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Phytocoenological and habitat analysis of wet meadows in Hanság

PhD THESIS

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1. Introduction

The rapid degradation and disappearance of natural and semi-natural habitats is a global problem. Different biotopes are endangered to varying degrees, but each has its own affliction (expansion of invasive species, dehydration, increased anthropogenic load). Wetlands are most negatively affected by the drying climate, invasive species, and fragmentation of contiguous areas. Grasslands are usually formed by edaphic or climatic extremes, or as a result of some anthropogenic effect. Wet meadows are mostly created due to human activities (deforestation, hayfield reclamation, grazing), so their survival usually requires human intervention. In many cases, these associations do not provide the potential vegetation cover for the areas, but their maintenance is justified in order to preserve their biotic values.

The area of wet meadows in Hungary is around 90,000 ha and is decreasing. Their shrinking area ratio is due to the increasingly unfavourable climate, their low economic value and their sensitivity to different grassland treatment methods. Therefore, their conservation and protection must be one of the priority tasks of nature conservation. In Hungary, wet meadows can be classified as less researched habitats. This is due to the fact that they are often difficult to access and their stand structure is often monotonous. However, due to their ecological features, many rare species find a home in their stands.

During my research, I dealt with the coenosystematic exploration of Kisalföld, in particular the wet meadows of Hanság and its region. Thorough knowledge of the organisms living there and their requirements is essential for conservation maintenance. Accordingly, the current flora, vegetation and habitat types of the areas were mapped during the examinations. Traditional and statistical methods were used to detect associations in the examined areas. The implementation of the grassland treatment was monitored. Interactions between microrelief, genetic soil type and vegetation were investigated. By publishing the results of this research, I intend to contribute to the expansion of the knowledge regarding grassland treatment from a nature conservation point of view, to the knowledge about the vegetation of Hungary, and to the conservation of the Hanság grasslands.

1.1 Objectives

At the start of the examination, the research directions listed below were set out:

1. Survey of the typical coenoses and habitat types of the wet meadows in the Hanság and Tóköz areas.
2. Preparing current vegetation and habitat maps of the surveyed areas.
3. Comparison of different coenological survey methods (traditional and statistical methods).
4. Examining the connection between vegetation pattern, soil characteristics and microrelief, and analysing the connection between altitude and vegetation in the examined areas.

2. Material and Methods

2.1 Methods for field surveys

The total area of the wet meadows surveyed is 784.91 ha. I carried out coenological survey of the selected sample areas in 2019–2020, from late spring to mid-summer. The relevés were set in patches with typical species composition and structure of the associations found in the examined areas. The relevés were square in shape and 5×5 m in size. Sampling points were fixed, using GPS-based point location. Photo-documentation was prepared of the actual vegetation of the relevés, from the north-west corner point. The relevé approach followed the principles of the classical Zurich-Montpellier school, with some adjustments: A-D values were not estimated on a six-point scale but were given in percentage.

Vegetation mapping was carried out at the same time as the relevés. The nomenclature of the coenoses follows the work of BORHIDI (2003). The works of KIRÁLY (2009), KIRÁLY *et al.* (2011), JÁVORKA & CSAPODY (1934) were used to identify the plant species. The nomenclature of plant species follows the work of KIRÁLY (2009). Herbarium specimens were collected from species of genera that are difficult to identify and those with a new locality in the area.

During the research, I noticed that treeless plant communities showed large mosaic patterns even within small areas. Depending on the site, the various treeless associations varied from stripe complexes to mosaic complexes. Also, closely related coenoses were often sharply separated (physiognomy, species composition). In order to identify the causes, I carried out soil tests in the areas. Soil profiles were opened by a Pürckhauer soil sampler for classifying the genetic soil type. Both the Hungarian genetic system and the nomenclature of the international soil classification system were used to name the soil types. Actual moisture content was also measured at depths of 0–10 cm, 10–20 cm and 20–30 cm. Soil samples were taken from the top10 cm of the soil layer for laboratory analysis and 100 cm^3 samples were taken with sampling cylinders to calibrate the measured actual water content and to measure the bulk density.

