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RESEARCH ARTICLE

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Is multifunctionality the future of mountain pastoralism? Lessons from the management of semi-natural grasslands in the Pyrenees

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Abstract

Land abandonment is pervasive in mountainous Europe. In the present situation of price-cost squeeze on pastoral households and general shift in the role of farming, the development of farming abandonment risk regions is generally associated with adoption of new multifunctional rural development strategies, such as farm tourism, which in the end entail less time being devoted to farming practices. We explored the effects of such developmental scheme on the preservation of semi-natural grasslands, in particular, and on the sustainability of mountain pastoralism, in general. While the effects on the preservation of semi-natural grasslands of full abandonment have been extensively explored, this is not the case of partial abandonment. Results showed that the adoption of simplified and low-cost management regimes, associated with partial abandonment and the increased adoption of part-time farming, immerses semi-natural grasslands in processes of secondary succession that undermine both their conservation and pastoral functions. This points the need for caution when endorsing multifunctional developmental schemes in farming abandonment risk regions, particularly when those imply less labor being devoted to pastoral practices. In conclusion, we stress that in farming abandonment risk regions it is possible to guarantee both viable pastoralism and diversified rural economy. However, it is necessary to implement developmental strategies that are centered on stimulating synergies between pastoralism and other economic activities, rather than promoting activities that depend on additional farmers' polyvalence.

Additional key words: land abandonment; diversification; rural development; *Arrhenatherion elatioris*.

Abbreviations used: CCA (canonical correspondence analysis).

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Introduction

Mountain pastoralism is a livelihood strategy designed to exploit the altitudinal zonation of its environment, fundamentally through the practice of different kinds of livestock mobility. Specifically in the Pyrenees, this is the case of transhumance, which entails the exploitation of semi-natural grasslands at medium-altitude lands for hay forage production for winter feeding, and the use of communal alpine pastures in summer months. Since semi-natural grasslands are the sole endogenous source of winter feeding in the Pyrenees, its availability determines the quantity of livestock a given pastoral household can raise (Taull *et al*., 2005) and constitutes a key limiting factors for the pastoral activity. Transhumance is a strategy developed to overcome the structural shortage of winter feedstuff. However, in the last decades, as a consequence of internal and external socio-economic and ecological transformations (Caraveli, 2000; MacDonald *et al*., 2000; Mitchley *et al.*, 2006; Vaccaro & Beltran, 2007), land abandonment is dramatically threatening this system. In fact, despite specificities, land abandonment is a common trend identified all around the mountains in Europe. Land abandonment in marginal and less-productive regions has become the most remarkable trend in land-use and land-cover change in Europe (Baldock *et al*., 1996; Ilbery, 1998; Moyano & Paniagua, 1998; Ramankutty & Foley, 1999). The shortage in semi-natural grasslands due to land abandonment is also being enhanced by displacements due to infra-

structure and tourism resort development (Laguna & Lasanta, 2003; Lasanta *et al*., 2005), as well as by the removal of EU subsidies (Strijker, 2005). The decline of the family-run, transhumant mountain pastoralism is pervasive in Europe (MacDonald *et al*., 2000; Gellrich *et al*., 2008). Some point the urgent need for semi-natural grassland restoration (Madruga *et al*., 2011).

The decrease in the number of pastoral households and pastures goes with major shifts in public attitudes, from picturing pastoralists as efficient producers of foodstuffs towards portraying them as stewards of nature and suppliers of multifunctional goods and services (McNally, 2001). In the present situation of price-cost squeeze on farms and the general shift in the role of agriculture, the development of mountain regions is generally associated with a shift away from the preoccupation with economies of scale and a move towards multifunctionality. Thus, in policy and scientific arenas multifunctionality is gaining relevance as a key policy notion to stimulate rural development in farming abandonment risk regions (Knickel & Renting, 2000; van der Ploeg *et al.*, 2000; Pinto & Breman, 2009; van der Ploeg *et al.*, 2009; López-i-Gelats & Tàbara, 2010). It would seem that the attainment of sustainable living mountains entails that pastoral households move from the traditional food-producing determination to adopt new multifunctional rural development strategies, such as farm tourism, nature conservation or off-farm employment.

The preservation of semi-natural grasslands is not only crucial to secure the endurance of pastoralism, but it is also crucial to preserve multiple economic, social, cultural and ecosystem services delivered by semi-natural grasslands (Bullock *et al*., 2011; Ford *et al*., 2012). This is for instance the case of preservation of cultural landscapes (Palombo *et al*., 2013) or biodiversity conservation. Semi-natural grasslands are among the most species-rich habitats in the world, even comparable with rainforests (Wilson *et al*., 2012). Semi-natural grasslands maintain an enormous variety of grass species and wildflowers, as well as birds, insects and invertebrates. For instance, 65% of the European Red List butterfly species depend on the maintenance of semi-natural grasslands (Van Swaay & Warren, 1999).

In Europe a total of 16% of the grassland area is located in mountains (Sarzeaud *et al*., 2008). However, semi-natural grasslands are among the most threatened ecosystems, decreasing by 12.8% from 1990 to 2003 in Europe (FAO, 2006). Land abandonment is the main factor threatening mountain pastoralism in Europe, and it goes with the cessation of traditional labor-intensive pastoral practices, such as mowing, hedgerow maintenance, dry stone walling preservation, organic fertilization, clearing of scrubs or moderate grazing (Baldock *et al*., 1996; Cernusca *et al*., 1996; MacDonald *et al*., 2000; Bartolomé *et al*., 2005; Pykälä *et al*., 2005; Hopkins & Holz, 2006; Gellrich *et al*., 2007, 2008; Lomba *et al*., 2013; López-i-Gelats, 2013), which are essential for the preservation of these semi-natural grasslands. It is well known the fact that the entire cessation of pastoral practices triggers changes in the species' composition and structure of semi-natural grasslands, becoming shrubland and ultimately forest with time (Kahmen & Poschlod, 2004; de Bello *et al*., 2006; Lomba *et al*., 2013). The effects of different grazing and mowing frequencies on the species' composition and structure of semi-natural grasslands have also been extensively explored (Bakker, 1989; Lavorel *et al*., 1997; Hansson & Fogelfors, 2000; de Bello *et al*., 2005; Sebastià *et al*., 2008; Peco *et al*., 2012). However, there is a lack of studies examining the impact on the preservation of mountainous semi-natural grasslands of the adoption of increasingly low-cost and simplified management regimes.

