Ecosystem services of mown, grazed and abandoned grasslands in the Csík Mountains, Eastern Carpathian Mountains, Romania

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Summary

Measuring ecosystem services is becoming a useful tool for people to understand the value of nature and also of HNV farmland. In this study we analyze several ecosystem services provided by grasslands in the Csík Mountains, Eastern Carpathians, like animal fodder, medicinal substances, pollination, nitrogen fixation and nature conservation. The analysis is based on data collected in the field about plant species composition and abundance (cover) and ecological indices available in the literature. Within grasslands, there is variation in plant species diversity according to land use. Mountain hay meadows are currently a threatened habitat and land use type with outstanding value. Here we compare the ecosystem services provided by mountain hay meadows with those of pastures and abandoned meadows. A very high percent of 79.2 plant species in the studied meadows provided some sort of ecosystem service and nearly half of these offered more than one ecosystem service. One of the most consistent differences was a higher frequency and abundance of very good quality fodder plants in grazed meadows. The very few excellent quality fodder plants had higher frequency in abandoned meadows because of their good competitive ability, but also had higher frequency and cover in grazed meadows because of a good tolerance to trampling by grazing animals. However, honey provider and nitrogen fixer species, red-listed-, toxic- and pollen-provider plants tended to have lower frequency and abundance under grazing regime. Our data likewise suggest that grazing can cause significant drop in rare species preservation and pollen provision. For example, the frequency of pollen-provider species is smaller with an average of 10 species/plot on pastures than on mown or abandoned meadows. Such changes might trigger important decrease of pollinator abundance in heavily grazed meadows. We also found differences between different meadows: the frequency and abundance of medicinal and aromatic plants was higher on currently mown mountain hay meadows while the same were higher on abandoned low-altitude meadows. This is probably explained by the different management history of these meadows: for example mountain hay meadows have never been ploughed and are under a less

intensive management regime than low altitude meadows. While abandonment decreases the frequency and abundance of some ecosystem services like honey-provider plants and medicinal plants, it may bring advantages to others. Frequency, and most often abundance of red-listed-, pollen-provider-, endemic- and nitrogen fixer species was higher in abandoned meadows, although differences were only significant for red-listed and pollen-provider species in the large dataset.
Mountain hay meadows have the highest frequency of several provisioning services like health and well-being, honey- and pollen provision and other genetic resources (toxic plants) in our study system. Mowing has also generated exceptionally high species diversity in our study area and elsewhere in Eastern Europe. Because most provisioning services were positively correlated with species richness, it results that the wider variety of species that provide different ecosystem services in mowed meadows is a direct consequence of these meadows higher plant diversity.
Our data represent strong evidence that low intensity mowing which may include short-term abandonment episodes coupled with the traditional seasonal light grazing (in autumn) is the best practice to produce and maintain a high variety of ecosystem services.

1. Introduction

Ecosystem goods and services represent direct or indirect benefits to humans from ecosystem functions (Costanza et al. 1997). Because ecosystem functions are impacted by land use practices, it results that ecosystem services may also vary with changing management regimes and could be used to support land use policies (Viglizzo et al. 2012). Mowing, grazing and abandonment of traditional haymaking are currently typical management regimes in grasslands of Eastern Carpathian Mountains (Romania), with hay meadows shrinking worryingly in the face of expanding abandoned meadows and pastures (Knowles 2011). These management regimes affected differently the functioning and composition of meadow ecosystems, because mowing generated higher levels of diversity than grazed meadows, and abandonment resulted in diversity loss from previously mown meadows (Csergő and Demeter, 2011). Consequently, a different spectrum of ecosystem services might have unfolded under the three types of land use regimes, yet little evidence has been brought so far how they might have altered provisioning services in our system.
In this study we explored how provisioning services (Millenium Ecosystem Assessment 2005) of grassland ecosystems varied depending on management regime in the Csík Mountains of the Eastern Carpathian Mountains. We asked the following questions: **1)** Do the number, frequency and abundance of provisioning services differ between land use regimes? **2)** How does species

diversity relate to the diversity of provisioning services offered? **3)** Can these measures of provisioning services help re-organizing management practices towards more balanced functioning and composition of the studied grasslands?

2. Methods

2.1. Site description

The study was conducted in meadows dominated by *Festuca rubra* and *Agrostis tenuis* in the Csík Mountains (Romanian: Muntii Ciucului) and the adjacent Csík Basin (Depresiunea Ciucului) in the Eastern Carpathians, Romania (Fig. 1), at altitudes between 671-1369 m. The climate is boreal-mountainous, average total annual precipitation ranges between 580 mm in the Csík Basin and 1000-1200 mm at high altitudes.

