)?

A.3. How the major types gained by the analysis (clusters) can be related to associations described in the literature?

A.4. Where the Hungarian semi-dry grasslands are positioned within the central-European semi-dry grasslands?

B.1. What major vegetation types of Hungarian semi-dry grasslands can be revealed by a country-scale analysis?

B.2. How the major types gained by the analysis (clusters) can be related to associations described in the literature?

B.3. Does the present syntaxonomical system satisfactorily reflect the floristic patterns of Hungarian semi-dry grasslands revealed by a numerical analysis based on high amount of data?

C.1. What factors affect the naturalness- based quality of Hungarian semi-dry grasslands on landscape level?

C.2. What is the overall relative importance of patch and matrix attributes in the naturalness of Hungarian semi-dry grasslands on landscape level?

D.1. What factors affect the species richness, diversity and other quality attributes of Hungarian semi-dry grasslands on stand level?

D.2. What are the relations among the quality attributes of Hungarian semi-dry grasslands?

D.3. What is the relative importance of the factors affecting the quality attributes of semi-dry grasslands on stand level?

D.4. Is it possible to predict the quality of a semi-dry grassland patch?

2. Material and methods

A. Variation in species composition of Central-European semi-dry grasslands

In the frames of an international cooperation we compiled a relevé database of semi-dry grasslands of Hungary, Czech Republic, Slovak Republic, east-Austria, Germany and Romanian Transylvania. Relevés with > 25% cover of *Brachypodium pinnatum* and/or *Bromus erectus* were geographically selected from a larger database. They were randomly split into two data sets, TRAINING and TEST, each with 422 relevés. Following outlier exclusion and noise elimination cluster analysis was performed for each data set on scores from significant principal coordinates. Different partitions of the TRAINING data set were validated on the TEST data set, using a new method based on the comparison of % frequencies of species occurrence in clusters. Clusters were characterized by statistically defined groups of diagnostic species and values of climatic variables.

B. Variation in species composition of Hungarian semi-dry grasslands

For this analysis 699 relevés were selected in which the percentage cover of at least one of the grasses *Brachypodium pinnatum*, *Bromus erectus*, *Danthonia alpina*, *Avenula adsurgens*, *A. pubescens* or *A. compressa* reached >10% cover. A geographical stratification of the dataset was performed and then it was split randomly into two equal parts (TRAINING and TEST datasets). Following outlier exclusion and noise elimination, clustering was performed separately for both datasets. Different partitions of the TRAINING data set were validated on the TEST data set, using a new method based on the comparison of % frequencies of species occurrence in clusters. Clusters were characterized by statistically defined groups of diagnostic species.

C. Analysis of the factors affecting the naturalness of Hungarian semi-dry grasslands on landscape level

For the analysis all cells of the MÉTA database – 35 hectare hexagons – were selected wherever the model habitat was present (4593 hexagons) using the SQL interface. The original five-grade naturalness-based quality values were simplified to bad and good quality. This binary form of naturalness-based habitat quality was the response (dependent) variable. Every other attribute from the database for the hexagons containing the model habitat were selected as well. The area of the model habitat in the cell, the proportional area of the model habitat to total cover of semi-natural habitat types in the cell, neighbourhood, connectedness, pattern, threats, presence / absence and area of all other habitat types, land-use in the cell, total cover of semi-natural habitat types, number of habitat types in the cell and total area covered by old fields and invasive alien species in the cell were used as explanatory variables. Geographical location was used as covariable. Since we did not have a priori hypotheses about the effects of studied predictors, the dataset was split into two equal

parts randomly. The TRAINING dataset was used to generate hypotheses, which were then validated with the TESTING dataset. Generalised linear models with binomial distribution and logit link were used. The models were evaluated by likelihood-ratio tests. Since the number of tested hypotheses was high, following the applied hypothesis generating procedure, the Benjamini-Hochberg correction was used to create a false discovery rate of 5%. Due to the large sample sizes, relatively small effects could prove to be statistically significant. Therefore, to avoid interpreting such effects, Nagelkerke's R^2 was calculated, and predictors with a value lower than 0.01 (i.e. 1%) were disregarded.

