Effect of grazing on grasslands in the Western Romanian Carpathians depends on the bedrock type

Vliv pastvy na složení travních společenstev se v Rumunských Západních Karpatech mění s druhem podloží

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This study correlated the floristic composition of grassland communities with environmental variation in the Western Romanian Carpathians, focusing on the effect of grazing. Grasslands were sampled using 231 plots each 0.25 km^2 in area. Vascular flora, altitude, aspect, slope, bedrock and grazing intensity were recorded for each plot. Data were processed using direct gradient analyses (CCA) and a generalized linear model. The results revealed three distinct communities associated with bedrock, landscape topography and grazing intensity. Grazing changes the floristic composition of grasslands on limestone more than on other types of bedrock. Specifically the floristic composition of the limestone-area plots subjected to low grazing pressure differ significantly from that of the plots of grassland on flysch and volcanic bedrock. When intensively grazed, the floristic composition of chalk grassland does not differ from that of the lightly grazed vegetation growing on flysch or volcanic bedrock. The reasons for this pattern and implications for management are discussed.

K e y w o r d s: Apuseni Mts, bedrock type, Canonical Correspondence Analysis, bedrock type, grazing pressure, semi-natural grasslands

Introduction

Semi-natural grasslands are the most valuable ecosystems within agricultural landscapes because they contain a huge diversity of plants and other organisms (Tscharntke et al. 2005). However, although included in Annex I of the Habitats Directive few of these habitats are currently protected (Hoekstra et al. 2005). The area of semi-natural grasslands traditionally used for grazing or the harvesting of hay and bedding for livestock has significantly decreased throughout Europe (Petit et al. 2001). Recent changes in agriculture have led to a decline in the more traditional land-use practices and now some of this grassland is abandoned or overgrazed.

In the mountainous areas of Europe, grassland biodiversity is primarily dependent on topography, soil and properties of the bedrock, and the type and intensity of agriculture (Barrio et al. 1997, Hoersch et al. 2002), with contrasting effects at diverse spatial and temporal scales (Wiens 1989, Levin 1992). Features of the landscape, such as elevation, slope and aspect, determine plant species composition of grasslands by affecting the quantity of incoming solar radiation, which determines air and soil temperatures (Pinder et al.

1997, Tekle et al. 1997). Soil properties (e.g., depth, chemistry and moisture) and bedrock also determine the distribution and abundance of particular species (Kikuchi & Miura 1993, Tyler & Falkengren-Grerup 1998, Bratli & Myhre 1999).

However, superimposed on the effects of topography, climate and soil, human land use determines local patterns of grassland plant biodiversity (Rudmann-Maurer et al. 2008). In particular, grazing by domestic livestock is thought to have had a major influence but the evidence is inconclusive. While some studies report no association between grazing and grassland biodiversity (Friedel et al. 1993) many others do (Hiernaux 1998, Sternberg et al. 2000, Sunohara & Ikeda 2003). Indeed grazing can even have a positive effect and high conservational value for some communities (Watkinson & Ormerod 2001, de Bello et al. 2006). Studies on European mountain grasslands growing on calcareous substrates, as in the Pyrenees (Sebastià 2004), indicate that land-use changes constitute a threat to the persistence of these ecosystems. Thus, while the response of vegetation to changes in grazing pressure and their interaction with the environment is an important issue in grassland management, it is hard to generalize from the currently available data.

Grasslands and meadows are still a common feature in Romania, covering about 11% of the total surface of the country. The majority have a high conservation value (Baur et al. 2006), not only in themselves, but also as part of a vanishing traditional rural landscape. As a result of the long interaction with man, some of them have evolved into species-rich communities harbouring plants of different biogeographical and ecological origins and are an important natural heritage in Europe (Rusdea et al. 2005). More than 60% of the Romanian vascular plants are grassland species and over 90% of the endemic, subendemic and threatened species in Romania are found in the Carpathian grasslands (Institutul de Cercetari si Amenajari Silvice 1996). Therefore, the monitoring and conservation of semi-natural grasslands in Romania is important not only for ecological, but also for cultural reasons (Schmitt & Rákosy 2007).