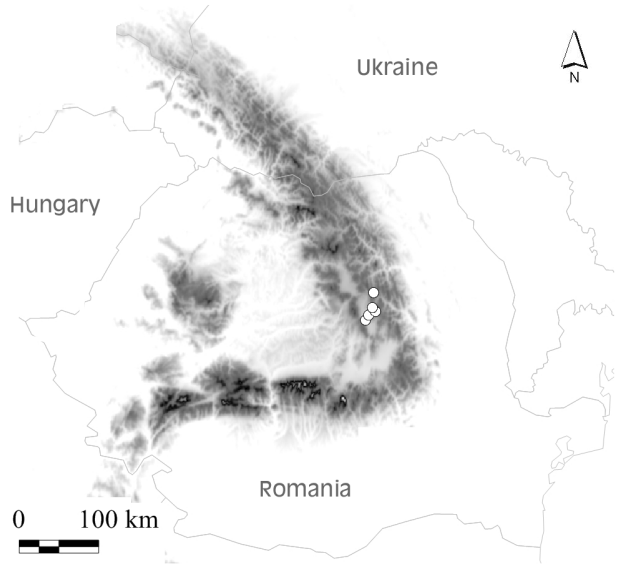


Figure 1. Map of the research area showing the sampling sites in the Carpathian Mountains.

The vegetation is a mosaic of spruce and mixed spruce forests with meadows and pastures, and arable fields. Grasslands were formed following almost complete deforestation of deciduous forests at lower altitudes (below 900 m) and partial deforestation of spruce or mixed spruce forests at higher altitudes (Csűrös et al. 1980). The history of land use traces back to historical times as in many other areas of Romania (Cioacă et Dinu 2010), but in remote mountainous areas deforestation occured rather late, following the appearance of human settlements in the XVIIIth century (Molnár and Babai 2009). Since the breakdown of socialism two decades ago, large grassland areas have been abandoned and large parts of the landscape currently experience secondary forest succession, as described by Taff et al. (2010).

2.2. Data collection

Three levels of management regime (mowed, grazed, previously mowed but now abandoned) were identified. Four localities were chosen: Somlyó (1.8 km^2) at lower altitude in Csík Basin, and Kolos (1.3 km^2), Pogányhavas (0.2 km^2), Jávárdi (1.2 km^2) at higher altitudes in Csík Mountains (Fig. 1). Each type of management was sub-sampled with four to 13, 1x1 m pseudo-replicate plots in each locality, totaling 196 plots. The number of accumulated plots was therefore N=34, N=37 and N=33 for mowed, grazed and abandoned grasslands respectively. Individual species were identified and their abundance was visually estimated in each plot (expressed as percentage cover). To even out the number of compared plots to 33, one mowed and three grazed, randomly chosen plots were eliminated from the final analyses.

The provisioning services different species of hay meadows may offer were identified from Csűrös et al. (1967-1970) and Oltean et al. (2004) as follows (acronyms used on figures are given in bold letters):

- Fodder provision (quality ranking: **F1**=poor, **F2**=medium, **F3**=good, **F4**=very good, **F5**=excellent)
- Health and well-being (medicinal and aromatic plants; **Medi**)
- Honey provision (meliferous plants; **Meli**)
- Nitrogen fixation (legumes; **N fix**)
- Pollen provision (entomogamous plants; **Pollin**)
- Rare and endemic species preservation (plants listed on the Red List of Romania; **Rare; End**)
- Other genetic resources (Toxic plants; **Toxi**)

2.3. Data analysis

In a first test we first calculated the observed and expected **1)** number, **2)** frequency, and **3)** average abundance of species that provide a given ecosystem service within mowed meadows, sheep and cattle pastures, and abandoned meadows. Number (**1**) was the total number of species that provided a given ecosystem service in all 33 plots of each mowed, grazed and abandoned grasslands; Frequency (**2**) was the number of plots in which various species that provide a given ecosystem service occurred; Average abundance (**3**) was the percentage cover of various species that provide a given ecosystem service averaged over 33 plots. With a Chi-squared test we examined whether management regime (mowing, grazing and abandonment) deviated the observed values from the values expected by chance. Relative (i.e., average) frequency instead of

absolute frequency values were used for the graphical comparison across different land use categories.

In a second test, we limited our analyses to two localities: Kolos (*n*=32 plots) and Somlyó (*n*=17 plots), where pastures were sheep grazed only, and intensity of grazing was higher. Dependent variables were the number and percentage cover (%) of an ecosystem service provider species in each plot. A one-way Analysis of Variance (ANOVA) was used to obtain mean differences in diversity estimates between different land use regimes (*glm*, SPSS 16.0). The model followed a randomized block design, with the two sites (Kolos and Somlyó) as blocks, land use regimes as treatments and individual plot as subsamples within treatments. The two sites were introduced as random effects and the model included three components: land use, block and land use x block effect. Residuals were checked for normality (Kolmogorov-Smirnov test) and homogeneity of Variance (Bartlett test). Dependent ariables were were square-root – transformed to meet the assumptions of normality.

The correlation between species diversity and frequency of each provisioning services was calculated the a two-tailed Pearson correlation coefficient (SPSS 160).

3. Results

3.1. Provisioning services of sheep- and cattle pastures, mowed- and abandoned meadows

3.1.1. Number of ecosystem service provider species

The total number of species encountered in 99 plots was 264, of which 209 offered provisioning services, and the total number of provisioning services was 362. Plant species offered on average 1.7±0.9 (mean±SD) services, and the maximum number of services offered was 4 (e.g., *Arnica montana* is red-listed, provides pollen- and honey and is also medicinal plant). 17 species provided 4-, another 17 species provided 3-, 70 species provided 2 ecosystem services, and 105 species provided 1 ecosystem service. Pollen-, fodder- and honey provision were the best represented ecosystem services, because a total of 160, 58 and 53 species fell within these categories, which represent 60.6%, 22.0% and 20.1% of all species. These were followed by medicinal and aromatic plants (41 species, 15.5%), legumes (20 species 7.6%) and rare species (13 species, 5.0%). The 17 recorded toxic plants represented 6.4% of all species.