2.2 Data evaluation methods

I used version 3.18 of the QGIS software package for the geospatial processing and visualization of the recordings. The vegetation maps prepared during the field surveys were digitized. A color-coded file was created to ensure the uniform marking of vegetation types. Four main categories were distinguished: basic associations, degraded versions of basic associations, hybrid associations, and categories not included in BORHIDI's work (2003).
Habitat maps were made, based on existing vegetation maps. The surveyed areas were divided into two major categories: homogenous habitats and hybrid habitats. Previous habitat maps of the sample areas and sub-areas were available. To study the changes in vegetation over the decades, these materials were digitized. Surface models were used to represent the microrelief of the surveyed areas. Then, the surface models were used to generate contour maps of the sample areas. The Lechner Knowledge Center's DDM-5 was used to visualize altitude generated by digitizing topographic maps at a scale of 1:10,000. Derived models were used to quantify the microrelief. A normalized elevation model and slope model was calculated, based on the DDM. The statistics calculations were done in an R environment. A one-way analysis of variance was performed using a post-hoc Tukey's HSD test to compare the soil properties assigned to the identified soil groups – genetic and TWINSPAN groups. Pairwise correlations were calculated between soil parameters using Bonferroni-adjusted P-values. Mean values of soil parameters were calculated at TWINSPAN group level. The soil parameters of the records assigned to TWINSPAN groups were compared by using ANOVA, and homogeneous groups were separated by Tukey's test. Canonical correspondence analysis (CCA) was used to examine the relationship between soil parameters and the distribution of dominant plants (percent covered) among TWINSPAN groups.

I imported the coenological tables into the TURBOVEG database management software. Statistical evaluation of the data was performed using the JUICE software package version 7.1. Modified TWINSPAN method was used to perform the classification. The maximum number of divisions was specified during the analysis, and the analysis was run using the mean of Jaccard's dissimilarity index. The diagnostic, stationary/permanent and dominant species of the established recording groups were determined. The range of diagnostic species was determined by calculating the fidelity values according to coefficient Φ. The table of synthetic data (fidelity, constancy) was compiled using Fisher's exact test ($P<0.05$) with $\Phi=0.30$ to eliminate biases.

I performed the laboratory examination of the soil samples in the soil laboratory of the Institute of Environmental and Earth Sciences of the University of Sopron. The samples from the sampling cylinders were weighed at the end of the field days, dried at 105 °C for 3 days to have constant weight, and then weighed again, so that the amount of actual water content for calibration and their bulk density were obtained. After drying, the skeletal parts, roots and snail shells were removed from the topsoil sample. The chemical reaction (pH(H_2O)) of the prepared soil samples was measured in a 2.5-fold distilled water suspension. Potassium (PAK) and phosphorus (PAP) contents for vegetation were determined by ammonium-lactate-acetic acid (AL) extraction. Finally, the organic carbon (TOC), total nitrogen (TN) and sulphur (TS) content of the soils were measured using an Elementar Vario MAX CNS elemental analyser according to international standards.

2.3 Method for systematic description of habitats occurring in the sample areas

During the listing of coenotaxons in each habitat category, I described the associations identified in the sample areas. The landscape names "Észak-Hanság", "Dél-Hanság", and "Tóköz" were used to localize the occurrences. The names of balk fields were used for more accurate location designation. Their area ratio was given as a percentage of the total area of the sample areas. For the description of the production site, my own soil sampling results were used, and where this was not available, the relevant literature data were used. During the description of the structure and species composition, my own field observations were reported.

For the dynamic findings, I reported changes observed during four years of fieldwork and made reference to the work of ZÓLYOMI (1934) and SEREGÉLYES & S CSOMÓS (1997). The determination of naturality was limited in the sense that category 3 was set as the expected minimum during the designation of the sample areas. Therefore, in this section, indicators ranging from 3 to 5 were used to characterize habitats. In addition, the conditions resulting from the spread of invasive species was discussed.

3. Results

I did not carry out my research on the entire area of the micro-regions, but only on grasslands of "good naturality".

The following types are common habitats within the examined sample areas (Hanság): B5 and its hybrid categories (B5 × D34; B5 × E1; B5 × OB), D2 and its hybrid categories (D2 × B1a; D2 × B5; D2 × D1; D2 × D34), D34, OC. Medium common habitats: B1a, D1 (D1 × E1), E1, OD, RB, RC. Rare habitats are B2, RA, OB, OF, S2, T10. Common habitat types of the examined sample area (Csorna plain): B5 and its hybrid categories (B5 × D34, B5 × OB), D34. Medium common habitat types: B1a, J4, OC, OD. Rare habitat types B2, D2, E1, OB, OF, OG, RB, S2.

3.1 A mintaterületeken azonosított élőhelyek

1. B1a – Eu- and mesotrophic reed and *Typha* beds
2. B2 – *Glyceria*, *Sparganium* and *Schoenoplectus* beds
3. B5 – Non-tussock tall-sedge beds
4. D1 – Rich fens (*Caricion davallianae*)
5. D2 – *Molinia* meadows
6. D34 – Mesotrophic wet meadows

3.2 Results of the coenological surveys

I surveyed a total of 299 relevés, the vegetation of which were classified into 17 homogenous, 21 hybrid, and 11 degraded association types using the traditional method. 17 groups were separated by statistical analysis. The categories displayed on the vegetation maps included 67 types. The determination of coenoses was based on Borhidi's category system (BORHIDI 2003). In the vast majority of the surveyed areas (65.29%), the surveyed associations were compatible with the above-mentioned system, but separate categories were formed to describe the vegetation of the remaining (34.71%) areas.

