# MODELLING OF GRASSLAND DISTRIBUTION IN THE POLONINY NATIONAL PARK

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Abstract

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Semi-natural grassland biotopes represent a specific feature of the Poloniny National Park (East Carpathian Mts, Slovakia) with the great biodiversity values. In this article we use habitat models to predict their distribution in the study area. Based on 285 phytosociological records, we identified 5 main grassland types: mountain meadows, mesophilous meadows, wet meadows, dry meadows and fens. We used logistic regression and classification and regression trees (CART) for creating habitat models for each respective grassland type. Basic environmental variables derived from digital elevation model (elevation, slope, aspect, topographical wetness index, potential direct solar irradiation), landscape structure (landscape indexes: number of different classes, diversity, fragmentation), soil map (fertility index, soil type) and geomorphology were analysed as predictors. In general, the highest predictive power was shown by elevation, slope, topographic wetness index and geomorphologic form. The main output of habitat modelling was the map of potential grassland types of the whole study area. Final map of predicted distribution of grasslands emerged after the intersection of grassland landcover class with the map of potential grassland types. The accuracy was assessed comparing the modelled distribution of grassland types to the validation subset (approx. 30% of original dataset). Generally, logistic-based model exhibited better accuracy. Its results have shown that almost 81% of all semi-natural grasslands in the study area represent mesophilous meadows followed by wet meadows (13%), fens (2.5%), dry meadows (2%) and mountain meadows (1.5%).

*Key words*: habitat modelling, grasslands, CART, logistic regression, Poloniny National Park

## Introduction

The Poloniny National Park is located in NE Slovakia and represents Slovak part of the trilateral East Carpathians Biosphere Reserve (Poland/Slovakia/Ukraine) of the Man and Biosphere programme of UNESCO. Besides virgin and native forests, grasslands are considered to be the most important habitat, contributing significantly to the biodiversity of the area. Grasslands of this region were studied by several authors (e.g. Hadač et al., 1988; Blažková, 1991; Blažková, Březina, 2003). More intensive research during last 10 years has been using both phytosociological and permanent plot approaches (Ružičková et al., 1998, 2001; Halada, 2000). Existing grassland dataset has a point character. In this paper we describe a spatial distribution of grasslands in the Poloniny National Park by means of habitat modelling. Habitat modelling has recently become widely used (see Guisan, Zimmerman, 2000). A main motivation of habitat modelling is often to minimize fieldwork and mapping especially when large or hardly accessible area should be mapped. Majority of the models are based on explored statistical relationship between existing occurrences of the species or habitats and environmental properties. The choice for relevant statistical technique depends primarily upon the type of the response variable modelled (Hirzel, Guisan, 2002). In any case, an expert knowledge of relations between particular habitats and environmental variables (a knowledge derived from an adequate empirical study) must be applied while creating habitat models (see Store, Kangas, 2001). Furthermore, selection of specific approaches and tools for habitat modelling strongly depends on available data and sampling design used (Hirzel, Guisan, 2002). In this paper we applied two different statistical techniques to design a map of potential grassland types in the study area. Then, based on the intersection of potential grassland types map and actual landcover map we tried to identify current status and distribution of main grassland types in the Poloniny National Park.

## Material and methods

As it was mentioned above, using specific approach and tools of habitat models strongly depends on available data and its character. Field data used in this work were collected by systematic vegetation survey of grasslands in the Eastern Carpathians (Ružičková et al., 2001). Totally, 285 vegetation records formed the sample design in the study area (Fig.1). Each site is represented a phytosociological relevé according to the Braun-Blanquet methodology. Based on visual interpretation of detailed aerial images (Olah et al., 2006), sampled grasslands cover almost 70% of all grassland patches in the study area. Ružičková, Halada (2002) prepared the classification of grassland vegetation of the region. They distinguished 13 types that can be grouped into five main types: mountain meadows, mesophilous meadows, wet meadows, dry meadows and fens. Afterwards, each sample site was assigned to the respective grassland type. Sample distribution of grassland types represents a dependent variable for statistical analyses (Table 1). Independent variables were represented large scale of available environmental variables that should determine the distribution of grasslands in the study area. In general, they can be divided in four basic groups: derived from digital elevation model (elevation, slope, aspect, topographical wetness index, potential direct solar irradiation), landscape composition (landscape indices like number of different classes, diversity, fragmentation), soil map (fertility index, soil type) and geomorphology.