Although the Chi-squared test did not detect significant deviations from the expected number of ecosystem service provider species ($p>0.39$), there were some minor qualitative differences between different land use categories (Figure 2). For example, mowed meadows had more excellent quality fodder plants (F5), nitrogen fixer legumes and red-listed species than expected by chance, compared to grazed or abandoned meadows. Grazed meadows had more poor- and medium quality fodder plants (F1 and F2 respectively) and less pollen provider- and toxic species than mowed or abandoned meadows. Abandoned meadows had fewer excellent quality fodder plants (F5) and nitrogen fixer species than any other land use category.

3.1.2. Frequency of ecosystem service provider species

Average frequency of ecosystem service provider species varied largely among different land use categories, being the highest in mowed meadows (37.9 species/plot), intermediate in abandoned meadows (34 species/plot) and the lowest in grazed meadows (30.6 species/plot). As with the general species count, the most frequent ecosystem service provider species were the pollen-, fodder-, and honey provider plants, with 22.9-, 13.5- and 8.8 species in each plot respectively. These were followed by medicinal plants (5.6 species/plot), legumes (3.7 species/plot), toxic plants (1.3 species/plot) and rare species (0.6 species/plot). The Chi-squared test detected significant deviations from the theoretical frequency of ecosystem service provider species in three instances (Figure 3). There was a significantly higher than expected frequency of very good quality fodder

plants (F4) in grazed meadows. Also, the frequency of red-listed- and pollen-provider species was significantly lower than expected in grazed meadows compared to other land use categories. Frequency of poor quality fodder (F1) plants was marginally significantly lower in mowed, and higher in grazed meadows (Figure 3). Also, abandoned meadows had a marginally significantly higher-, and mowed meadows a marginally significantly lower than expected frequency of excellent quality fodder plants (F5).

3.1.3. Abundance of ecosystem service provider species

Good quality fodder (F3) and pollen-provider species had the highest average abundances (43.7% and 38.3% respectively), whereas the least abundant ecosystem services were rare species preservation (1.2%) and excellent quality fodder plants (F5) (0.8%). The Chi-squared test detected two marginally significant differences (Figure 4): abundance of good quality fodder (F3) plants was on average 6.3% lower than expected in abandoned meadows ($p=0.075$) and abundance of pollen-provider plants was on average 7.7% lower than expected in grazed meadows and 7.0% higher than expected in abandoned meadows ($p=0.089$). There were some other minor differences of 1-4% average cover across land use regimes. The cover of very good quality fodder plants (F4), was on average 2.4% higher than expected in grazed meadows. Grazed meadows also had nearly 2% higher than expected medicinal plant cover, but performed less well with regards to honey provider-, nitrogen fixer-, red-listed-, toxic and pollen-provider species (Figure 4). Abandoned meadows had lower than expected cover of poor quality (F1) fodder plants and higher than expected cover of medium quality fodder- (F2), meliferous-, nitrogen fixer-, rare and toxic plants.