In the Pyrenees, semi-natural grasslands are dominated by the *Arrhenatherion elatioris* association. Typical of Atlantic regions, this association is characterized by high abundance of well-adapted plants to diverse frequencies of mowing and grazing - hemicryptophyte graminoids. In the Pyrenees these grasslands are located between 1100 and 1400 m a.s.l. and coincides with the isohyet of 900-1000 mm of annual precipitation (Creus *et al*., 1984). As pointed by Fillat *et al*. (1993), this indicates that the *Arrhenatherion elatioris* semi-natural grasslands of the Pyrenees constitute the Southern distribution limit of this habitat in Europe. For that reason they are particularly vulnerable to any type of change, such as water stresses or management modifications.

We picture land abandonment as a more or less long and gradual process of devoting less and less time to farming, along which single pastoral households drop out little by little specific management practices from their routine, particularly those more time-consuming, while increasingly adopting low-cost and simplified management regimes, which eventually ends up with the total cessation of the pastoral activity. It is a sequence of pastoral adjustments inserted in a mesh of interdependent transformations in the environmental, economic and cultural spheres. Given that the endorsement of multifunctionality is the chief strategy being applied at present to promote rural development in farming abandonment risk regions, such as mountains, and keeping in mind that it usually entails combining the pastoral activity with other economic activities; here we ex-

amined the effects of the implementation of such developmental schemes on semi-natural grasslands, in particular, and on mountain pastoralism, in general. In so doing, the objective of this study was to assess the impacts on mountain semi-natural grasslands of the partial abandonment resulting from the adoption of less time-consuming pastoral practices. Specifically, we examined the substitution of mowing for grazing and the adoption of different types of livestock farming (sheep-, cattle- or horse-farming) on the species' composition and structure of semi-natural grasslands in Eastern Pyrenees.

Material and methods

Study area

The study was performed in the county of El Pallars Sobirà, in the Eastern Pyrenees, in Catalonia (Spain). It is a region of 1378 km², which embraces a large diversity of landscapes, from semi-natural grasslands in the valley floors and foothills, to alpine highlands at peaks of around 3000 m. Nine tenths of the territory have a slope steeper than 20%. The abrupt topography and the location on the Northern boundary of the Mediterranean climate zone contribute to the existence of a large variety of climates, which are altitudinally organized. Thus, the climate is Mediterranean in the lower valleys, becoming Atlantic as elevation increases (from 800 to 2300 m a.s.l.), and Alpine at the highest altitudes (Fillat *et al*., 2008). Annual rainfall is about 700 mm on the valley floors. It increases to 1500 mm at 2000 m a.s.l.

Pastoralism and a recent transition to a service-based economy, largely based on the tourism sector (Vaccaro & Beltran, 2007) are the main features of the economy of the region. Land abandonment is a pervasive trend, comprising multiple changes and consequences. López-i-Gelats (2013) points that the current context of high risk of land abandonment is to a large extent the conjoint effect of processes of agroecosystem degradation, due to simplification in farming practices; economic restructuring, due to high opportunity costs of all assets devoted to pastoralism; and social recomposition, entailing a changing role of pastoralism and rural areas as a whole. Thus, the adoption of pastoral practices less time-consuming and more compatible with part-time farming is a general trend (Laguna & Lasanta, 2003; Lasanta *et al*., 2005; López-i-Gelats *et al*., 2009, 2011).

In particular, the conversion of meadows into pastures, that is, the reduction of mowing in favor of grazing (Garcia-Ruiz *et al*., 1996; Di Pietro, 2001; Fanlo *et al*., 2004; Mottet *et al*., 2006); and shifting to forms of livestock farming less time-consuming, that is, from sheep- and cattle-farming to horse-farming, are two of the most relevant transformations observed in pastoral management. In view of that, Bartolomé *et al*. (2008) claims that one mown-and-grazed plot turns into only-grazed every year per pastoral household in the region. Also, Bartolomé *et al*. (2008) observed that in the Pyrenees 80% of the sheep farmers work full time, while 54% of the cattle farmers are full time committed to the pastoral activity, and only 8% of horse farmers do not have a complementary source of income. This is explained by the fact that in the Pyrenees, sheep are shepherded most of the time and stabled during the cold season, cattle are less guarded and not always stabled in the cold season, and horses stay unguarded on the pastures and meadows and under no circumstances are stabled. Consequently keeping horses requires less labor than raising cattle and particularly sheep.

Field measurements

The impacts on semi-natural grasslands of two sorts of pastoral management transformations derived from increased adoption of part-time farming were examined. Thus, mown-and-grazed and only-grazed plots, on the one hand, and sheep-, cattle- and horse-farmed plots, on the other hand, were compared given the decreasing levels of labor requirements they entail. A total of 22 sites of *Arrhenatherion elatioris* semi-natural grasslands were surveyed between 2005 and 2006 (5 and 17 respectively) to conduct these comparisons. All of them shared the following features and low-intensive management characteristics, namely: not located at the valley floor; non-irrigated land; not resown; at least 20 years of fidelity to the same meadow management and livestock farming; between 0.5 and 2 ha of surface, altitude between 1100 and 1400 m a.s.l.; Southern aspect; and finally in all cases manure was the only fertilizer applied, either spread by animals when grazing or spread by farmers.