The main approach of our work should be outlined in 3 main steps:

1. **Creating of statistical model.** We used classification and regression trees (CART) and logistic regression (LR) as a basis in order to create statistical model. As we used logistic regression, we had to transform values of the dependent variable into the form of presence (1) or absence (0) for each grassland vegetation type. Afterwards, we made and validated one logistic model for each grassland type separately. The final resulting score in the 0–1 scale indicated which grassland type should be assigned to the site. On the contrary, CART analysis used the assignment to a grassland type as the categorical dependent variable. The C&RT-style exhaustive search for univariate splits option and Gini measure of goodness of fit (Breiman et al., 1984) were used within the Statistica ver. 7 software while building the tree. The FACT-style direct stopping has been selected as the stopping rule for the analysis (Loh, Vanichestakul, 1988).
2. **Validation of the model.** Because of differences between statistical procedures used we had to validate them separately. We randomly selected 30% of sample sites for validation reasons. Afterwards, a simple cross-validation identifying percentage of correctly classified samples were used.

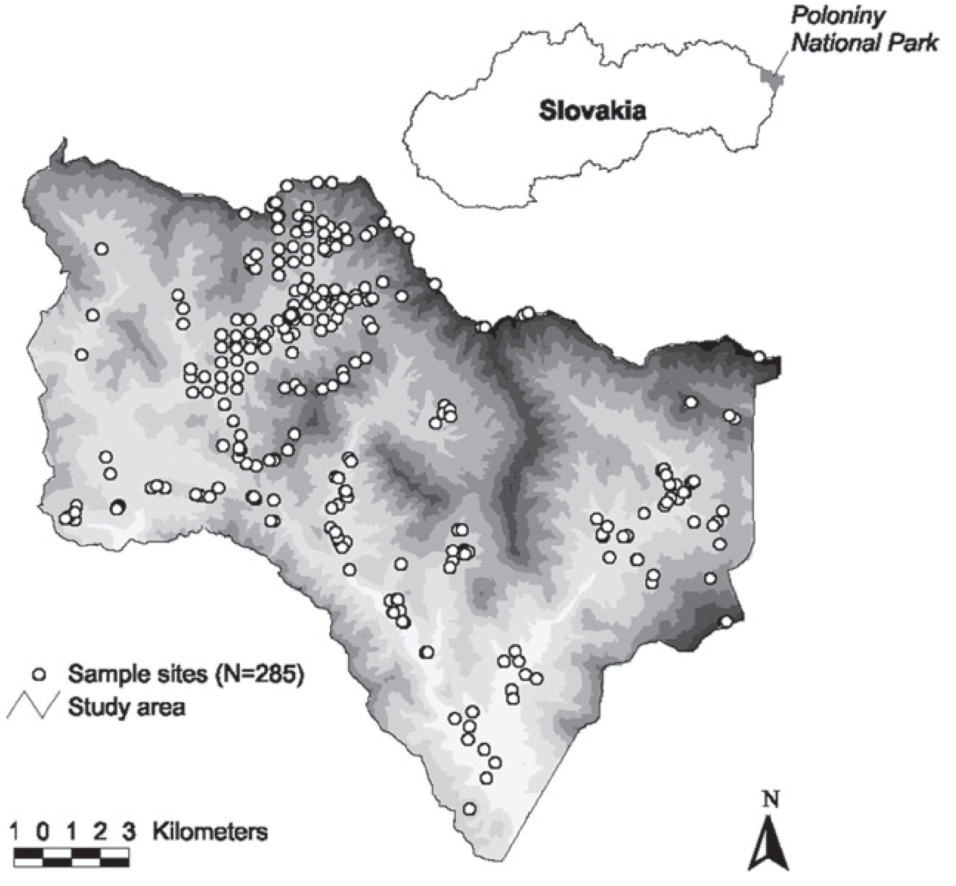


Fig. 1. Sample sites in the study area.

T a b l e 1. Sample distribution of grassland types.

| Grassland type | Area (ha) | % | N | % |
|---|---|---|---|---|
| Mesophilous meadows | 1054.50 | 61.38 | 98 | 52.97 |
| Wet meadows | 446.50 | 25.99 | 37 | 20.00 |
| Dry meadows | 135.00 | 7.86 | 16 | 8.65 |
| Fens | 59.75 | 3.48 | 12 | 6.49 |
| Mountain meadows | 22.25 | 1.30 | 22 | 11.89 |
| Total | 1718.00 | 100 | 185 | 100 |

3. **Spatial interpretation.** Spatial interpretation of the logistic statistical model was made by using selected independent variables as predictors within the IDRISI Kilimanjaro software (Eastman, 2003). Decision rules derived from CART analysis were used for knowledge engineering module in ERDASS IMAGINE 8.4 software (Erdas, Inc., 2004) followed by knowledge classification to make map of potential grassland types in the study area based on CART analysis.