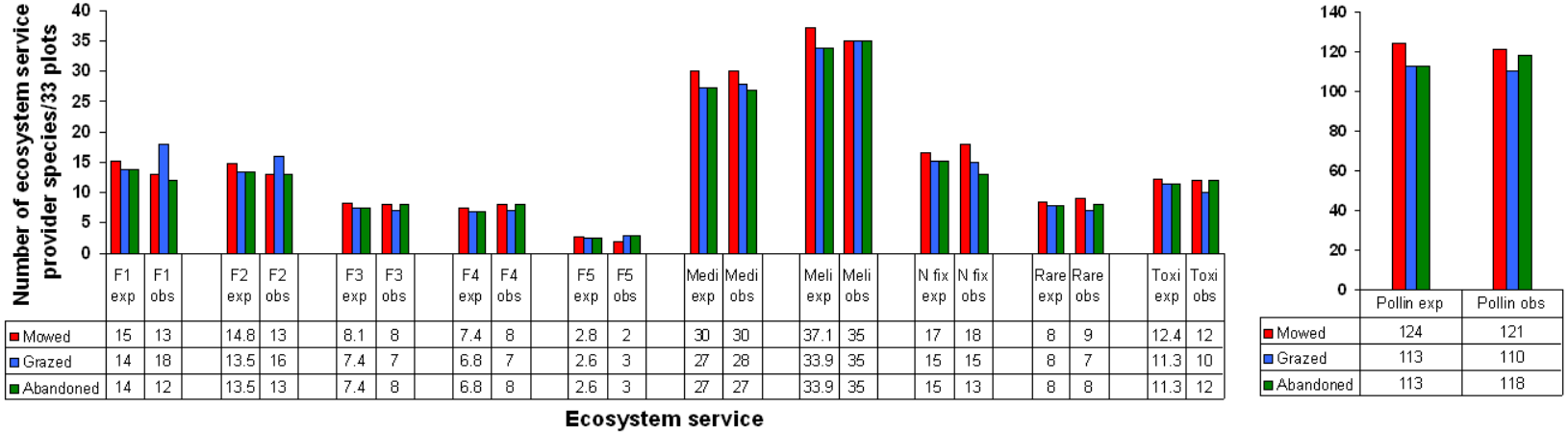


Figure 2 Observed and expected number of ecosystem service provider species across different land use types (Number of study plots: N_{mowed}=33, N_{grazed}=33, $N_{abandoned}$=33; Total number of species: N_{mowed}=194, N_{grazed}=177, $N_{abandoned}$=177, N_{total}=264). Note the different scale of pollen-provider species.

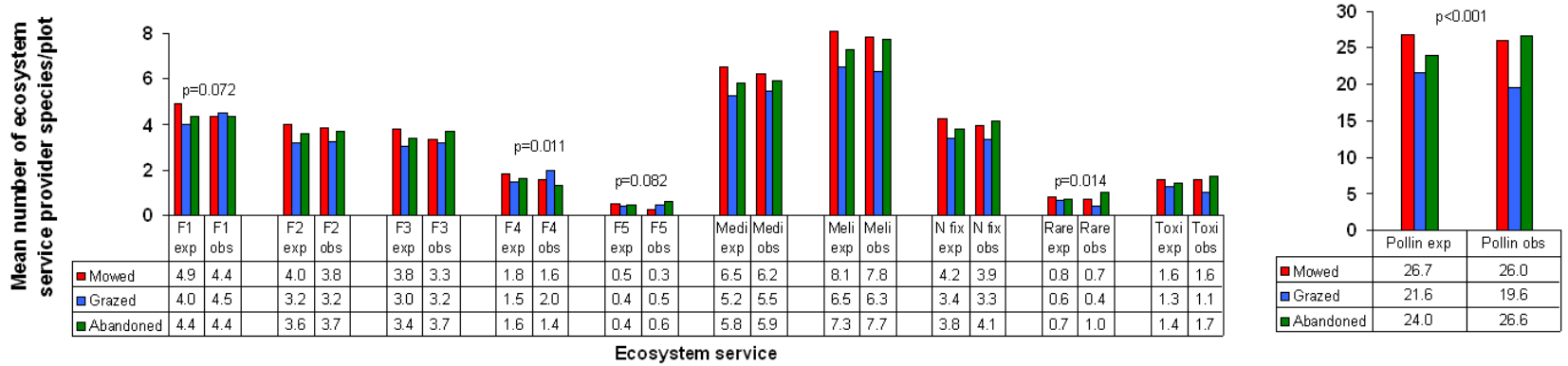
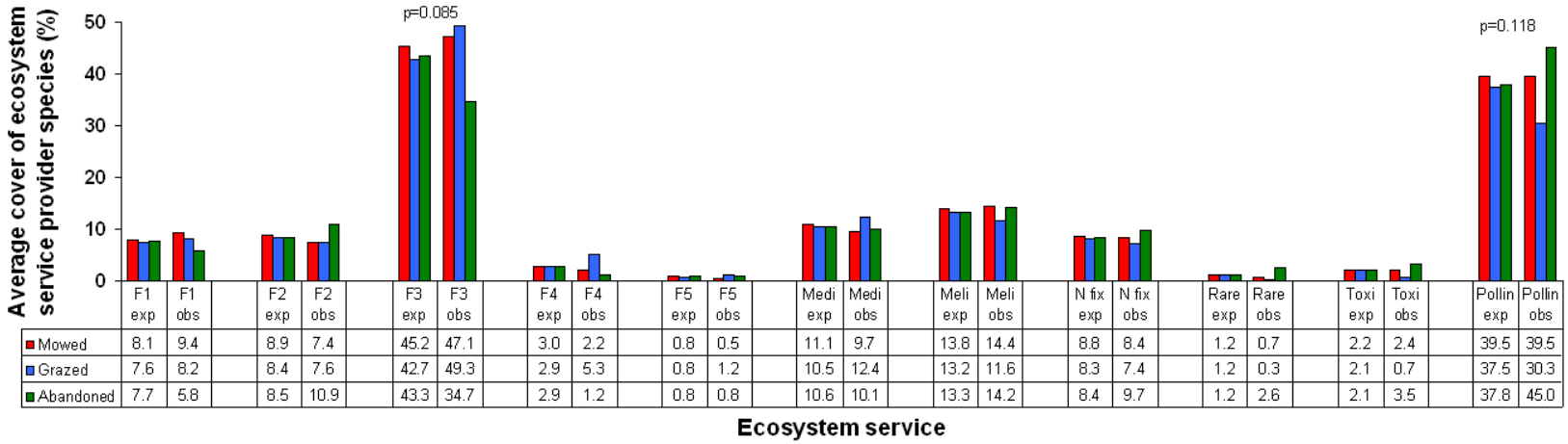


Figure 3 Observed and expected frequency of ecosystem service provider species across different land use types (Number of study plots: N_{mowed}=33, N_{grazed}=33, $N_{abandoned}$=33). Significant and marginally significant differences (p values of Chi-squared test) are shown above bars. Note the different scale of pollen-provider species.