For grassland management it is important to identify potential determinants of species composition so that biodiversity conservation strategies can be adjusted at local and regional scales. In the case of the Romanian Carpathian grasslands, there are few quantitative studies on floristic gradients and their associated environmental and anthropogenic factors (such as grazing). Several authors have focussed on the effects of grazing on mountain and alpine grasslands in the Southern Carpathians (Coldea & Cristea 1998, Baur et al. 2006). Recently Puşcaş et al. (2005) reported that the floristic variation of *Carex curvula* grasslands in the Carpathians is mainly affected by both the successional and nutrient availability gradients. Cremene et al. (2005) present interesting observations on biodiversity hotspots in the steppe-like grasslands of Transylvania and indicate that the subalpine hay meadows in the same region have a high conservation value.

This study addresses for the first time the interaction between grazing and bedrock, and its effects on the mountain grassland communities in Romania. The prime objective of this study is to identify gradients in compositional variation explained by the measured factors for a broad range of semi-natural grasslands in the Apuseni Mts (Western Romanian Carpathians). Secondly, the role of individual environmental factors and their interaction with increasing intensity of agriculture in these highly diverse grasslands are compared. Finally, possible conservation management strategies for limestone grasslands in the area are discussed.

Methods

Study area

The study was carried out within an area of about 60 km^2 around Întregalde village (Fig. 1), located 41 km NE from the town of Alba Iulia, in the S Apuseni Mts (Western Romanian Carpathians; 5°20' – 5°28' E; 46°16' – 46° 12'N). The study area encompasses the following reserves: the Întregalde, Galdiţei and Turcului Gorges. The range in altitude is between 480 m (Galda Valley) and 1211 m (Dealul Caprei). The study area has a diverse karst landscape and, until recently, traditional rural structure and use of the grasslands, which consisted of intensive cattle/sheep grazing and mowing.

The climate is continental temperate, with a mean annual precipitation and temperature for the last decade of 650 mm and 9.5° C, respectively. The study area belongs to the Euro-Siberian phytogeographical region, district of the Apuseni Mts (Borza & Boşcaiu 1965).

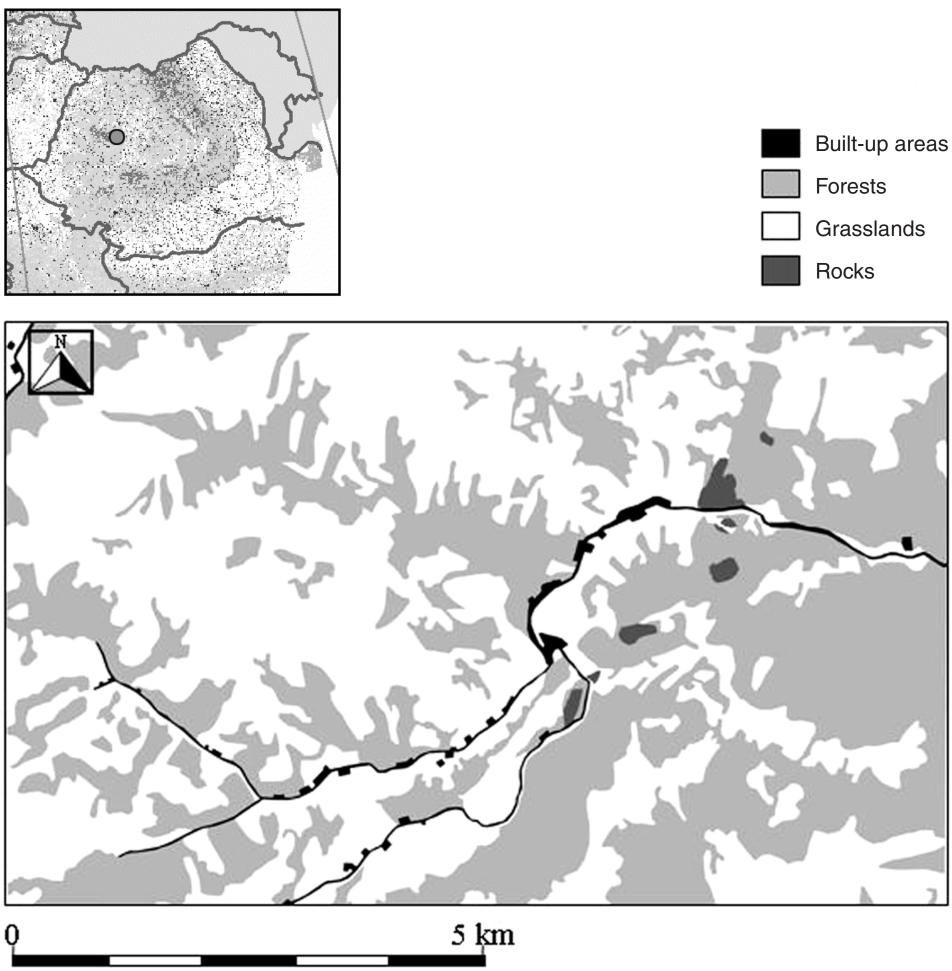

Fig. 1. – Study area in the Western Carpathians, Romania (original land cover map).