## Results

### *Classification and regression tree (CART)*

In total, 201 sample sites were used for creating the classification tree. For validation there were reserved 77 randomly selected sites. A reasonably simple classification tree was built with splitting rules allowing relatively easy interpretation (Fig. 2). The strong-

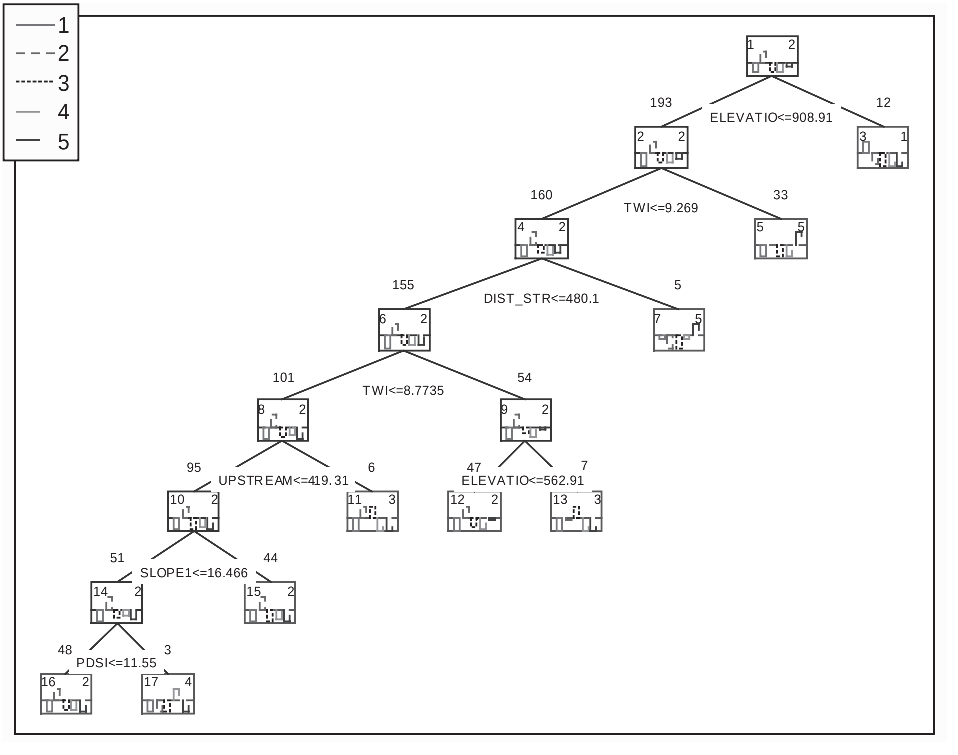


Fig. 2. Classification tree of grassland vegetation types. *DIST_STR – distance to streams (m), UPSTREAM – upstream flow distance (m), ELEVATIO – elevation (m), TWI – topographical wetness index, PDSI – potential direct solar irradiation (kcal m$^{-2}$ month$^{-1}$), SLOPE1 – slope ($^{o}$), 1 – mountain meadows, 2 – mesophilous meadows, 3 – fens, 4 – dry meadows, 5 – wet meadows.

T a b l e 2. Cross validation of validation subset (N = 77); CART based model.

| Actual/ predicted | Mountain meadows | Mesophilous meadows | Fens | Dry meadows | Wet meadows | Total | ErrorC |
|---|---|---|---|---|---|---|---|
| Mountain meadows | 3 | 0 | 0 | 0 | 0 | 3 | 0.00 |
| Mesophilous meadows | 1 | 36 | 2 | 4 | 9 | 52 | 0.31 |
| Fens | 0 | 3 | 3 | 0 | 0 | 6 | 0.50 |
| Dry meadows | 0 | 0 | 0 | 1 | 1 | 2 | 0.50 |
| Wet meadows | 0 | 5 | 0 | 0 | 12 | 17 | 0.29 |
| Total | 4 | 44 | 5 | 5 | 22 | | |
| ErrorO | 0.25 | 0.18 | 0.40 | 0.80 | 0.45 | | |