	F1 exp	F1 obs	F2 exp	F2 obs	F3 exp	F3 obs	F4 exp	F4 obs	F5 exp	F5 obs	Medi exp	Medi obs	Meli exp	Meli obs	N fix exp	N fix obs	Rare exp	Rare obs	Toxi exp	Toxi obs	Pollin exp	Pollin obs
Mowed	8.1	9.4	8.9	7.4	45.2	47.1	3.0	2.2	0.8	0.5	11.1	9.7	13.8	14.4	8.8	8.4	1.2	0.7	2.2	2.4	39.5	39.5
Grazed	7.6	8.2	8.4	7.6	42.7	49.3	2.9	5.3	0.8	1.2	10.5	12.4	13.2	11.6	8.3	7.4	1.2	0.3	2.1	0.7	37.5	30.3
Abandoned	7.7	5.8	8.5	10.9	43.3	34.7	2.9	1.2	0.8	0.8	10.6	10.1	13.3	14.2	8.4	9.7	1.2	2.6	2.1	3.5	37.8	45.0

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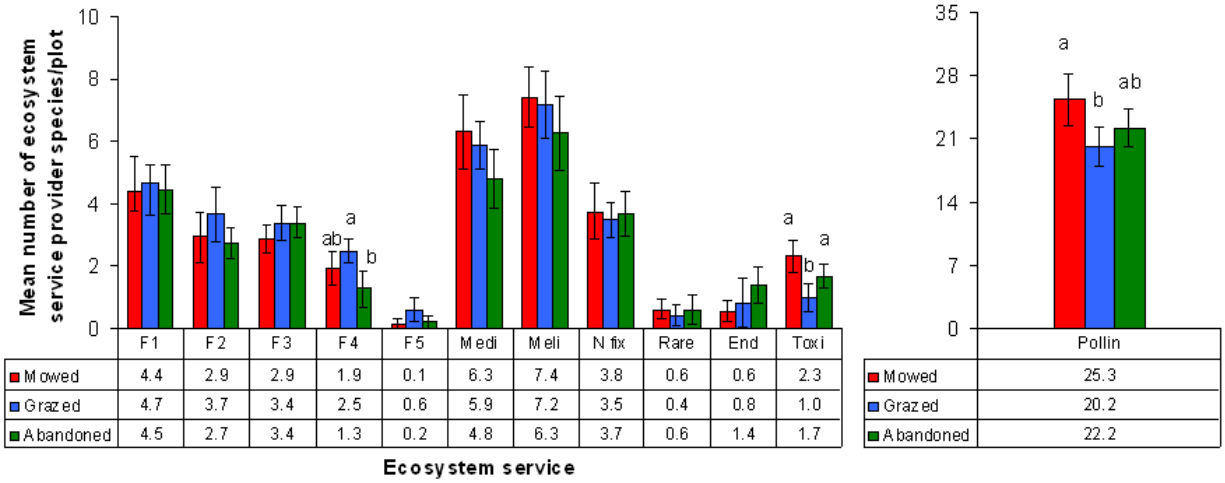
Figure 4 Observed and expected abundance of species within each ecosystem service category averaged over 33, 1m^2 plots in different land use types (Number of study plots: N_{mowed}=33, N_{grazed}=33, $N_{abandoned}$=33; Mean total cover: 101.1%). Marginally significant differences (p values of Chi-squared test) are shown above bars.

3.2. Provisioning services of sheep pastures, mowed - and abandoned meadows

As with the broader dataset, average frequency of ecosystem service provider species was higher in mowed meadows (36.4 species/plot), intermediate in abandoned meadows (33.3 species/plot), and lower in sheep pastures (31.5 species/plot). The most frequent ecosystem service provider species were the pollen-, fodder-, and honey provider plants, with an average of 22.0-, 12.9- and 6.84 species/plot. These were followed by medicinal plants (5.6 species/plot), legumes (3.6 species/plot), toxic plants (1.6 species/plot) and rare species (1.1 species/plot). The Analysis of Variance detected significant differences in mean frequency of ecosystem service provider species across different land use categories (Figure 5). Grazed meadows had a significantly higher frequency of very good fodder (F4) plants plants than abandoned meadows ($p=0.001$), and a significantly lower frequency of toxic plants than mowed meadows ($p<0.05$). Mowed meadows had a significantly higher frequency of pollen-provider plants than grazed meadows ($p<0.01$). There was a significant land use x locality interaction with respect medicinal plants, because their frequency was significantly higher in mowed than abandoned meadows of Kolos (mean+-SD: 7.5+/-1.5 versus 4.9 +/- 1.9 species/plot), and lower in mowed than grazed and abandoned meadows of Somlyó (mean+-SD: 4.3+/-1.6 5 versus 5.2 +/-1.8 and 5.0+/-1.7 species/plot respectively) ($p<0.05$). Both land use type and locality had significant effect on mean frequency of honey-provider plants ($p<0.01$): abandoned meadows had on average one species less honey-provider plants than mowed and grazed meadows (Figure 5), and the average frequency of honey provider plants at Kolos site was significantly higher than at Somlyo site (mean+-SD: 7.56+-1.9 and 5.88+-1.9).