Four samplings were conducted in every site twice a year, once in summer (with a total of 88 samplings) and again in autumn (with a total of 76 samplings). A total of 164 samplings were conducted in fenced plots of these semi-natural grasslands: 40 in sheep-farmed and mown-and-grazed plots, 20 in sheep-farmed and grazed plots, 36 in cattle-farmed and mown-and-grazed plots, 16 in cattle-farmed and grazed plots, 36 in horse-farmed and mown-and-grazed plots, and finally 16 in horse-farmed and grazed plots. Twelve samples could not be taken for logistic reasons. Each sampling con-

sisted in conducting 5-metre linear transects laid out at random. All the species intercepted by a vertical pointer at 10-cm intervals were recorded along these lines. The plant cover and species' composition of the plots were estimated using the Line-Intercept Method, adapted from Cummings & Smith (2000) by Sebastià (2004) for semi-natural grasslands in the Pyrenees.

In order to characterize the dissimilar species' composition and vegetation structure of the different sorts of plots, five sets of parameters were recorded (Table 1): (i) morphological traits, (ii) flowering traits, (iii) plant composition traits; (iv) biodiversity indices, and (v) agronomical parameters. Particularly interesting is the use of plant functional traits, since they are non-phylogenetic groupings of species which perform similar roles in ecosystem processes based on a set of common biological attributes (Gitay & Noble, 1997). Functional classifications are particularly adequate to describe vegetation responses to disturbances (McIntyre *et al*., 1995; Lavorel *et al*., 1997). They allow to reduce the initial large quantity of species to a few functional groups, and to relate the generated groupings to ecological functions rather than phylogeny. In this regard, several features of the species identified were examined, such as guilds (distinguishing among graminoids, legumes and forbs), life forms (distinguishing among therophytes, caespitose hemicryptophytes, scapose hemicryptophytes, rosulate hemicryptophytes, biennial hemicryptophytes, phanerophytes, chamaephytes and geophytes), maximum expected canopy height (distinguishing between <30 cm and >30 cm), flowering period (distinguishing between summer- and spring-flowering species), and finally length of flowering period (distinguishing among very-short-, short-, long-, and very-long-flowering species). The biogeographical region to which the species belong was also considered (comprising Eurosiberian, Pluriregional, Mediterranean and Boreoalpine species).

Concerning vegetation structure, several features were examined, such as (i) the presence of species characteristic of *Arrhenatherion elatioris* semi-natural grasslands (distinguishing among very-common, <50%; common, 25-50%; moderately-common, 25-5%; and scarce species, <5%); (ii) several biodiversity indices (some weighting more on species abundance, such as Species Richness and the Simpson index, and others weighting more on species evenness, such as the Shannon-Wiener index and the Equitability index); (iii) several production variables (species density, production and the maximum vegetation height); and finally (iv) the fodder quality (developed by Daget & Poissonet (1972), it estimates the quality of fodder resources combining the following attributes: digestibility, palatability, production and nutritional value).

Data analysis

To identify the species' composition and vegetation structure that were most strongly associated with the different situations considered to describe partial abandonment of semi-natural grassland in the Pyrenees, a canonical correspondence analysis (CCA) was conducted, by means of the CANOCO 4.5 program (ter Braak & Šmilauer, 2002). The substitution of mowing for grazing and three different types of livestock farming were the two factors considered. While mown-and-grazed and grazed plots, as well as sheep-, cattle- and horse-farmed plots, were considered factor levels. In addition, given that the plots were sampled between 2005 and 2006, and regarding the characteristic fluctuations of the Mediterranean climate (Lionello *et al*., 2006), the effect of the year of sampling was included in the analysis as a block factor. In particular, the precipitations recorded in the region in 2005 and 2006 were 15% and 31% lower than average, respectively (Meteosort, 2008). On the valley floor, at 700 m a.s.l., 608 mm and 502 mm were recorded, correspondingly.

The phanerophytes, chamaephytes, geophytes and biennial hemicryptophytes life forms were excluded from the analysis beforehand due to rare presence. Likewise Mediterranean and Boreoalpine chorologies were barred. For the CCA ordination, the full species data set and 38 explanatory variables were initially used, namely: 29 parameters (see Table 1) and the 7 aforementioned factor levels. However, the number of parameters was first reduced by considering colinearity aspects. When correlations between parameters were greater or equal to 0.7 (ter Braak, 1987), the parameter with the lower correlation value with the CCA axis was removed. This was the case of the Shannon-Wiener index, Simpson index, species density, height, graminoids, tall species, pluriregional and summer-flowering species. Multicolinearity was also taken into consideration (ter Braak & Šmilauer, 2002) and the parameters with variance inflation values higher than 20 were removed since they were considered redundant. This was the case of short-flowering species. The automatic forward selection option of the CANOCO program was then applied to choose the parameters that when added improved the model's fit (p<0.05), judged by a Monte-Carlo permutation test. All of them were included except the factor levels summer and autumn. Thus, 20 parameters and 7 factor levels were found significant. Both parameters and factor levels were used as explanatory variables in the analysis: the parameters as quantitative variables and the factor levels as nominal variables. Although CCA does not require the explanatory variables to be normally distributed, percentages were converted to proportions and arcsine

Table 1. List of parameters recorded to examine the effects of partial abandonment on the botanical composition, structure and production of semi-natural grasslands in the Pyrenees.