D. Analysis of the factors affecting the species richness, diversity and other quality attributes of Hungarian semi-dry grasslands on landscape level

For estimating quality on stand level we chose the following indicators: species richness, diversity, cover of dominant grasses, and presence of valuable species and proportion of rough physiognomical forms (graminoids, forbs, shrubs and trees). These data were derived from newly sampled vegetation relevés. We calculated correlation between the quality indicators to reveal positive and negative relations among them. We tested the effect on the quality of a grassland patch of several factors including soil properties, local and regional landscape neighbourhood, former and recent land use and threats. Single models were built for each response variable with all of the predictor variables respectively. Linear models with normal distribution were used, since the distribution of the residuals for each model and for each independent variable was checked by QQ-plots and more or less followed normal distribution. Significant effects revealed in the TRAINING dataset were validated and tested on the TEST dataset. An effect was regarded as significant if the p value was smaller than 0.05 in both datasets and the direction of the effect was the same. Due to the large sample sizes, relatively small effects could prove to be statistically significant. Therefore, to avoid interpreting such effects, R^2 was calculated for all models, and predictors with a value lower than 0.05 (i.e. 5%) were ignored. In cases where the geographical position was revealed to be significant, variation partitioning was performed to separate the effects of the geographical position and the particular independent variable by calculating the R^2 for the single model with geography, for the single model with the factor and for the combined models. Factors which had a significant effect but the R^2 of their single model was < 0.05 (i.e. 5%) were not interpreted.

3. New scientific results

A. Variation in species composition of Central-European semi-dry grasslands

A.1. A well-defined gradient from subatlantic to subcontinental communities was found in the floristic composition of the six clusters gained from the analysis of central European semi-dry

grasslands. The species composition of semidry grasslands changes considerably along the NW-SE gradient across Central Europe. In areas characterized by suboceanic climate in central Germany and the middle altitudes of the Czech Republic and Slovakia these grasslands contain subatlantic species. By contrast, in the drier parts of the study area, semi-dry grasslands contain several species of continental distribution, which are also typical of dry oak forests or continental steppe species. This pattern provides the basis for the traditional phytosociological division of the alliances *Bromion erecti* and *Cirsio-Brachypodion pinnati*. Two clusters of the six were dominated by *Brachypodium pinnatum* or *Bromus erectus* and were distributed in Germany and Bohemia (Clusters A and B); they represented the subatlantic communities. Two clusters represented the subcontinental types; one of them had wide distribution from south-central Germany through Czechia to some localities in Hungary and Romania (Cluster E), while the other was restricted to the Carpathian basin (Cluster F). There were two clusters with transitional character both floristically and geographically between the two alliances. One of them represented the semi-dry grasslands of the White Carpathians (Cluster D), the other reflected special site-conditions, namely heavy and intermittedly wet soils (Cluster C).

A.2. We found singificant differencies among the geographical range and climatic attributes of the six clusters. Clusters A and B (subatlantic *Brachypodium pinnatum* and *Bromus grasslands*) are the most oceanic ones according to geographic position, precipitation and temperature. Clusters C (semidry grasslands on wetter soils with wider distribution), D (species-rich meadows, mainly found in the White Carpathians) and E (open subcontinental dry grasslands) have a transitional character, while cluster F (*Brachypodium grasslands* of the inner Carpathian Basin) are confined to the driest and warmest areas.

A.3. The artificially defined 25% cover limit of *Brachypodium pinnatum* or *Bromus erectus* in the relevés selected for this analysis makes it impossible to interpret our valid clusters directly in terms of the traditional phytosociological syntaxa. Still, when compared with the Central European phytosociological literature, the valid clusters can be linked to the traditional associations. Cluster A and B corresponds to the association *Carlino acaulis-Brometum erecti* Oberdorfer 1957, which is also frequently called *Gentiano-Koelerietum pyramidatae* Knapp ex Bornkamm 1960. Cluster A represents managed or recently abandoned stands, while Cluster B represents successional stages after abandonment, as indicated by the occurrence of shrubs. Cluster C has been traditionally assigned to several associations, within which it was often considered as a transitional type to other associations. Although this type is well delimited in the current data set, it tends to be neglected in the local phytosociological literature. In our opinion it corresponds the best with the description of *Potentillo reptantis-Caricetum flaccae* Studnička 1980. Relevés of Cluster D largely correspond to *Brachypodio pinnati-Molinietum*

arundinaceae Klika 1939, and partly also to other species-rich grasslands which are transitional between the class *Festuco-Brometea* and the mesic meadows of the alliance *Arrhenatherion*. Cluster E corresponds to the *Scabioso ochroleucae-Brachypodietum pinnati* Klika 1933, but in different countries, these grasslands were traditionally assigned to different, locally described associations, e.g. in Germany to the *Adonido-Brachypodietum* (Libbert 1933) Krausch 1961, *Scorzonero hispanicae-Brachypodietum* Gauckler 1957 or *Festuco rupicolae-Brachypodietum* Mahn 1965, and in Slovakia to the *Salvio verticillatae-Brachypodietum* Ružičková 1986. Cluster F corresponds to the *Polygalo majoris-Brachypodietum pinnati* Wagner 1941 or *Verbasco austriaci-Inuletum ensifoliae* Tlusták 1975. For these grasslands a new association *Euphorbio pannonicae-Brachypodietum pinnati* Horváth 2009 was proposed.