*errorO – error of omission (false positive rate), errorC – error of commission (false negative rate)

est predictive power referring to the tree was shown by elevation, topographical wetness index (TWI) and slope. Later on, we used CART derived decision rules for prediction of grassland vegetation types on reserved validation set (77 samples that were not used for creating the tree). A simple cross-validation with a proportion of correctly classified cases was used for this purpose (Table 2). Both errors of commission (false positive) and errors of omission (false negative) rates have to be considered while general predictive power of model is validated. Respecting this fact, the results have shown that the mountain meadows, mesophilous meadows and wet meadows are considerably well predicted by the model (Table 2). A good predictability of mountain and wet meadows can be caused by the high specificity of these habitats and their strong connection to the elevation (mountain meadows) and wetness environmental gradient (wet meadows). This would imply a good association of topographical wetness index (TWI) as an indicator of site wetness. A good predictability of mesophilous meadows can be caused by the fact that they cover majority of the whole area and accounted for high prior probabilities of occurrence. On the other hand, a low predictability of fens and dry meadows would imply that the input independent environmental variables are not good predictors of these types of grasslands. Furthermore, a small number of fens and dry grasslands in training set can be the cause of the low predictability. Finally, based on the CART model, the map of potential grassland vegetation types was designed for the whole study area (Fig. 3A). It shows potential occurrence of respective grassland vegetation types based on the basic environmental factors as identified by the CART-based model.

*Logistic regression (LR)*

The same input variables as within the CART were used for logistic regression. However, a forward step selection identified those variables that are mostly important in order to predict respective grassland type. The results have shown that different environmental