Parameters		Description	Source
(A) Morphological traits			
GUILDS	Graminoids	Graminoids are grasses and grasslike plants such as sedges and rushes.	Bolòs *et al*. (1990)
	Legumes	Legumes are known for their ability to fix atmospheric nitrogen.	
	Forbs	Forbs are any plants that are not graminoids or legumes.	
LIFE FORMS	Therophytes Caespitose Hemicryptophytes Scapose Hemicryptophytes Rosulate Hemicryptophytes Biennial Hemicryptophytes Phanerophytes Chamaephytes Geophytes	Life form definitions following Raunkiaer (1934).	Gómez *et al*. (2008)
MAXIMUM CANOPY HEIGHT	Short, <30cm Tall, >30cm	Expected average adult height.	Bolòs *et al*. (1990)
(B) Flowering traits:			
FLOWERING PERIOD	Summer-Flowering, from June on Spring-Flowering, from February to May	Usual flowering months.	Bolòs *et al*. (1990)
LENGTH OF THE FLOWERING PERIOD	Very-Short-Flowering, < 2 months Short-Flowering, >2 and < 3 months Long-Flowering, > 4 and < 6 months Very-Long-Flowering, > 6 months	Duration of the flowering period.	Bolòs *et al*. (1990)
(C) Plant compositional traits			
CHOROLOGY	Eurosiberian Pluriregional Mediterranean Boreoalpine	Biogeographical region to which each species belongs.	Bolòs *et al*. (1990)
DISTINCTIVE SPECIES	Very-Common, >50% Common, 25-50% Moderately-Common, 25-5% Scarce, <5%	According to how many times each species has been detected in the 215 transects contained by the Catalan biodiversity database Biocat on the *Arrhenatherion elatioris* W. Koch 1926 grassland alliance.	Font (2010)
(D) Biodiversity indices			
BIODIVERSITY	Species richness Simpson index Shannon-Wiener index Evenness index	Species richness only considers species abundance. Evenness index merely explains species evenness. Shannon and Simpson indexes account for both.	Magurran (1988)
(E) Agronomical parameters			
PRODUCTION	Species density (number of species/ sampling point)	Number of species intercepted by a vertical pointer at 10-cm intervals.	
	Production (t/ha)	Metric tons of dry weight (2 days at 70 ºC) of grass per hectare, calculated from samples of 0.25 m² of herb mown next to each transect.	
	Height (cm)	Average of the five maximum heights recorded at 1-m intervals of each transect.	
FODDER QUALITY	Pastoral index	It measures the quality of fodder resources, considering digestibility, palatability, production and nutritional value. It ranges from 0 to 100.	Daget & Poissonet (1972)

transformed prior to analysis, so as to reduce the influence of extreme values. It was not necessary to log transform absolute species abundance since the data were not skewed. The influence of rare species was downweighted to prevent excessive influence.

Finally, to examine the effects of the substitution of mowing for grazing and the different types of livestock farming on each parameter in an isolated manner, a three-way ANOVA and the ANOVA post-hoc Fisher's PLSD test ($p<0.05$) (StatView, SAS Institute Inc.) were performed. Before the analysis all data were assessed for conformation to the assumption of normality by means of the Kolmogorov-Smirnow test and visual inspection of histogram. The variables that did not follow that distinction were log (p'=log p) or arcsine transformed (p' = arcsin).

Results

A total of 134 taxa were recorded from the plots examined. The following species were found with the highest average plant cover in the plots, as estimated through the Line-Intercept Method: *Dactylis glomerata* (12%), *Poa pratensis* (9%), *Trisetum flavescens* (7%), *Taraxacum officinale* (6%), *Plantago lanceolata* (6%), *Festuca pratensis* (6%), *Lathyrus pratensis* (4%), *Arrhenatherum elatius* (4%), *Lotus corniculatus* (4%) and *Bromus erectus* (3%). In Table 2 the most commonly identified species in the different types of plots considered are described. *Dactylis glomerata*, *Poa pratensis*, *Lotus corniculatus*, *Plantago lanceolata*, *Taraxacum officinale* and *Trisetum flavescens* were present in almost all plots sampled.

Fig. 1 shows the most distinguishing species identified in each type of plot. It is evident that a larger number of forbs and a minor occurrence of species distinctive of *Arrhenatherion elatioris* semi-natural grasslands characterize the only-grazed plots. On the contrary, the mown-and-grazed plots are distinguished by the presence of grasses, caespitose hemicryptophyte, and species distinctive of *Arrhenatherion elatioris* semi-natural grasslands. The horse-farmed plots are characterized by greater diversity of life forms and guilds, as well as by the presence of species of a pluriregional chorology. In contrast, cattle- and sheep-farmed plots are distinguished by the presence of grasses and species distinctive of *Arrhenatherion elatioris* semi-natural grasslands.

The results of the CCA are shown in Fig. 2, as a scatter plot of explanatory variables. The angle of the arrows with the axes is indicative of their correlation with the axes. Arrows that are parallel with an axis are highly correlated. Those that are perpendicular are uncorrelated. The length of the arrows and distance of centroids from the origin are representative of the extent to which species distribution differs along the range of the given variables (ter Braak, 1987). The first canonical axis (eigenvalue = 0.278), explaining 20% of the variance, is clearly illustrative of the transition from mown-and-grazed to only-grazed managements, with biplot scores of variables ± 0.755 respectively, as well as the year factor (± 0.241). It opposes the mown-and-grazed and the less dry-year plots, which are plots with more legumes, caespitose hemicryptophytes, species characteristic of *Arrhenatherion elatioris* semi-natural grasslands, and greater production in the positive direction; to only-grazed and dry-year plots, which are those plots with more forbs, spring-flowering species, scarce species, very-short flowering species and greater values of species richness in the negative direction.