In few instances average cover of ecosystem service provider species was affected by land use regime alone (Figure 6). Grazed meadows had a significantly higher cover of good quality fodder plants than abandoned meadows ($p=0.001$) and marginally significantly higher cover of excellent quality fodder plants ($p=0.058$)-, and a marginally significantly lower cover or toxic plants ($p=0.081$) than mowed and abandoned meadows (Figure 6). The average cover of medium- and good quality fodder plants varied across different sites, being significantly higher at Kolos than Somlyó (mean +/-SD: 8.15+-6.28 and 4.35+-4.07, $p<0.05$) and marginally significantly lower at Kolos than Somlyó respectively (mean +/-SD: 43.2+-15.7 and 62.4+-17.7, $p=0.074$). Likewise, red-listed plants varied across sites only ($p=0.032$), with an average cover of 1.02 species at Kolos and 0.1 percent cover at Somlyó. Very good quality fodder plants showed a significant land use x site interaction ($p<0.05$), being significantly higher in grazed- than mowed and abandoned meadows of Kolos, and higher in mowed meadows of Somlyó. Medicinal plant cover also showed a marginally significant land use x site interaction ($p=0.07$), being 2% lower in abandoned than grazed and mowed meadows of Kolos

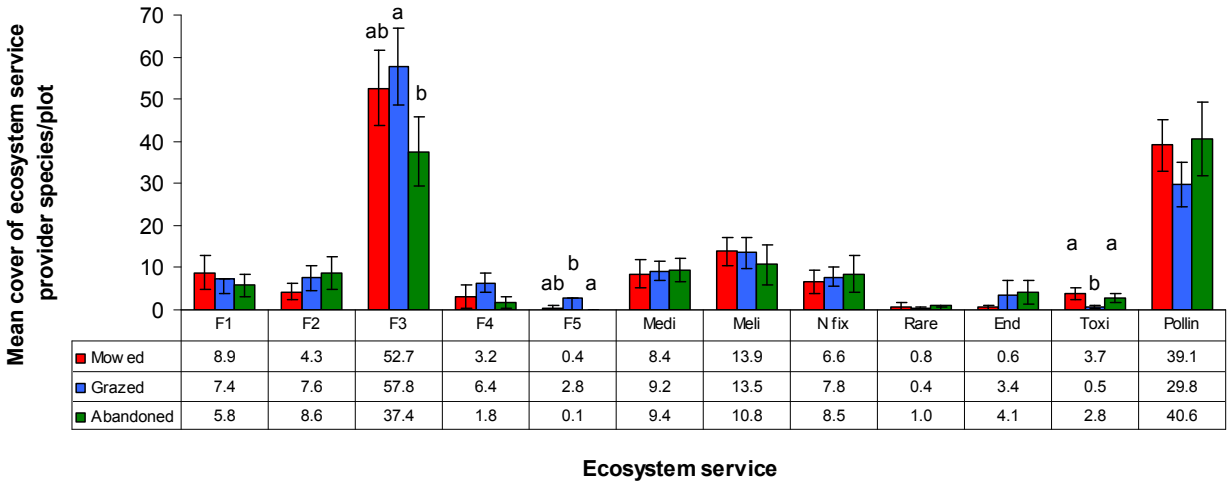
(9.2%, 11.34% and 11.02% respectively) and 5% higher in abandoned than grazed and mowed meadows of Somlyó (9.9%, 5.7% and 4.7% respectively). Although pollen-provider species had low cover in grazed meadows at both sites (Figure 6), species in this provisioning service category achieved the highest abundance in mowed meadows at Kolos, and in abandoned meadows at Somlyó (land use x site interaction, $p < 0.05$).



	F1	F2	F3	F4	F5	Medi	Meli	N fix	Rare	End	Toxi
Mowed	4.4	2.9	2.9	1.9	0.1	6.3	7.4	3.8	0.6	0.6	2.3
Grazed	4.7	3.7	3.4	2.5	0.6	5.9	7.2	3.5	0.4	0.8	1.0
Abandoned	4.5	2.7	3.4	1.3	0.2	4.8	6.3	3.7	0.6	1.4	1.7

	Pollin
Mowed	25.3
Grazed	20.2
Abandoned	22.2

Figure 5 Relative frequency of provisioning services across different land use types at Kolos and Somlyo sites (Number of study plots: $N_{mowed}=16$, $N_{grazed}=18$, $N_{abandoned}=15$, $N_{total}=49$). Error bars represent 95% Confidence Intervals of means. Significant pairwise differences (Bonferroni post-hoc test, ANOVA) are shown above bars. Note the different scale of pollen-provider species.