Associations isolated by traditional method (without hybrid and degraded types)	**Vegetation groups detected during TWINSPAN analysis**
Agrostio–Deschampsietum caespitosae Ujvárosi 1947	Mixed Molina meadows
Seslerietum uliginosae Soó 1941	Tussock grass
Succiso–Molinietum hungaricae (Komlódi 1958) Soó 1969 corr. Borhidi 2001	Tussock grass – Molina meadows
Caricetum acutiformis Eggler 1933	Molina meadows (from Fehértó)
Caricetum distichae Steffen 1931	Molina meadows (from Hanság)
Caricetum elatae Koch 1926	Molina meadow–Blue Moor Grass transition types
Caricetum gracilis Almquist 1929	Blue Moor Grass
Caricetum melanostachyae Balázs 1943	Acute sedges
Caricetum vulpinae Soó 1927	Brown sedges–Acute sedges transition groups
Carici gracilis–Phaladrietum (Kovács & Máthé 1967) Soó 1971 corr. Borhidi	Acute sedges (from Rich fens)
Galio palustris–Caricetum ripariae Bal.-Tul. et al. 1993	Lesser pond sedges
Glycerietum maximae Hueck 1931	Greater pond sedge–Glyceria transition group
Agrostetum albae Ujvárosi 1941	Mixed greater pond sedge groups
Brometum erecti	Mesotrophic wet meadows with foxtail grass and creeping bentgrass transition type
Carici vulpinae–Alopecuretum pratensis (Máthé & Kovács M. 1967) Soó 1971 corr. Borhidi 1996	Mesotrophic wet meadows with meadow fescue
Cirsium cani–Festucetum pratensis Májovsky & Ružičková 1975	Mesotrophic wet meadows– Arrhenatherum hay meadows transition group
Pastinaco–Arrhenatheretum (Knapp 1954) Passarge 1964	Mesotrophic wet meadows mixed group

3.3 Examination results of the relationship between vegetation and topsoil

I examined a total of 7 association types in the research areas:

1. *Glycerietum maximae* Hueck 1931
2. *Galio palustris–Caricetum ripariae* Bal.-Tul. et al. 1993
3. *Caricetum acutiformis* Eggler 1933
4. *Caricetum gracilis* Almquist 1929
5. *Caricetum distichae* Steffen 1931
6. *Cirsio cani–Festucetum pratensis* Májovsky & Ružičková 1975
7. *Carici vulpinae–Alopecuretum pratensis* (Máthé & Kovács M. 1967) Soó 1971 corr. Borhidi 1996

Association types typically occurred together in the form of stripe or mosaic complexes in the areas. They were well separated by their species composition and physiognomy.

The results of the analysis show that the examined coenoses were not as sharply separated from each other as it had been identified in the field. 94 coenological relevés and 21 soil sampling points were established.

During the analysis 6 clusters formed.

- *Caricetum gracilis* × *Caricetum distichae* group
- *Caricetum acutiformis* × *Caricetum ripariae* group
- *Galio palustris-Caricetum ripariae* × *Glycerietum maximae* group
- *Galio palustris-Caricetum ripariae* × *Caricetum gracilis* group
- *Carici vulpinae-Alopecuretum pratensis* × *Caricetum gracilis* group
- *Carici vulpinae–Alopecuretum pratensis* × *Cirsio cani–Festucetum pratensis* group

3.4 Soil examination results

I described hydromorphic soils during the field examinations, which had topsoil of different thicknesses and organic matter content. Typical meadow soils were found in 3 cases, marshy meadow soils were more common, which were present in 12 relevés. Transitional types of the two soil types were identified in 6 cases.

There were no statistically significant differences between soil groups in terms of pH(H_2O), elevation and PAP. A significant difference was found for PAP, but the post-hoc examination evaluated only typical meadow soils as different from the other two soil groups. TOC, TN, TS, BD, VWC1, VWC2 and VWC3 parameters were found to be significantly different for all three soil groups.

During the examination of the correlations between the individual soil test parameters, no relationship was found with other parameters in the case of altitude and pH(H_2O). A significant and negative correlation ($R > 0.80$) was found for BD. A significant and very strong positive relationship was found between PAP, TOC, TN and TS ($R > 0.90$).

I examined the parameters, using regression analysis when I suspected causality. Of these, the relationship between TOC and BD is very striking.