The second canonical axis (eigenvalue = 0.242), explaining 17% of the variance, primarily describes changes in Eurosiberian species, Evenness index and long-flowering species in the negative direction; and therophytes and very-long-flowering species in the positive direction (see Fig. 2). This axis is also highly illustrative of the transition to forms of livestock keeping more compatible with part-time farming, from sheep- and cattle-farmed to horse-farmed plots. Whereas no remarkable difference is identified between sheep- and cattle-farmed plots, with biplot scores of variables being −0.580 and −0.265 respectively; horse-farmed plots, with a biplot score of variables of +0.867, are located at the other extreme end of the second canonical axis.

In Table 3, it can be distinguished how sheep- and cattle-farmed plots tend to perform similarly, while clear differences exist with regard to horse-farmed plots. Horse-farmed plots are characterized by: lower occurrence of graminoids, short-flowering species, and Eurosiberian species; larger presence of forbs, terophytes, Pluriregional species, and species not characteristic of *Arrhenatherion elatioris* semi-natural grasslands; larger species abundance and lower species evenness; and minor production. Likewise are the existing differences between mown-and-grazed and only-grazed plots. Only-grazed plots show higher presence of forbs, spring-flowering species, Pluriregional species, and species not characteristic of *Arrhenatherion elatioris* semi-natural grasslands; lower occurrence of graminoids, tall species, and Eurosiberian species; and minor production and fodder quality. Concerning the effect of the year, the driest year (2006) is characterized by the presence of less legumes, summer-flowering species, very-long-flowering species, and species characteristic of *Arrhenatherion elatioris* semi-natural grasslands; more species abundance and lower species evenness; and minor hay production.

Table 2. Presence frequency of the species identified in each 10-cm interval in the sheep-, cattle-and horse-farmed plots, and in the mown-and-grazed and only-grazed plots in semi-natural grasslands in the Pyrenees.

Species	%	Species	%	Species	%
DIFFERENT TYPES OF LIVESTOCK FARMING					
Sheep-farmed		**Cattle-farmed**		**Horse-farmed**	
Dactylis glomerata	10.6	***Dactylis glomerata***	13.0	***Dactylis glomerata***	14.1
Festuca pratensis	9.7	***Poa pratensis***	9.6	***Poa pratensis***	14.0
Trisetum flavescens	8.5	***Taraxacum officinale***	8.8	***Plantago lanceolata***	11.9
Arrhenatherum elatius	8.2	***Trisetum flavescens***	7.7	***Taraxacum officinale***	6.2
Lathyrus pratensis	5.0	*Festuca pratensis*	5.9	*Medicago sativa*	5.2
Lotus corniculatus	4.7	*Lathyrus pratensis*	4.8	***Trisetum flavescens***	3.9
Taraxacum officinale	4.4	***Lotus corniculatus***	4.5	*Trifolium repens*	3.8
Poa pratensis	4.2	*Ranunculus sp.*	4.4	*Bromus erectus*	3.7
Plantago lanceolata	4.2	*Achillea millefolia*	3.4	*Lolium perenne*	3.4
Bromus erectus	3.7	*Agrostis capillaris*	3.3	*Convolvulus arvensis*	3.4
SUBSTITUTION OF MOWING FOR GRAZING					
Mown-and-grazed		**Only-grazed**			
Dactylis glomerata	13.8	*Festuca pratensis*	12.4		
Poa pratensis	8.7	***Poa pratensis***	8.5		
Trisetum flavescens	8.4	***Dactylis glomerata***	8.1		
Taraxacum officinale	7.8	***Plantago lanceolate***	5.2		
Plantago lanceolata	6.3	*Bromus erectus*	5.1		
Lathyrus pratensis	5.7	***Lotus corniculatus***	5.0		
Arrhenatherum elatius	4.4	*Trifolium pratensis*	4.2		
Festuca pratensis	3.8	*Achillea millefolia*	4.1		
Lotus corniculatus	3.5	*Ranunculus sp.*	3.2		
Vicia cracca	2.8	*Medicago lupulina*	3.1		
All plots					
Dactylis glomerata	12.3				
Poa pratensis	8.6				
Trisetum flavescens	7.0				
Taraxacum officinale	6.3				
Plantago lanceolata	6.0				
Festuca pratensis	5.9				
Lathyrus pratensis	4.4				
Arrhenatherum elatius	4.0				
Lotus corniculatus	3.9				
Bromus erectus	3.0				

In bold, those species most characteristic of *Arrhenatherion elatioris* semi-natural grasslands in the Pyrenees.

Table 3. Means of parameters to assess the impacts of the substitution of mowing for grazing, the different types of livestock farming and year on the species' composition and vegetation structure of semi-natural grasslands in the Pyrenees, and three-way ANOVA with the post-hoc Fisher's PLSD test (p<0.05).