The bedrock consists of calcareous flysch, rocky limestone, or volcanic rocks (Ianovici et al. 1976). The dominant soils are rendzins, especially over the broken microrelief (i.e., steep slopes, cracks), with brown soils in the grasslands. Land cover in this area is mainly semi-natural grasslands and beech forests (alliance *Symphyto-Fagion*, Pop et al. 1960), the latter representing the natural potential vegetation.

Field survey

The study area was divided into 240 grid squares, each 0.25 km^2. One sampling point was assigned to each square with more than 10% of area covered by grassland. Topographic maps and satellite images provided the basis for determining the relative cover of the main types of vegetation. The sampling points were randomly located within the grassland area in the squares, their geographic locations being determined by the Global Positioning System (GPS). Finally, 231 squares were sampled from April to June (2000–2003). At each sampling point, a single floristic relevé of the vascular flora was recorded, using the methodology and the ordinal scale of Braun-Blanquet (1964). The area of each relevé was 50 m^2. Species identification was aided by the lists of vascular species and descriptions of the vegetation in the area previously published by Pop et al. (1960), Ghişa et al. (1965) and Başnou (1998, 2004). The nomenclature follows Tutin et al. (1964–1980), Coldea (1991) and Pop (1991).

Environmental variables and grazing

The following environmental variables were recorded at each relevé location: altitude, aspect, slope and bedrock. Altitude and slope were measured using GPS and a clinometer, respectively. Aspect was coded as 0 or 1, corresponding to northern-facing (NW, N, NE, E) or southern-facing slopes (SE, S, SW, W), respectively.

Bedrock (volcanic rocks, flysch and limestone) was considered as a surrogate for soil acidity, which affects nutrient uptake of plants (Thuiller et al. 2003). Compared to soil acidity, bedrock is much more useful when studying wide geographical areas. Of our 231 samples, 26 were from areas growing on volcanic rock, 166 on flysch and 39 on limestone.

Grazing intensity was estimated by direct observation, as well as based on information provided by local shepherds, and categorized as low to moderate (low) or high (high). Both bedrock and grazing intensity were coded in the statistical analyses as factors, with three and two levels, respectively.

Data analysis

Questions asked in our study were addressed using the constrained ordination method – Canonical Correspondence Analysis (CCA, ter Braak & Šmilauer 2002) and a GLM model. Species data were log-transformed, starting with cover values replacing the Braun-Blanquet estimation scale (+, 0.5%; 1, 5%; 2, 12.5%; 3, 37.5%; 4, 62.5%; 5, 87.5%) and rare species were down-weighted. Detrended Correspondence Analysis (DCA) was run a priori, in order to choose between linear and unimodal ordination methods (Lepš & Šmilauer 2003). Resulting gradient lengths (e.g., 4.897 for the first axis) clearly indicated that the unimodal method of CCA was more appropriate.

Consequently, five CCAs were used: (1) to evaluate the independent (marginal) effects of individual variables; (2) to summarize the joint effect of the explanatory variables that had a significant independent effect in analysis 1; (3) to test the interaction between grazing intensity and bedrock. For this, both main effects were used as covariables, while the interactions between the three bedrock dummy variables and the two grazing pressures were used as explanatory variables; (4) to demonstrate that a significant interaction indicates that the effect of the intensity of grazing depends on the bedrock, the two factors were recoded into six combinations of bedrock and grazing intensity; (5) to compare the differences of each of these six combinations, the difference of each from the pooled remaining five groups was tested using the initial-stage tests in the forward selection procedure. Only the species with the best fit were plotted in the ordination diagrams, as their positions have a more meaningful ecological interpretation (Lepš & Šmilauer 2003). Multivariate analyses were performed using CANOCO for Windows 4.5 (ter Braak & Šmilauer 2002).