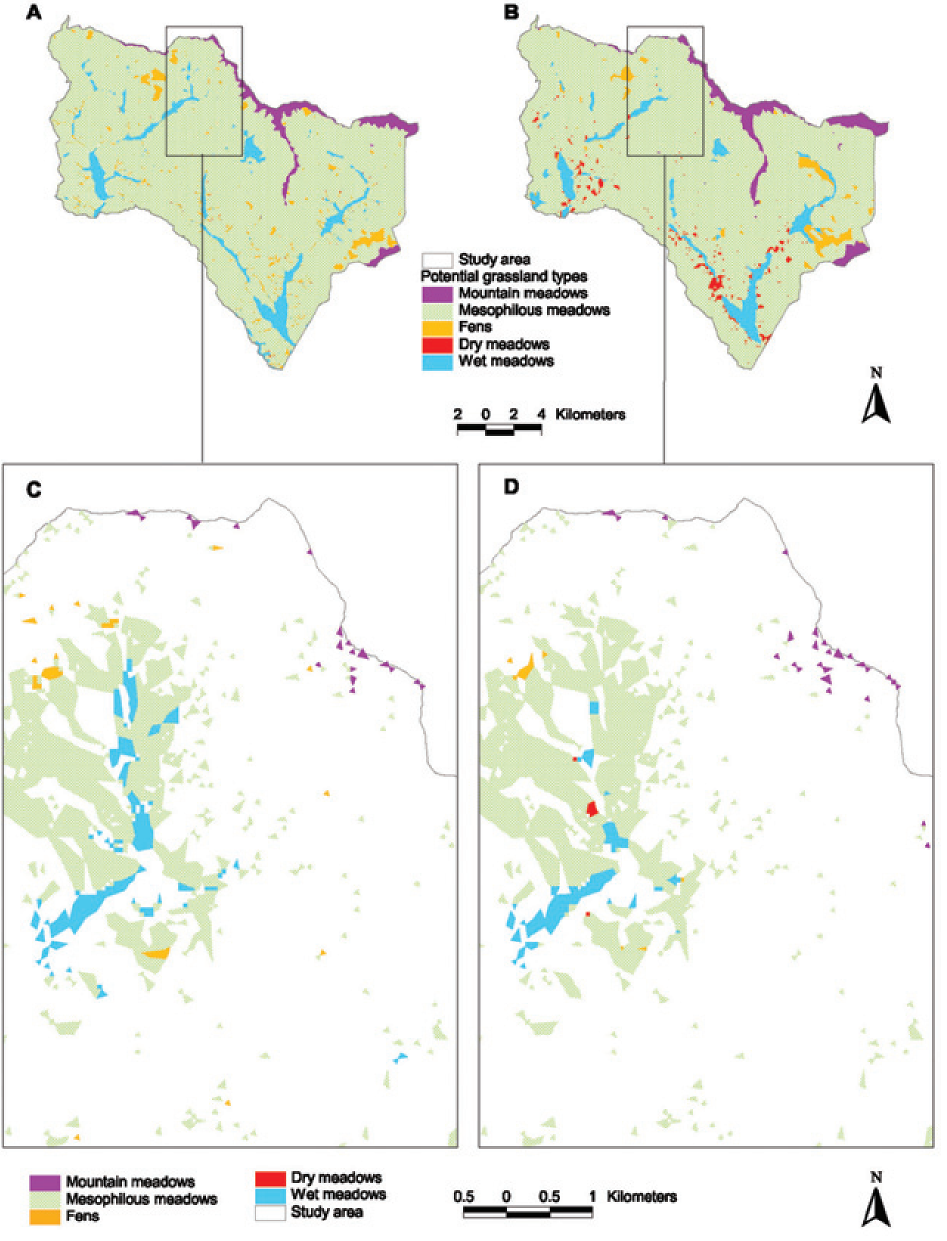


Fig. 3. Results of habitat modelling. A – Potential grassland types in the study area (CART based model). B – Predicted distribution of grassland types (CART based model). C – Potential grassland types in the study area (LR based model). D – Predicted distribution of grassland types (LR based model).

T a b l e 3. Logistic regression results.

| Grassland type | Constant | Selected variables | B | Exp(B) | New cut off |
|---|---|---|---|---|---|
| Mountain meadows | –12.618 | Elevation | 0.013 | 1.013 | 0.38 |
| Mesophilous meadows | –0.619 | TWI | –0.687 | 0.502 | 0.55 |
| | | Morpho1 | 7.106 | | |
| Fens | –2.633 | Morpho7 | 1.332 | | 0.26 |
| | | Morpho8 | 1.974 | | |
| Dry meadows | 2.742 | Elevation | –0.006 | 0.993 | 0.22 |
| | | PDSI | 0.937 | 2.553 | |
| | | Morpho1 | –12.205 | | |
| Wet meadows | –20.346 | TWI | 2.119 | 5.059 | 0.37 |

*TWI – Topographical wetness index, PDSI – Potential direct solar irradiation, Morpho1 – denudation landforms, Morpho7 – gravitation slope landforms, Morpho8 – erosion landforms

T a b l e 4. Cross validation of validation subset (N = 77), logistic-based model.

| Actual/ predicted | Mountain meadows | Mesophilous meadows | Fens | Dry meadows | Wet meadows | Total | ErrorC |
|---|---|---|---|---|---|---|---|
| Mountain meadows | 3 | 0 | 0 | 0 | 0 | 3 | 0 |
| Mesophilous meadows | 1 | 32 | 0 | 4 | 8 | 45 | 0.29 |
| Fens | 0 | 5 | 5 | 0 | 2 | 12 | 0.58 |
| Dry meadows | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| Wet meadows | 0 | 7 | 0 | 0 | 12 | 19 | 0.37 |
| Total | 4 | 44 | 5 | 5 | 22 | | |
| ErrorO | 0.25 | 0.27 | 0 | 0.8 | 0.45 | | |

*errorO – error of omission (false positive rate), errorC – error of commission (false negative rate)

T a b l e 5. Predicted grassland types distribution.

| | CART based model | | | | Logistic regression based model | | | |
|---|---|---|---|---|---|---|---|---|
| | area (ha) | % | N | % | area (ha) | % | N | % |
| Mountain meadows | 31.50 | 1.32 | 53 | 3.60 | 38.50 | 1.62 | 68 | 5.26 |
| Mesophilous meadows | 1882.00 | 79.02 | 945 | 64.15 | 1941.75 | 81.53 | 918 | 71.05 |
| Fens | 105.50 | 4.43 | 212 | 14.39 | 56.50 | 2.37 | 68 | 5.26 |
| Dry meadows | 10.75 | 0.45 | 35 | 2.38 | 48.50 | 2.04 | 67 | 5.19 |
| Wet meadows | 352.00 | 14.78 | 228 | 15.48 | 296.50 | 12.45 | 171 | 13.24 |
| Total | 2381.75 | | 1473 | | 2381.75 | | 1292 | |