	Year			Substitution of mowing for grazing			Different types of livestock farming			
	2005 n=36	**2006** n=128		**Mown-and-grazed** n=112	**Only-grazed** n=52		**Cattle-farmed** n=52	**Horse-farmed** n=52	**Sheep-farmed** n=60	
(a) Morphological traits										
GUILDS										
Legumes	0.24	0.18	***	0.19	0.18	*	0.17 [a]	0.19 [b]	0.21 [b]	***
Graminoids	0.24	0.26	ns	0.26	0.22	*	0.27 [a]	0.23 [b]	0.26 [a]	**
Forbs	0.53	0.57	**	0.54	0.60	***	0.56[ab]	0.59 [a]	0.54 [b]	*
LIFE FORMS										
Terophytes	0.11	0.10	ns	0.10	0.10	ns	0.08 [c]	0.12 [a]	0.11 [b]	***
Caespitose Hemicryptophytes	0.27	0.25	ns	0.27	0.23	*	0.29 [a]	0.23 [b]	0.24 [b]	***
Scapose Hemicryptophytes	0.46	0.48	ns	0.49	0.44	**	0.47	0.48	0.47	ns
Rosulate Hemicryptophytes	0.11	0.10	*	0.10	0.10	ns	0.10	0.10	0.09	ns
MAXIMUM CANOPY HEIGHT										
Short	0.31	0.27	ns	0.27	0.29	ns	0.27	0.27	0.28	ns
Tall	0.74	0.73	ns	0.75	0.71	ns	0.76	0.73	0.72	ns
(b) Flowering traits										
FLOWERING PERIOD										
Summer	0.86	0.82	***	0.86	0.77	***	0.84 [a]	0.82 [b]	0.84[ab]	**
Spring	0.13	0.18	***	0.14	0.23	***	0.16 [a]	0.18 [b]	0.17[ab]	**
LENGTH OF FLOWERING PERIOD										
Short	0.08	0.11	**	0.10	0.11	ns	0.10 [b]	0.08 [c]	0.12 [a]	**
Medium	0.02	0.10	***	0.08	0.08	ns	0.11 [a]	0.06 [b]	0.07 [b]	***
Long	0.53	0.52	ns	0.52	0.53	ns	0.55 [a]	0.50 [b]	0.53[ab]	***
Very long	0.37	0.27	***	0.30	0.28	**	0.24 [c]	0.35 [a]	0.30 [b]	***
(c) Plant community traits										
CHOROLOGY										
Eurosiberian	0.46	0.51	**	0.52	0.48	**	0.53 [a]	0.45 [b]	0.53 [a]	***
Pluriregional	0.51	0.45	***	0.45	0.51	***	0.42 [a]	0.53 [c]	0.45 [b]	***
DISTINCTIVE SPECIES										
Very common	0.33	0.27	***	0.30	0.26	***	0.29	0.29	0.28	ns
Common	0.23	0.26	ns	0.26	0.24	ns	0.26	0.24	0.25	ns
Moderately common	0.26	0.22	*	0.23	0.21	**	0.22 [b]	0.20 [b]	0.25 [a]	***
Scarce	0.18	0.26	***	0.22	0.29	***	0.23[ab]	0.27 [a]	0.22 [b]	*
(d) Other parameters										
BIODIVERSITY										
Species Richness	19.1	25.2	***	23.6	24.6	ns	23.4	24.5	23.7	ns
Simpson Index	0.13	0.13	ns	0.13	0.14	ns	0.12 [b]	0.15 [a]	0.12 [b]	***
Shannon-Wiener Index	2.29	2.38	ns	2.36	2.36	ns	2.42	2.29	2.36	ns
Equitability Index	0.79	0.74	***	0.75	0.75	ns	0.78 [c]	0.72 [a]	0.75 [b]	**
PRODUCTION										
Species density (nº sp./point)	4.1	3.87	ns	4.2	3.4	***	4.0 [a]	3.5 [b]	4.2 [a]	***
Production (t/ha)	2.54	1.30	***	1.89	0.87	***	1.51 [b]	1.14 [c]	1.98 [a]	***
Height (cm)	61.6	35.5	**	48.0	26.6	***	37.3 [b]	31.4 [b]	53.2 [a]	***
FODDER QUALITY										
Pastoral Index	61.2	58.1	ns	60.0	56.2	*	56.1	61.44	58.9	ns

Except for those indicated, the units of the parameters are %. * $p < 0.05$; ** $p< 0.01$; *** $p < 0.001$; ns, not significant.