Effects of environmental factors and land-use intensity on the frequency of rare species were examined using generalized linear models, with the count of rare taxa modelled by a Poisson distribution with the log link function. Final model was selected using chi-square. These analyses were performed using R software, version 2.8 (R Development Core Team 2008).

Results

Independent effects of individual variables

Table 1 shows the size and significance of the independent effects, with variables ordered in terms of their effect from high to low. The bedrock has the largest effect on floristic composition, with the greatest difference being between the plots on limestone and the other two bedrocks. Slope and altitude are also important in explaining floristic composition.

The CCA ordination plot shows that moderately grazed limestone grasslands (on the right-hand side of Fig. 2), at medium to high altitudes, have steep, sunny slopes and rocky soils. They support typical *Seslerio-Festucetum pallentis* and *Seslerietum rigidae* communities (Pop et al. 1960, Başnou & Pino 2003, Başnou 2004). These grasslands, when moderately grazed, have a high number of endemic and endangered species, along with species commonly found growing in soils on calcareous rocks: *Festuca pallens*, *Helictotrichon decorum*, *Sesleria rigida*, *Seseli gracile*, *Sedum hispanicum* and *Thymus comosus*.

Table 1. – Independent effects of individual variables. P (probability of a type I error) was estimated using a Monte Carlo permutation test with 999 permutations. The low and high predictors refer to the intensity of grazing.

Variable	Pseudo-F statistic	P
Limestone	4.59	0.002
Flysch	3.06	0.002
Altitude	1.82	0.002
Slope	1.85	0.004
Low grazing	1.63	n.s.
High grazing	1.63	n.s.
Volcanic	1.58	n.s.
Aspect	1.20	n.s.

Overgrazed pastures (Fig. 2, upper part) contain mainly species characteristic of a ruderalized community (*Lolio-Cynosuretum*) found mainly at lower altitudes and on moderate slopes. Typical species are *Lolium perenne*, *Poa annua*, *Polygonum aviculare*, *Rumex crispus*, *Matricaria perforata*, *Capsella bursa-pastoris* and *Elymus repens*. There are a high number of grass and legume species in this community. In addition, there are also species that are tolerant of trampling in this community, such as: *Leontodon autumnalis*, *Potentilla reptans*, *Hieracium pilosella*, *Poa annua*, *Plantago major*, *Lolium perenne* and *Trifolium pratense*.

The occurrence of mesophilous grasslands belonging to the association *Festuco rubrae-Agrostietum capillaris* (Fig. 2, centre) is only associated with volcanic and flysch bedrocks and moderate grazing. Among the dominant and characteristic species are *Agrostis capillaris*, *Cynosurus cristatus*, *Lolium perenne*, *Trifolium repens*, *Festuca pratensis*, *Leontodon autumnalis*, *Phleum pratense* and *Festuca rubra*.

As for the rare species, GLM shows that the only significant environmental predictor of species richness is bedrock, with the highest count of rare species on limestone. Neither the intensity of grazing nor its interaction with bedrock is significant in the case of rare species (Table 2).

Table 2. – GLM model of the effect of substrate and grazing intensity, and of their interaction upon the frequency of rare species. Significance value (P) was obtained by comparing changes in deviance using χ^2 distribution with "DF" degrees of freedom.

	DF	Deviance change	DF residual	Residual deviance	P
Null			230	349.38	
Bedrock	2	72.87	228	276.51	$< 10^{-6}$
Grazing	1	0.80	227	275.72	n.s.
Bedrock: grazing	2	1.92	225	273.79	n.s

Interaction between grazing intensity and bedrock

The interaction between grazing intensity and bedrock explains a relatively small amount of variation, but it is significant (Table 3) and accounts for more of the variation than bedrock alone (2.6%).

Table 3. – Eigenvalues, species – environment correlations and variance accounted for by the two canonical CCA axes. (Test of significance of both canonical axes: pseudo-F-ratio = 2.036, P-value = 0.002).

Axes	1	2
Eigenvalues	0.247	0.087
Species-environment correlation	0.608	0.535
Cumulative percentage variation of species data [%]	2.2	3.0

Size of grazing effect and bedrock

This hypothesis is illustrated by the CCA presented in Fig. 3. This analysis produced five canonical axes, but their effect decreases rapidly with the first three axes accounting for 2.1, 1.0 and 0.6% of the total variation, respectively.