A.4. Most of the relevés of Hungarian semi-dry grasslands belonged to Cluster F, which was restricted only to the Carpathian Basin. This pattern strenghten the conception of the uniqueness Pannonian communities among the Central-European semi-dry grasslands.

B. Variation in species composition of Hungarian semi-dry grasslands

B.1. Seven valid clusters could be identified by the analysis of Hungarian semi-dry grasslands. The clusters are separated geographically; however, there are considerable overlaps in the species compositions.

B.2. All the grasslands belong to the *Cirsio-Brachypodion* alliance; non of the relevés represent the *Bromion erecti* alliance. Interpretation of the clusters in syntaxonomical terms is problematic, mainly due to the fact that most of the associations of semi-dry grasslands mentioned in the Hungarian literature have no relevés published. Finally, the seven valid clusters were assigned to five main groups of semi-dry grasslands in Hungary: 1. *Brachypodium pinnatum* (and partly *Bromus erectus*) dominated, species rich meadow-steppe-like grasslands occurring on deep loess in central Pannonia, identified as *Euphorbio pannonicae-Brachypodietum* Horváth 2009 (Clusters A, B and C); 2. *Brachypodium pinnatum* dominated mountain grasslands restricted to the Bükk Mts; identified as *Polygalo majoris-Brachypodietum* Wagner 1941 (Cluster D); 3. mostly *Bromus erectus* dominated grasslands on shallow, calcium-rich soils of the Dunántúl region, proposed as a new association *Sanguisorbo minoris-Brometum erecti* Illyés, Bauer & Botta-Dukát 2009 (Cluster E); 4. *Brachypodium pinnatum* and *Danthonia alpina* dominated stands occurring mainly in the Északi-középhegység, characterized by species of nutrient poor soils, proposed as a new association *Trifolio medii-Brachypodietum pinnati* Illyés, Bauer & Botta-Dukát 2009 (Cluster F); 5. transition towards meadows and successional stands dominated mainly by *Brachypodium pinnatum* (Cluster G).

B.3. The available syntaxomical systems did not reflect the floristic patterns of semi-dry grasslands revealed by our analysis. We found no representatives of the *Bromion erecti* alliance, and could not support the concept of several associations published earlier in the literature (namely: *Lino tenuifolio-Brachypodietum pinnati* (Dostál 1933) Soó 1971, *Hypochoerido-Brachypodietum pinnati* Less 1991, *Poo badensis-Caricetum montanae* V. Sipos & Varga 1996, *Hypochoerido-Brachypodietum pinnati* Less 1991, *Onobrychido viciifoliae-Brometum erecti* T. Müller 1966 and *Carlino acaulis-Brometum* Oberdorfer 1957). We had to introduce the concept of two new associations (*Trifolio medii-Brachypodietum pinnati* Illyés, Bauer & Botta-Dukát 2009 and *Sanguisorbo minoris-Brometum erecti* Illyés, Bauer & Botta-Dukát 2009) in order to satisfactorily describe two cluters of our analysis. Our results supported the concept of *Euphorbio pannonicae-Brachypodietum* Horváth 2009, which is the unique semi-dry grassland type of central Pannonia.

C. Analysis of the factors affecting the naturalness of Hungarian semi-dry grasslands on landscape level

C.1. The naturalness-based quality of Hungarian semi-dry grasslands was affected both by local (intra-patch) factors and factors describing the composition and structure of surrounding vegetation (landscape or matrix factors). Presence of other grassland types similar in ecological demands to the model habitat positively affects the naturalness of that type, while invasive alien species and diffuse pattern have negative effects. The higher proportions of (semi-)natural habitats in the cell, as well as the number of habitat types in the cell, have positive effects.

C.2. The results based on the analysis of the MÉTA database indicate that the overall importance of the matrix (landscape) factors is much higher than that of the intra-patch (local) factors. The summed variance explained by the matrix factors was 12.5 %, while that of intra-patch factors remained only 3%. However, we have to admit that the percentage variance explained by the single factors was rather low, it ranged between 1.4 and 3.7 %.

D. Analysis of the factors affecting the species richness, diversity and other quality attributes of Hungarian semi-dry grasslands on landscape level

D.1. Species richness of the semi-dry grasslans stands was affected both by patch and landscape attributes. Soil parameters, elevation, disturbance by animals and number of neighbouring habitat types were the patch attributes, while climatic parameters and landscape neighbourhood were the landscape attributes which affected species richness. Intersingly enough, Shannon diversity was only affected by the disturbance of animals, which had positive effect. Number of valuable species was affected largely by the structural attributes of the stand. Animal

disturbance had positive effect also on this quality variable. Cover of the dominant grass *Bromus erectus* was affected positively by the area of grasslands in the surrounding landscape. Cover of graminoids was negatively affected by animal disturbance.