	F1	F2	F3	F4	F5	Medi	Meli	N fix	Rare	End	Toxi	Pollin
Mowed	8.9	4.3	52.7	3.2	0.4	8.4	13.9	6.6	0.8	0.6	3.7	39.1
Grazed	7.4	7.6	57.8	6.4	2.8	9.2	13.5	7.8	0.4	3.4	0.5	29.8
Abandoned	5.8	8.6	37.4	1.8	0.1	9.4	10.8	8.5	1.0	4.1	2.8	40.6

Figure 6 Mean abundance of provisioning services across different land use types at Kolos and Somlyo sites (Number of study plots: $N_{mowed}=16$, $N_{grazed}=18$, $N_{abandoned}=15$, $N_{total}=49$). Error bars represent 95% Confidence Intervals of means. Significant pairwise differences (Bonferroni post-hoc test, ANOVA) are shown above bars.

3.3. Species diversity and provisioning services

There was a significant negative correlation between frequency of excellent quality fodder (F5) plants and species richness (r=-0.432, p=0.002). Poor- and good quality fodder-, medicinal and aromatic-, meliferous-, nitrogen fixer-, red-listed- and pollen-provider species frequency was positively correlated with species richness (r>0.281, p<0.051) (Figure 7a, b).

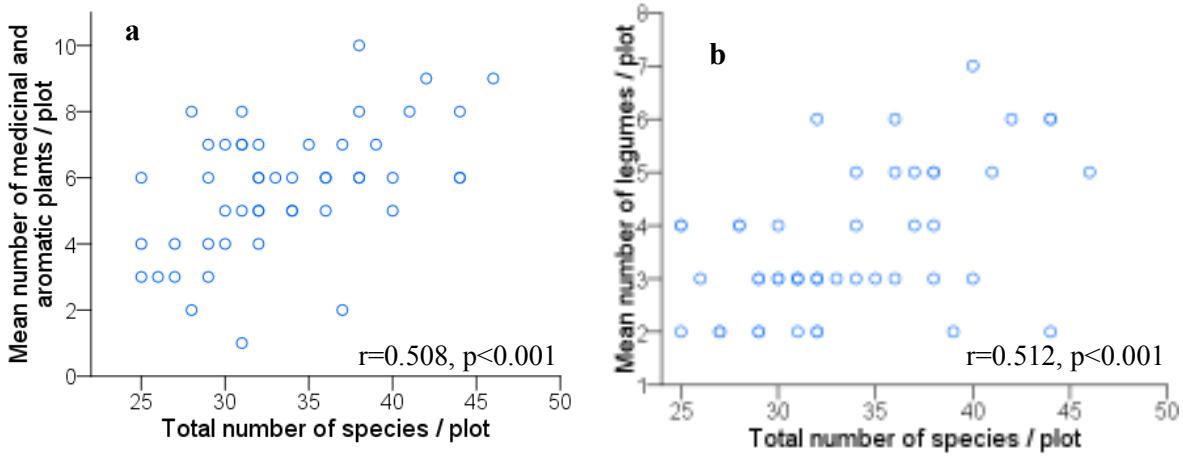


Figure 7 Scattergram showing the relationship between frequency of medicinal and aromatic- (**a**) and nitrogen fixer (**b**) plants and species richness in the studied meadows.

4. Discussion

4.1. Provisioning services of mowed, grazed and abandoned meadows

General patterns. A very high percent of 79.2 plant species in the studied meadows provided some sort of ecosystem service and nearly half of these offered more than one ecosystem service. A one meter-squared plot may contain up to 8 poor quality-, 7 medium quality-, 6 good quality-, 4 very good quality-, 3 excellent quality fodder plants, 10 medicinal-, 10 meliferous-, 4 toxic-, 7 nitrogen fixer-, 3 red-listed-, 5 endemic and 35 pollen-provider plant species. Regardless of meadow type, provisioning services were unequally represented. Pollen-providers (e.g., *Fragaria vesca, Ranunculus oreophilus*), poor, medium and good quality fodder plants (e.g., *Brachypodium pinnatum, Holcus lanatus, Festuca rubra*) and honey providers (e.g., *Cirsium erisithales, Trifolium repens*) were consistently the most frequent and abundant species, whereas excellent quality fodder plants (e.g. *Dactylis glomerata, Lolium perenne*), red-listed plants (e.g., *Pulsatilla patens, Centaurea kotschyana*) and toxic plants (e.g., *Veratrum album, Colchicum autumnale*) were the least frequent and least abundant species of all meadows. There was a higher number of pollen-provider- than honey provider species because about half of pollen provider plants like *Campanula patula* or *Viola tricolor* do not constitute a rich source of honey. The patterns of some ecosystem services like pollen provision and rare species preservation were consistent across all tests of frequency and abundance, whereas others were not. For example, of 160 pollen provider plants found in 99 plots, a high number (20-30) consistently appeared in each plot and together acquired high abundances (30-45% on average). On the contrary, the very few good quality fodder plants (7-8 species) of a low frequency (2.9-3.4 species/plot), acquired very high abundances (35-47%). This was an expected result because most of the good quality fodder plants are actually dominant grasses of the meadows (*Festuca rubra, F. nigrescens, Agrostis tenuis*). Almost all provisioning services were roughly equally represented in the species pools of mowed, grazed and abandoned meadows respectively, yet their frequency and abundance differed. For example, a quasi equal frequency of good quality fodder plants of 3-4 species/plot in mowed, grazed and abandoned meadows acquired a much higher cover in mowed and grazed meadows (47-49%) than in abandoned meadows (35%).