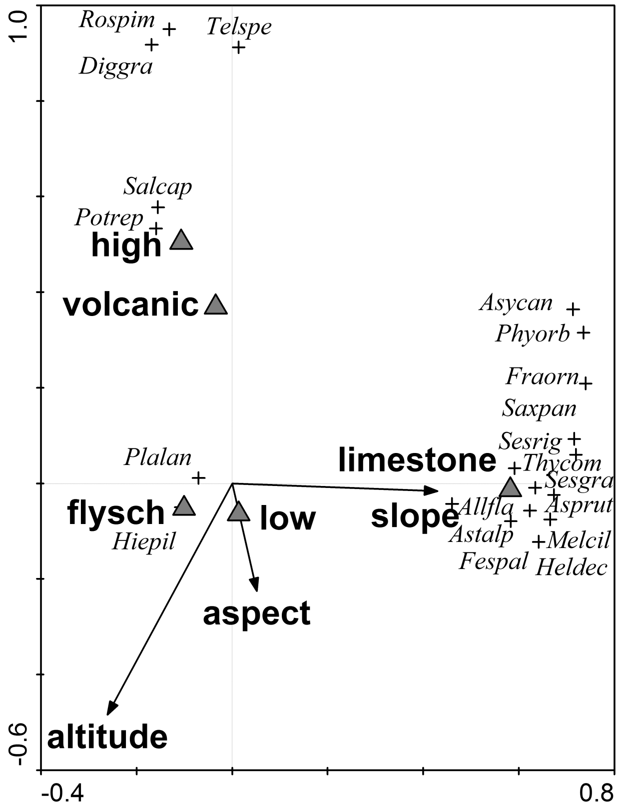

Fig. 2. – Species-environment ordination biplot (CCA axes 1 and 2, account for 3% of the variation). The 'low' and 'high' predictors refer to the intensity of grazing. Allfla – *Allium flavum*, Asprut – *Asplenium ruta-muraria*, Astalp – *Aster alpinus*, Asycan – *Asyneuma canescens*, Diggra – *Digitalis grandiflora*, Fespal – *Festuca pallens*, Fraorn – *Fraxinus ornus*, Heldec – *Helictotrichon decorum*, Hiepil – *Hieracium pilosella*, Melcil – *Melica ciliata*, Phyorb – *Phyteuma orbiculare*, Plalan – *Plantago lanceolata*, Potrep – *Potentilla reptans*, Rospim – *Rosa pimpinellifolia*, Salcap – *Salix capraea*, Saxpan – *Saxifraga paniculata*, Sesgra – *Seseli gracile*, Sesrig – *Sesleria rigida*, Telspe – *Telekia speciosa*, Thycom – *Thymus comosus*.

The largest difference (see also Table 4) is between the low-intensity grazed plots on limestone (on the right hand side of the graph) and the remaining plots (Fig. 3a). The fact that the "volc:high" symbol seems to be further apart (along the second, vertical axis) is because there are few plots with this combination (only five) whereas there are many low-intensity grazed plots on limestone. Species shown in Fig. 3c illustrate the floristic changes in the plots: with high grazing intensity, species like *Sesleria rigida*, *Festuca pallens*, *Helictotrichon decorum*, *Seseli gracile* and *Thymus comosus* tend to disappear in calcareous areas.

On the third ordination axis (vertical axis in Fig. 3b) the plots on limestone subjected to high grazing intensity are clearly separated from the other plots. Obviously, the great abundance of *Cirsium vulgare* in intensively grazed pastures on limestone is an important difference.