In the following, I examined the average soil parameters for the TWINSPAN groups identified. There was a correlation between the soil groups and the TWINSPAN groups.

Similar to the classification by soil group, there was no sharp distinction between the TWINSPAN groups in terms of altitude, pH(H_2O) and PAK. For PAP, TOC, TN and TS parameters, the TWINSPAN groups were sharply divided into two groups. The moisture contents showed a consistent picture.

The relationship between vegetation and soil parameters was confirmed by CCA results. The analysis was based on data from 21 relevés, represented by dots and coloured by their TWINSPAN group. The CCA model was found to be significant by the permutation test ($F=1.748$, $P=0.004$). The total inertia was 4.746 of which 53.8% was described by ordination axes. The first axis explained 18.4%

of the total inertia, while the second axis covered 14.9% of the total inertia. The correlation coefficient (R^2) was 0.538 and the adjusted correlation coefficient (R^2adj.) was 0.234. The species-environment correlation was strong, with r=0.95 for axis 1 and r=0.89 for axis 2. The most important factors were BD, VWC, EOVY, PAP and PAK. Axis 1 showed a strong positive correlation with BD (r=0.818), strong negative with VWC1, EOVY, PAP (r=-0.856, -0.687, -0.639), moderately positive with altitude (r=0.409). The second axis was most correlated with PAK (r=0.446), with a medium negative correlation with EOVX (r=-0.394) and pH (r=-0.305).

3.5 Correlations between vegetation and microrelief properties

In the light of the above results, I concluded that the fine mosaic pattern of vegetation in flat areas was also due to variations in microrelief. Therefore, 5 × 5 m resolution digital topography models were fitted to the examined areas and compared with the pattern of vegetation patches surveyed during vegetation mapping. It can be stated that the vegetation reliably follows the changes in the surface of the sample areas.

Differences in altitude in these areas are minimal. It can be clearly seen that the vegetation also shows the 10–20 cm height differences well. Where the surface rises “suddenly” the coenoses are arranged in stripes, while where the surface is nearly flat, they show a patchier arrangement. As the plant communities found here are the coenoses of swampy, marshy habitats, the presence or absence of water is a crucial factor in their survival and development.

The normalised elevation values of the TWINSPAN groups differed significantly (F =32.94, P<0.001). There were three subsets separated by Tukey’s test. TWINSPAN group 00, 010, 0110, and 0111 are the ones which have average values lower than 0. Group 10 is a transient group and group 11 had the highest values and highest average. Normalised slope values showed a different image. Significant difference among the groups was evident (F=16.67, P<0.001). The lowest values were accompanied with group 00 and 0111. Group 0110 showed a transition between subset a and b. Subset b (TWINSPAN group 010 and 10) was in the mid-range, while group 11 had again the highest average.

I assigned the TWINSPAN groups with the category of hummock or hollow according to the combined models of normalised elevation and slope on the level of relevés. The groups showed considerable differences (F=18.04, P<0.001). Tukey’s test divided the group into two subsets. TWINSPAN group 00, 010, 0110, and 0110 are assigned to the hollow subset and TWINSPAN group 10 and 11 classified into the hummock subset. TWINSPAN group 00 has relevés only in hollows, 0110 and 0111 have three and one hummock relevés respectively while the rest of the relevés are hollows. TWINSPAN group 010 has five hummock and 12 hollow relevés, group 10 has a similar distribution but with swapped groups (13 hummocks and six hollows). Group 11 has only hummock relevés.

4. New scientific findings

T1 – I identified the habitats currently occurring in the area of the wet meadows of Hanság and Tóköz and in their immediate surroundings and prepared overview habitat maps. Their locations, production sites, structure, species composition, dynamics and naturality were described.

T2 – I demonstrated that altitude had little effect on habitat occurrence but influenced their development through its positive/negative effects on ecological factors. As the land level rises, moisture-demanding habitats decline and are replaced by drier habitats.

T3 – I demonstrated the coenotaxons currently occurring in the examination area. I evaluated and made a list of current vegetation types in the area. I gave the characteristic species combination, occurrence, and structure of the coenotypes. I made synoptic tables containing fidelity and constant values for the characteristic species of associations. I compared classification methods based on traditional and mathematical methods.

T4 – I prepared the current vegetation and habitat maps of the examination areas. I surveyed the protected vascular plant species occurring in and around the examination areas, gave their site and specimen numbers, and displayed their occurrence on a dot map.

T5 – I demonstrated that soil properties did not determine the quality of the vegetation at the association level, for that the microrelief differences and the resulting differences in water availability are responsible. At habitat level, however, there is a strong correlation between the species and the habitat type.

5. List of the author's main publications on the subject

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