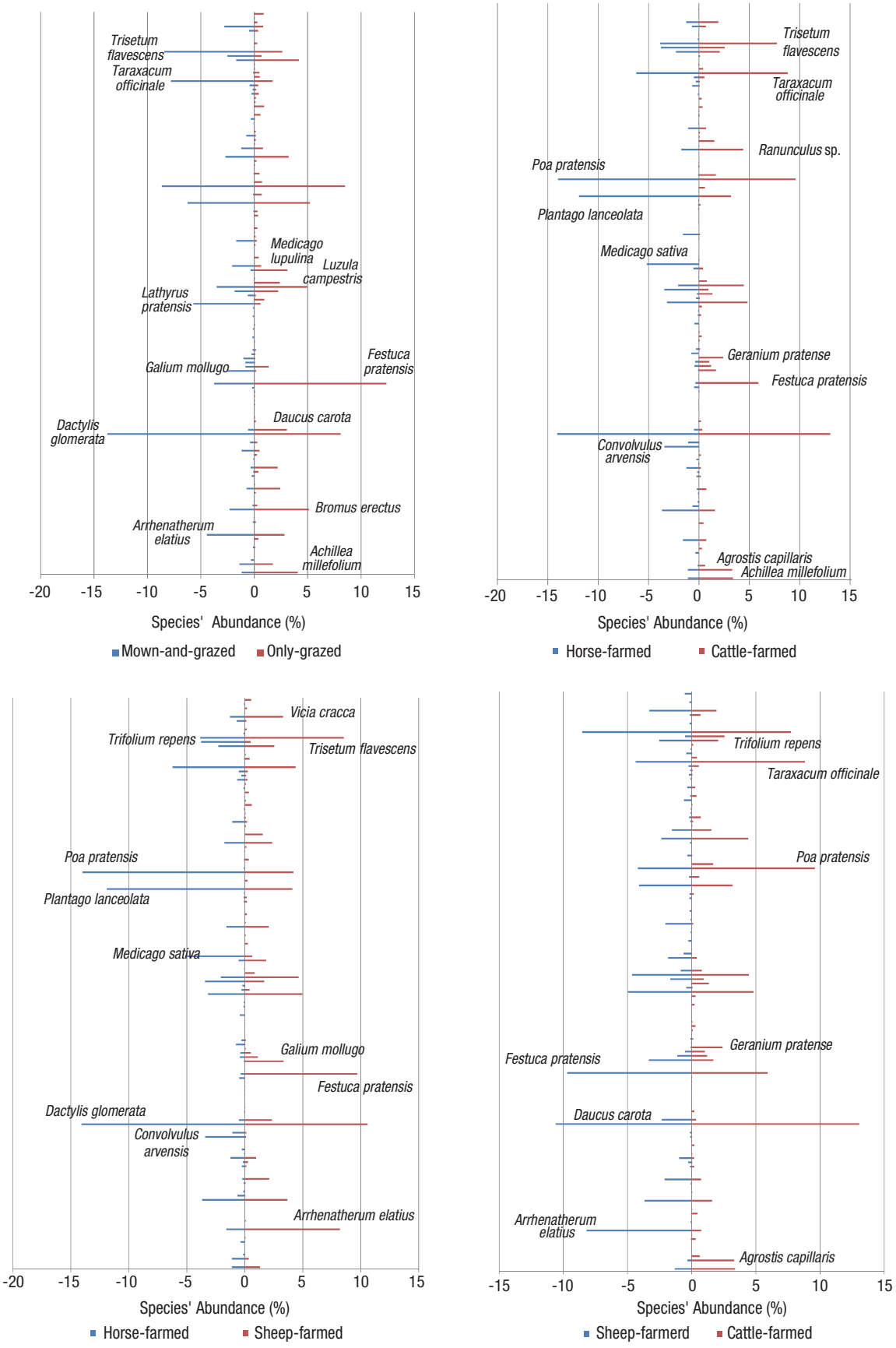

Figure 1. Distinctive species' abundance in sheep-, cattle-and horse-farmed plots, and mown-and-grazed and only-grazed plots of semi-natural grasslands in the Pyrenees.

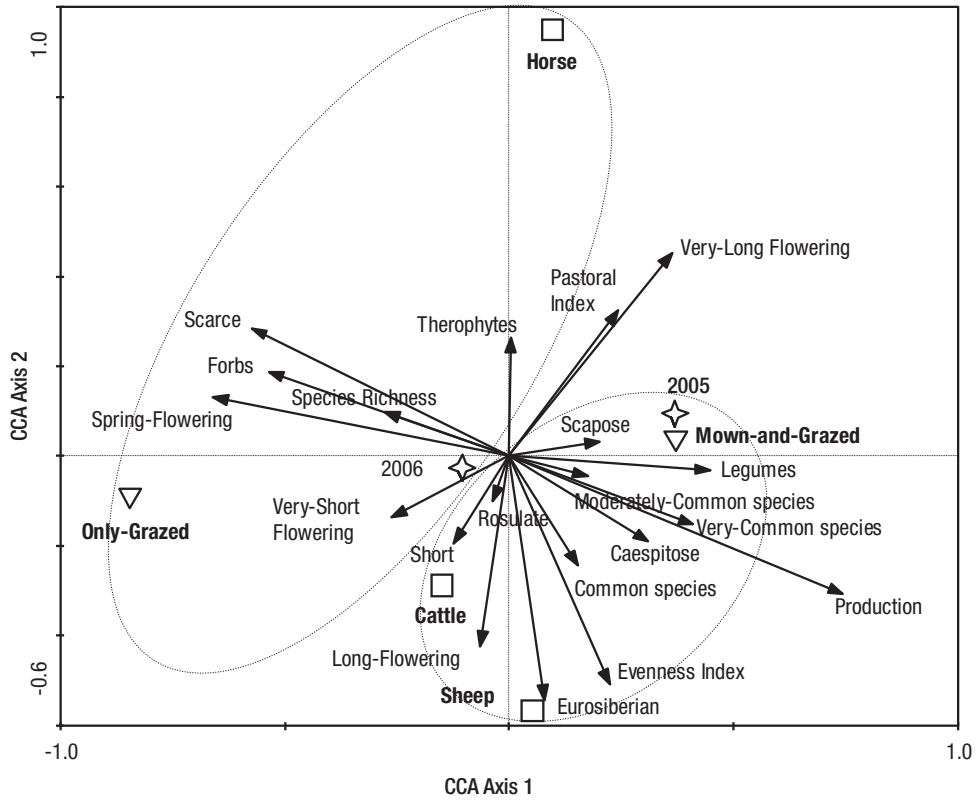

Figure 2. Plot scores for the first two axes of the canonical correspondence analysis for species' composition and vegetation structure of semi-natural grasslands under partial abandonment in the Pyrenees. Arrows represent the parameters. The centroids □ and ▽ correspond, respectively, to the diverse levels of adoption of part-time farming, and substitution of mowing for grazing. (✧) corresponds to the two years of sampling.

Discussion

The mown-and-grazed plots and the sheep- and cattle-farmed plots, where the pastoral management required is more time-consuming, tend to be grouped separately from only-grazed and horse-farmed plots, which are largely associated with part-time farming and partial abandonment. An interannual variation has also been identified between the plots sampled in 2005 and in 2006. This variation is attributed to the usual rainfall fluctuations of the Mediterranean climate. But it is also due to the fact that there are some plots that under normal precipitations are mown and grazed, while they are only grazed in dry years, a situation that was particularly observed in 2006.