Differences between land use regimes. As expected, land use regime triggered notable variations in the spectrum of provisioning services analyzed. One of the most consistent differences in the two tests was a higher frequency and abundance of very good quality fodder plants in grazed

meadows (e.g., *Poa pratensis, Trifolium repens, Medicago lupulina*). The short, prostrate, rosette and stoloniferous growth forms of these species are favored in grazed meadows because their growing points are situated below height that permits their removal by large herbivores, an effect termed herbivory avoidance. Also, their high vegetative/generative shoots ratio permits a quick vegetative regeneration after defoliation (herbivory tolerance) (Branson 1953). The very few excellent quality fodder plants (*Dactylis glomerata, Festuca pratensis, Lolium perenne*) had higher frequency in abandoned meadows because of their good competitive ability, but also had higher frequency and cover in grazed meadows because of a good tolerance to trampling by grazing animals. Moreover, meliferous- and nitrogen fixer- species in the large dataset, and red-listed-, toxic- and pollen-provider plants in both datasets tended to have lower frequency and abundance under grazing regime. Grazing, especially by sheep, was often reported to decrease species diversity in the Carpathian Mountains with high livestock density (Baur et al. 2007, Başnou et al. 2009). Our evidence likewise suggests that grazing can cause significant drop in provisioning services as well, especially in rare species preservation and pollen provision. For example, the frequency of pollen-provider species may decrease with an average of 10 species/plot, and the frequency of red-listed species may be lower with one species/plot on average in grazed than mowed or abandoned meadows. Such changes might trigger important decrease of pollinator abundance in heavily grazed meadows. A constantly lower presence of toxic species in grazed meadows also suggest that these plants are mechanically removed by shepherds to avoid poisoning of grazing animals. However, some provision services may benefit from the effect of grazing. Medicinal plants like *Alchemilla monticola* increased frequency and abundance locally (Somlyó), probably due a high herbivory avoidance and tolerance ability.

Some provisioning services varied depending on land use regimes at particular sites. Mowing enhanced frequency and abundance of medicinal and aromatic plants, the frequency of honey-provider plants and abundance of pollen-provider plants at Kolos site, whereas at the Somlyó site these were true for abandoned meadows. Meadows of the low elevation Somlyó are spatially very close to human settlements and might have been subjected to a very intensive mowing regime, which is known to disadvantage the development of dicotiledonous species (Huhta and Rautio 1998). At the remote Kolos site however, mowing practice has been rather moderate, taking place at the end of July-beginning of August, and in some years being left fallow - something might have contributed to an increased presence of provisioning services, in addition to an increased diversity. Mowing at intermediate intensities like traditional haymaking, coupled with seasonal light grazing might have had increased benefits at the Kolos site, as opposed to the Somlyó site and the heavily machine mowed systems reported by Hansson and Fogelfors (2000). While abandonment

decreases the frequency and abundance of some ecosystem services like honey-provider plants and medicinal plants, it may bring advantages to others. Frequency, and most often abundance of red-listed-, pollen-provider-, endemic- and nitrogen fixer species was higher in abandoned meadows, although differences were only significant for red-listed and pollen-provider species in the large dataset. In the studied meadows dominated by *Festuca* spp. and *Agrostis tenuis*, short-term abandonment causes rather an increase of forb species cover and a decrease of dominant species cover. Indeed, in both of our datasets, good quality fodder plants (e.g., *Festuca rubra, F. nigrescens, Agrostis tenuis*) had lower abundance in abandoned meadows. Despite a high clonal mobility, these dominant species are sensitive to shading and the identity of neighbors (Herben et al., 1994) and are disadvantaged when overgrown by a herbaceous canopy. Thus, in abandoned meadows where light becomes limiting, their abundance decreases because of a higher vulnerability to displacement. Consequently, a trade-off between forb and grass cover seems to be one of the key factors of high species- and ecosystem service diversity in these meadows. Periodic short-term abandonment (a less intensive management) might favor the completion of forb species' life-cycle, which would also bring benefits to the invertebrate community of the meadows, as suggested by Baur et al. (2006).

4.2. Relationship between diversity and provisioning services

Moderate mowing intensity has increased frequency of several provisioning services like health and well-being, honey- and pollen provision and other genetic resources (toxic plants) in our system. Mowing has also generated exceptionally high species diversity in the studied meadows and elsewhere in Eastern Europe (Csergő et Demeter 2011, Aavik et al. 2008). Because most provisioning services were positively correlated with species richness, it results that the wider variety of species that provide different ecosystem services in mowed meadows is a direct consequence of these meadows' increased diversity.

4.2. Provisioning services and land use policy

Based on the available evidence, low intensity mowing which may include short-term abandonment episodes coupled with the traditional seasonal light grazing of mowed meadows is the best practice to produce a high variety of provisioning services. It must be noted however that most differences in frequency and abundance of ecosystem service provider species were small, and other biological and ecological measures like individual plant performance and life cycle, soil nutrient supply rates, root and shoot decomposition rates etc., might be better indicators of management impact on ecosystem functioning and ecosystem service provisioning in the meadows of Csík Mountains.

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