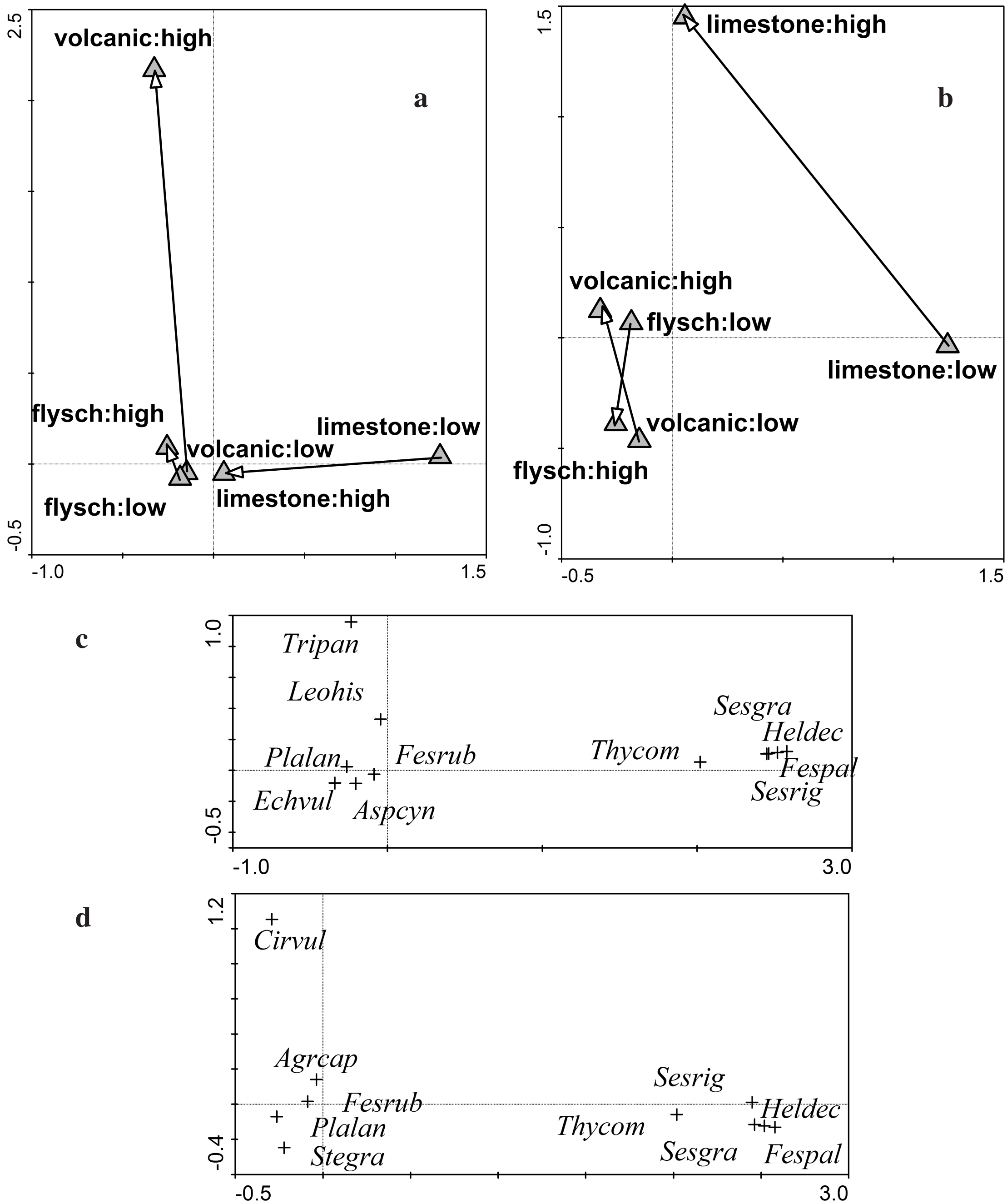

Fig. 3. – CCA ordination diagrams in which six combinations of bedrock and grazing intensity are the explanatory variables. The two diagrams in the top (a and b) row show the centroids of the six plot classes, with arrows indicating the direction of change from low to high grazing pressure, while the bottom row shows the corresponding scatter of species scores. The left hand column shows CCA axes 1 and 2, and the right CCA axes 1 and 3 (with axis 1 plotted horizontally). The 'low' and 'high' predictors refer to the intensity of grazing. Agrcap – *Agrostis capillaris*, Aspcyn – *Asperula cynanchica*, Cirvul – *Cirsium vulgare*, Echvul – *Echium vulgare,* Fespal – *Festuca pallens*, Fesrub – *Festuca rubra,* Heldec – *Helictotrichon decorum*, Leohis – *Leontodon hispidus,* Plalan – *Plantago lanceolata*, Sesgra – *Seseli gracile*, Sesrig – *Sesleria rigida*, Stegra – *Stellaria graminea,* Thycom – *Thymus comosus*, Tripan – *Trifolium pannonicum.*

Table 4. – Tests of significance of the difference between the composition of vegetation in plots on each combination of bedrock type and grazing intensity and that of all the other plots pooled. P (probability of a type I error) was estimated using a Monte Carlo permutation test with 999 permutations.