D.2. Most of the dependent variables are correlated with one another. The correlation analysis revealed two groups of variables which behave similarly. Within the groups the variables are correlated with each other positively, while among the groups the correlation is negative. The first group is composed of the variables 'species number', 'Shannon diversity', 'evenness' and the 'number of valuable species' which are positively correlated to one another. The second group is formed by the variables 'cover of valuable species', 'cover of *Brachypodium pinnatum*' and 'cover of graminoids', which are correlated positively to one another and mainly negatively to the first group. Besides these two groups we found negative correlation between the variables 'cover of *Brachypodium pinnatum*' and 'cover of *Bromus erectus*'. Interestingly enough we found that variable 'cover of *Helitotrichon praeusta*' is positively associated with the number of valuable species. We found no correlation with variables 'cover of shrubs' and 'cover of trees'.

D.3. We found the presence of animal disturbance to have the most important effect on quality attributes, since it affected species richness, diversity and number of valuable species positively, while the total cover of graminoids negatively. The importance of disturbance by animals alone ranged between 1 and 12%, while 36 to 47% when it was combined with geographic location. Nonetheless, the pure effects of other significant predicting factors was rather low, they ranged between 1 and 15%

D.4. According to our analysis it is not possible to predict the exact quality of a semi-dry grassland patch even with data on the geographical location, climatic conditions, local and landscape neighbourhood threatening factors and recent and former management of the particular grassland patch. Nevertheless, the prediction of the quality of a grassland patch is possible to some extent. Geographical location combined with local and landscape neighbourhood, climatic and soil paramaters, stand structure and presence of any management activity or disturbance by animals indicates the quality of a grassland patch quite well.

4. Conclusions

- The concept of the uniqueness of Hungarian semi-dry grasslands and steppes was supported by the results of the large-scale analyses of the floristic patterns of central European semi-dry grasslands and the detailed study of the Hungarian ones as well.
- The conservation of semi-dry grasslands can only be effective if representatives of all types of semi-dry grasslands can be maintained in the long run. Therefore, the national and

European level conservation policy should incorporate the results of recent vegetation studies.

- The main types of Hungarian semi-dry grasslands identified and assigned into associations by this thesis could serve as a basis for the refinement of the definition and description of the "Sub-Pannonic steppic grasslands" (6240) Natural Habitat Types of Community Interest according to Annex I of the Habitats Directive (92/43/EEC); and for the identification of Pannonian subtypes of these habitat types which is inevitable for effective conservation practice.
- At landscape level the richness of the surrounding landscape in natural habitat types had the largest positive effect on the quality of semi-dry grassland patches. Presence of natural woodlands and grasslands also predicted good quality. Therefore conservation efforts focusing on semi-dry grasslands are recommended to take place in areas with different grasslands and dry forest habitats present in the vicinity of the semi-dry grasslands embedded into a relatively diverse landscape, since there the conservation of grasslands is predicted to be effective in the long run. This approach needs the harmonisation of the conservation of different habitat types and rather recommends to conserve landscape units as a whole rather than single habitat patches.
- Without management, the quality of semi-dry grassland habitats decreases rapidly and there is no way to get the lost values back. Proper habitat management run exclusively for conservation purposes, however, is expensive and in many cases difficult to perform. Re-establishment of traditional forms of land-use instead would be a far more economical – and at the same time ecological – solution. The proper strategy would amalgamate rural developmental strategies, ecologically sustainable agriculture and nature conservation.

5. Publications covering the topic of the thesis:

Publications published in ISI journals:

Illyés, E., Bauer, N. & Botta-Dukát, Z. (2009): Classification of semi-dry grasslands in Hungary. – *Preslia* 81:239-260.

Illyés, E., Chytrý, M., Botta-Dukát, Z., Jandt, U., Škodová, I., Janišová, M., Willner, W. & Hájek, O. (2007): Semi-dry grasslands along a climatic gradient across Central Europe: Vegetation classification with validation. – *Journal of Vegetation Science* **18**: 835-846.

Publications published in non-ISI journals:

Illyés, E. & Botta-Dukát, Z. (2008): Factors affecting the naturalness based quality of three model grassland habitats in Hungary. – *Acta Bot. Hung.* 50 (Suppl.): 179-198.

Illyés E., Molnár, Cs., Garadnai, J. & Botta-Dukát, Z. (2007): Északi-középhegységi erdőssztyeprétek természetvédelmi állapotának felmérése – esettanulmány. *Természetvédelmi Közlemények* **13**: 163-172.