variables are important for occurrence of respective type (Table 3). As it was expected, elevation was the factor that explained the distribution of the mountain meadows at best. Mesophilous meadows are mainly predicted by denudation landforms (morpho1) and lower topographical wetness index (TWI) that correspond with them. Fens are mainly connected to erosion cuts of valleys and streambeds (morpho7) as well as to block slides (morpho8) that represent areas where a local water sources feed the fens. Mainly lower elevation and higher potential direct solar irradiation (PDSI) behaved as predictors for dry meadows related to dry and heat conditions. On the contrary, higher values of topographical wetness index (TWI) predicted occurrence of wet meadows at best. TWI indicates locations where water flows gravitationally down, ensuring higher surface wetness. As it was mentioned before, logistic regression results show the predicted occurrence probability of respective grassland type in the 0–1 scale. Therefore, we had to make a correct reclassification that would consider a prior probabilities of occurrence caused by a number of respective grassland types in the training set. The new cut-off (threshold) value was selected (Table 3), such that, after reclassification, the number of fitted positive predicted occurrences matches the number of observed positive occurrences in the dependent variable (Eastman, 2003). The final assignment of respective grassland type per site was later identified as the highest positive difference from respective cut-off value. After this reclassification and assignment to grassland patches we have got a final categorical image of grassland vegetation types (Fig. 3B) that could be used for cross-validation (Table 4). Similar to the CART results, mountain, mesophilous and wet meadows are predicted quite well. The same reasons as in CART cause a worse prediction of fens and dry meadows. Although all five observed fens in validation subset were correctly classified, another seven sites were classified wrongly, what decreased the overall predicting accuracy and implies an overestimating of fens. An opposite case occurred in dry meadows prediction. Only 1 case from 5 was classified correctly, although no other grassland type was classified as dry meadow.

*Prediction of grassland distribution in the whole study area*

The prediction was made after the intersection of the map of potential grassland types with the respective grassland patches derived from landcover analysis (Fig. 3C,D). Both, total area and number of patches were compared (Table 5). Similar results are presented in regards to mountain, mesophilous and wet meadows. On the other hand, the great differences are evident in predicting fens and dry meadows. This would document a weak capability for prediction of fens and dry meadows. Anyway, a general overview of grassland distribution in the whole area is clear. The major area is represented by mesophilous meadows (cca 80% of the total area), followed by wet meadows (cca 13% of the total area). The minor area is represented by mountain meadows, fens and dry meadows because of very specific environmental conditions (Table 5).

## Discussion

There are a great variety of habitat models used in the ecology. In our case study we used two completely different statistical techniques for creating habitat models. However, we have not been focused on precise comparison of different statistical methods, but on identification of main differences of results, which could imply weak points of final predictions. Despite of generally known disadvantage and restrictions of logistic regression used for this purpose (Guisan, Zimmermann, 2000), this method is still commonly used for habitat modelling (Munoz, Felicísimo, 2004). We tried to set aside these problems by precise selection of input variables (supported by expert knowledge), logarithmic transformation of those with nonparametric data distribution and the use of forward stepwise variable selection (while using logistic regression procedure). Contrarily, CART represents statistical methods that need no strong assumptions and represents a flexible and simple tool for modelling complex ecological relationships (De`ath, Fabricus, 2000). In our case, the resulting decision tree has a relatively simple structure allowing quite good interpretation. This would be caused by proper selection of input variables. This confirms the thesis that the expert ecological knowledge is strongly needed for habitat modelling.

Another methodological comment on habitat modelling refers to its validation. Firstly, we used only an independent dataset for correct validation of model accuracy (Manel et al., 1999; Munoz, Felicísimo, 2004). Many possibilities of validation methods are available in assessment of accuracy of the model and the proportion of correctly classified cases is still commonly used (Fielding, Bell, 1997). We used this approach also because of identification of both false positive and false negative error rate that would help in later selection of model usage. The final selection of habitat models depends on specific motivation of their use. In our case, cross-validation tables, especially false positive and false negative rates for respective grassland types can serve as a basis for model selection. Munoz, Felicísimo (2004) describe a suitable way for this decision. If the purpose of the study is to identify sites where we need to be certain that a habitat of interest will be found, we must select the model that minimizes false positive error rates. On the contrary, if the aim is conservation of the same habitat, the model must be chosen to minimize false negative error rates. From this aspect, following priority habitats of the high importance in the study area, we would use logistic-based model for prediction of mountain meadows. Contrarily, CART-based prediction can be used in regards to wet and mountain meadows for the conservation purposes. Predicted distribution of habitats with a lower accuracy (fens and dry meadows) can be used mainly for the (field) mapping of these rare habitats.