Bedrock/grazing combination	Pseudo-F statistic	P
Limestone: low	4.92	0.001
Flysch: low	2.55	0.001
Volcanic: high	2.22	0.067
Limestone: high	1.47	n.s. (0.187)
Volcanic: low	1.44	n.s. (0.089)
Flysch: high	1.40	n.s. (0.112)

Results presented in Table 4 quantify the extent and the significance of the difference between each unique combination of the bedrock and grazing intensity and the pooled results for the remaining plots. Limestone-area (as well as the flysch-area) plots with low grazing intensity differ significantly from the rest, the second largest difference is that of the volcanic-area high grazing pressure plots, whereas the remaining plot categories cannot be reliably distinguished by their vegetation composition.

Discussion

Grassland composition, environmental variables and grazing

The floristic composition of the grasslands studied is influenced by both environmental factors and land use (such as grazing) and their interaction. In particular, grazing and bedrock shape the floristic composition of the grasslands in the Apuseni Mts.

Our finding that topographical variables (altitude and slope) influence the floristic composition is consistent with the results of previous studies in mountainous areas (Barrio 1997, Lomolino 2001). Landscape topography effects overlap with those of agriculture, as grazing intensity increases with altitude. Moreover, slope and microtopography influence soil water content and the accumulation or export of nutrients (Sebastià 2004).

Grasslands on limestone are more sensitive to grazing

An interesting result is that grazing has a greater effect on the floristic composition of grasslands growing on limestone. Specifically, the limestone-area plots subjected to low grazing pressure differ significantly from the other grassland types (i.e., those on flysch and volcanic bedrock). However, when subjected to high grazing pressure the floristic composition of extensively pastured chalk grasslands is similar to that of the vegetation growing in the flysch areas (or on volcanic bedrock subject to low grazing pressure). This is due to the spread of ruderal species, which typically occur in overgrazed grasslands (*Poa annua*, *Capsella bursa-pastoris*, *Cirsium vulgare*, *Rumex crispus*) and are extremely rare or absent in low or moderately grazed *Seslerio-Festucetum pallentis* and *Seslerietum rigidae* communities.

The greater vulnerability to grazing of limestone grasslands compared to grasslands on other types of bedrock may be due to their more specialized flora, which includes relic and endemic species. Species like *Aquilegia nigricans* subsp. *nigricans*, *Leontopodium alpinum*, *Seseli gracile* and *Thymus comosus* are unlikely to be adapted to overgrazing.

Moreover the grazing and bedrock effects can jointly affect the basic demographic characteristics determining plant fitness, i. e. lifetime reproductive success and survival.

Another possible explanation of the vulnerability of limestone grasslands to grazing is the higher frequency of shallow soils, steeper slopes and rocky outcrops in limestone areas, which reduce the water storage capacity of the soil. These results are consistent with those of other studies on grassland and indicate that the plant species and communities present are determined by the depth and rockiness of the soil (Nuzzo 1996, Tyler 1996, Casas & Ninot 2003). Both factors affect soil water availability, which constrains the development of vegetation (Casas & Ninot 2003). Consequently, in limestone areas it takes much longer for overgrazed vegetation to recover than in areas on other types of bedrock. Similar changes in species composition in response to increases in grazing pressure are reported for other dry herbaceous communities (Milchunas & Lauenroth 1993).

Land use history, which is always difficult to track in countries like Romania with little tradition of vegetation mapping, could also be an important factor influencing the floristic composition of grasslands. It is reported that systems with a short evolutionary history of grazing are non-resilient, that is, they do not return to their previous state after a perturbation (Cingolani et al 2005). Prior to 1989 overgrazing of grasslands on steep slopes occurred occasionally in the Carpathians (Baur et al. 2006), but since then land degradation or even destruction resulted in sheep flocks being moved to more suitable grazing grounds. This phenomenon seems to have increased recently in the Apuseni Mts (C. Başnou, personal observation) and sheep flocks are now grazing on the steep limestone slopes. Therefore it is possible that overgrazing of limestone grasslands is a new phenomenon in the study area.