The parameters that correlate highly with only-grazed plots are illustrative of characteristics of grassland communities under conditions of heavy grazing (Briske, 1996; Lavorel *et al*., 1997; Kahmen & Poschlod, 2004; de Bello *et al*., 2005; Díaz *et al*., 2007; Peco *et al*., 2012), with abundance of spring-flowering, very-short-flowering and rosulate hemicryptophyte species. They also show remarkable presence of species that are characteristic of other habitats than *Arrhenatherion elatioris* semi-natural grasslands, such as scarce species and forbs. The minor presence of distinctive species and the higher values of species richness observed point to the fact that the absence of mowing triggers a process of secondary succession towards habitats other than *Arrhenatherion elatioris* semi-natural grasslands. The process of cessation of mowing entails the interruption of long-time controlled conditions in the management of semi-natural grasslands in favor of generalist conditions that stimulate opportunistic species. As highlighted by Canals & Sebastià (2000), the increase in the amount of species in absence of mowing should not be understood as something that enhances the conservation value of mountain semi-natural grasslands, since it is due to the advent of species not characteristic of *Arrhenatherion elatioris* semi-natural grasslands. In line with this, Díaz & Cabido (2001) and McIntyre &

Lavorel (2001) indicate that species richness is not the most appropriate indicator to illustrate that the fundamental functions of a well-preserved ecosystem are occurring. In contrast, in mown-and-grazed plots the features of better-preserved *Arrhenatherion elatioris* semi-natural grasslands are observed (Fanlo & Chocarro, 1989; Chocarro & Reiné, 2008), with abundance of legumes, caespitose hemicryptophytes, scapose hemicryptophytes, Eurosiberian, very-long flowering species and species characteristic of *Arrhenatherion elatioris* semi-natural grasslands, as well as high values in fodder quality and hay forage production.

The sheep- and cattle-farmed plots show similar features. Both of them fit the expected characteristics in well-preserved *Arrhenatherion elatioris* semi-natural grasslands. The differences found coincide with those described in the literature (de Bello *et al*., 2007; Sebastià *et al*., 2008), with cattle grazing increasing the vegetation heterogeneity and sheep grazing reducing it. This is also illustrated in Fig. 2, with sheep-farmed plots showing higher values in the Evenness index. In contrast, the features that distinguish horse-farmed plots are analogous to those of *Arrhenatherion elatioris* semi-natural grasslands under perturbation (Lavorel *et al*., 1997). Similarly to the only-grazed plots, and unlike the sheep- and cattle-farmed ones, horse-farmed plots seem to be immersed in a process of secondary succession, with larger frequencies in forb, therophyte, scarce and spring-flowering species, as well as little hay production and low values in Evenness index, jointly with large values in species richness. These differences are poorly explained if merely the dissimilar grazing and trampling effects of the three livestock types are taken into consideration. If this were the case, the major differences would have been found between small and big livestock types (Rook *et al*., 2004), with sheep grazing shorter the sward than cattle and horses, and selecting higher quality plant parts. But this was not the case.

In conclusion, results point that the increasing adoption by pastoralists of simplified and low-cost management regimes, associated with partial abandonment, is manifestly modifying the species' composition and vegetation structure of the *Arrhenatherion elatioris* semi-natural grasslands in the Pyrenees. It goes with abundance of species not distinctive of this type of semi-natural grassland, descent in biodiversity value in terms of evenness, and significant loss in hay forage production, which is where the main value of this agro-ecosystem for pastoralism lies in. Partial abandonment thus immerses semi-natural grasslands in a process of secondary succession, which undermines its role for both conservation and pastoral purposes.

In view of that and taking up again the discussion on the convenience of endorsing developmental schemes based on the promotion of multifunctionality in pastoralism for mountain regions, and for farming abandonment risk regions in general; these results indicate the need for caution. When endorsing multifunctionality entails the promotion of less labor being devoted to pastoralism, and consequently stimulates the adoption of low-cost and simplified management practices among pastoral households, this line of action accelerates partial abandonment and the degradation of semi-natural grasslands, as has been shown here. In view of that and in order to shed light on the convenience to implement multifunctional development schemes in farming abandonment risk regions, we propose to distinguish between two different conceptions of multifunctionality: (i) the multifunctionality of farmer, and (ii) the multifunctionality of farming. The two notions stress the need to profit from the multiple social benefits that the implementation of farming brings about, both directly and indirectly. But they suggest doing it differently, considering different scales, at a farming household scale and at a regional scale, respectively. While the former stresses farmer polyvalence, and consequently the shift of labor from pastoral activities to other activities, such as rural tourism, nature conservation or off-farm employment; the latter stresses stimulating synergies among diverse economic activities in a given region, thus not compromising the minimum amount of labor and specialization to conduct any given activity appropriately, such as the maintenance of semi-natural grasslands through appropriate mowing and grazing.

As suggested by numerous authors (Knickel & Renting, 2000; van der Ploeg *et al.*, 2000; Pinto-Correia & Breman, 2009; van der Ploeg *et al*., 2009; López-i-Gelats & Tàbara, 2010;), we strongly believe multifunctionality should play a major role in the rural development of farming abandonment risk regions, as it is often the case of mountains, and it is undoubtedly the case of the Pyrenees; but this should not be done at the expense of pastoralism, but mostly thanks to pastoralism. As shown in this paper, the adoption of simplified and low-cost management regimes accelerates partial abandonment, which in turn decimates semi-natural grasslands and the pastoral activity as a whole. For this reason, to further exploit the multifunctional potential of pastoralism, it is crucial to preserve it in good conditions and stop encouraging development strategies based on shifting pastoral labor to other economic activities. The use of the notion of the multifunctionality of farming to design rural development strategies is a first step in this direction towards dynamic mountain futures with numerous and sustainable pastoralism.

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