The expert knowledge for this study was derived by long-term vegetation survey of grasslands in Poloniny. Previous multivariate statistical analysis of vegetation data (Halada et al., 2002) identified altitude and depth of soil humus horizon as key factors influencing grassland species distribution. They can be interpreted as gradients of climate and productivity (nutrients availability).

Derived habitat maps and factors explained distribution of grassland habitats correspond with the results of mentioned authors. Not surprisingly, altitude was correlated with mountain grasslands. This factor determines their existence – all grasslands in altitudes higher than 800 m have characteristic species composition and are classified as mountain meadows ("poloniny"). Topographic wetness index and distance to streams were most important factors for modelling of wet meadows distribution. Location in alluvial plains and topographic depressions is characteristic for wet meadows, such positions provide water regime with sufficient amount of water close to soil surface during whole or significant part of the year. Fens are typical especially for slopes formed by landslides and for valley bottoms. Dry meadows are located in the warmest sites of the region: in lower altitudes, slopes exposed to S (SE, SW) and usually shallow soils. Altitude and potential direct solar irradiation (PDSI) represented main factors determining their distribution. The predicting of mesophilous meadows can be affected by broader definition of the unit (and therefore heterogeneous grassland types included) and by the location usually in the middle part of environmental gradients, with no strong correlations to any factor.

## Conclusions

Identification of grassland distribution in the study area would contribute to the general knowledge of biodiversity importance in the Poloniny National Park. Halada et al. (2002) describe biodiversity values of grasslands in the study area and main priorities for nature conservation of the study area. Specific management measures for individual grassland types are identified, as well, to ensure their conservation. From this aspect, the map of grassland distribution in the Poloniny National Park would serve as the basis for conservation and management plans of the local authorities. As the mountain meadows are of high biodiversity importance and are situated in the most remote parts of the area, specific management of this habitat should be implemented in relevant documents. On the other hand, due to location of wet meadows in the areas with good access (near residences and in the valleys), these are exposed to high pressure of local agriculture. Anyway, a great pressure on grasslands is represented by overgrowing of meadows followed by possible afforestation. Derived habitat maps combined with landscape change modelling would also help in prediction of future grassland distribution, considering afforestation as the main driver of landscape change.

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Halabuk A., Halada Ľ.**: Modelovanie rozšírenia lúk v Národnom parku Poloniny.**

Poloprírodné lúky v Národnom parku Poloniny reprezentujú významné hodnoty z hľadiska biodiverzity. Poznanie ich rozšírenia je dôležité pre ich zachovanie ako i správny manažment prírodných hodnôt celého územia. V tomto článku sa zaoberáme využitím habitatových modelov pre identifikáciu rozšírenia jednotlivých typov lúk v Národnom parku Poloniny. Použité habitatové modely vychádzajú zo štatistickej analýzy vzťahov jednotlivých typov lúk

a určujúcich environmentálnych premenných. Z existujúcich 285 fytocenologických zápisov bolo identifikovaných 5 hlavných typov lúk. Základné environmentálne premenné boli odvodené z digitálneho modelu terénu (nadmorská výška, sklon, orientácia, potenciálne priame oslnenie, topografický index vlhkosti), z krajinnej kompozície (krajinné indexy: index fragmentácie, počet tried krajinnej štruktúry), pôdnej mapy a geomorfologických foriem. Pre skúmanie závislostí a tvorbu habitatových modelov boli použité klasifikačné a regresné stromy (CART) a logistická regresia. Výsledky oboch modelov boli testované pomocou matice krížového overenia na testovacom súbore (30 % zápisov), ktorý nebol použitý pri tvorbe modelu. Hlavný výstup habitatových modelov predstavovali mapy potenciálneho výskytu jednotlivých typov lúk v celom študovanom území. Po intersekcii s reálnym výskytom lúk vznikol obraz o celkovom zastúpení a priestorovom rozšírení lúčnych biotopov v Národnom parku Poloniny. Väčšinu, 81% zo všetkých lúk tvoria mezofilné lúky, 13% vlhké lúky, 2,5% slatiny, 2% sub-xerofilné lúky, a 1,5% horské lúky. Ich priestorové rozšírenie je načrtnuté na priložených obrázkoch.