Other possible explanations, which also apply to overgrazed plots in the flysch area, are trampling, phosphorus enrichment and nitrogen availability. Such perturbations can also change the species composition and are reported by other studies (Critchley et al 2002, Güssewell & Bollens 2003). These authors indicate that calcareous grasslands are characterized by certain soil conditions (low nutrient levels, particularly phosphorus) and are unlikely to recover if as a result of overgrazing the soil conditions are changed. Indeed, overgrazing of limestone grasslands led to a shift in species composition, in particular their colonization by mesophilous species such as *Festuca rubra*, *Plantago lanceolata*, *Leontodon hispidus* and *Rumex crispus*, typically found on nutrient-rich soils. The addition of nutrients results in changes in the abundance and composition of species in calcareous grasslands (Pauli et al. 2003) and it has been shown experimentally that overgrazing results in changes in the N:P ratio with critical consequences for species interactions in herbaceous communities (Güssewell & Bollens 2003). Thus, grazing might increase heterogeneity in resource distribution (i.e., a spatially heterogeneous structure with both nutrient-rich and nutrient-poor patches) and promote the coexistence of species with dissimilar resource acquisition strategies (de Bello et al. 2006). This potential link between floristic composition and the soil properties of grazed and overgrazed grasslands opens up new possibilities for further research.

Land use and grassland conservation

Recent studies of mountain grasslands in landscapes with old agricultural traditions have also shown that low-intensity grazing and mowing are valuable conservation alternatives to overgrazing (Rudmann-Maurer et al. 2008). Meadows on the steep slopes, which are difficult to mow, could be moderately grazed, which is preferable to abandonment. Limestone grasslands in particular harbour a large number of species and are an important habitat in need of conservation management in Europe (Poschlod & WallisDeVries 2002). Changes in land use result in changes in vegetation cover and reductions in species richness, leading to both ecological and socio-political impacts. In our study area, limestone grasslands are of special conservation concern as they are rarity hotspots, with 10 or 11 rare species/0.25 m^2 grid square and a total of 35 rare vascular plants (Başnou 2004), according to the Romanian Red Lists (Boşcaiu et al. 1994).

Based on our results, we propose that for efficient long-term grassland conservation grazing pressure should be adjusted to take account of the bedrock type, especially in limestone areas. The optimal grazing policy is a combination of rotational grazing of limestone grasslands and moderate grazing in other areas. Otherwise, over-grazing in karst areas could lead to rocky desertification, a process of land degradation characterized by soil erosion. This is one of the most serious land degradation problems in karst areas, an obstacle to local sustainable development (Li et al. 2006) and grassland conservation. Land degradation could further lead to abandonment and a dramatic decline in the area of grassland and in biodiversity (Galvánek & Lepš 2009), with implicit threats to local communities. It is important to convince the local population of the great value of their traditional landscapes, of the biodiversity and the necessity of conservation, with implicit benefits for the local communities (Soran et al. 2000). However, this has to be accompanied by an improvement in management by more effectively integrating local customs (i.e., dates of mowing, pasture areas) into a program of regular grassland monitoring carried out by Romanian agricultural institutions.

Land use is often cited as an important factor influencing the distribution of mountain grasslands (Tasser & Tappeiner 2002, Vandvik & Birks 2002, Rudmann-Maurer et al. 2008). Although it has proved difficult to accurately measure the effect of land use, our study indicates it affects the species composition of grasslands at a local scale. On a more general level, these findings also emphasize the importance of studying interactions between explanatory variables, since the influence of the environment on biotic communities often cannot be reduced to components that act additively, using a priori chosen parameters or categories.

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Souhrn

Studie popisuje vztah druhového složení travních společenstev Rumunských Západních Karpat k variabilitě podmínek prostředí a zaměřuje se na změnu tohoto vztahu s intenzitou pastvy. Travní společenstva byla charakterizována pomocí 231 ploch o velikosti 0.25 km^2 a pro každou z nich byly kromě druhového složení zaznamenány i nadmořská výška, orientace, sklon, typ podloží a intenzita pastvy. Analýzy byly prováděny za užití kanonické ordinace (CCA) a zobecněného lineárního modelu. Byly rozlišeny tři hlavní typy společenstev, vyskytující se na odlišném podloží a také v krajině s odlišnou topografií a intenzitou pastvy. Intenzivnější pastva měnila floristické složení více u travních společenstev vyskytujících se na vápencovém podloží. Nejvíce odlišné byly plochy s níz-

kou intenzitou pastvy na vápencovém podloží, významně se lišily od ploch na flyši a vyvřelých horninách. Se zvyšující se intenzitou pastvy se složení vegetace na vápenci přibližovalo složení na dalších dvou typech podloží. Článek diskutuje příčiny popisovaného jevu a také doporučení pro ochranu studované vegetace.

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