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Forage consequences of the continued reduction of stocking rate in subalpine grasslands: the case of *Festuca eskia* grasslands

R. Fanlo, M. Ros and M. Bou

Universidad de Lleida, Agrotecnio. Rovira Roure 191, 25198 Lleida (Spain)

Abstract. From the mid-20th Century abandonment of rangelands is the biggest threat in the European high mountain. Although this grassland has been used as means of grazing for many centuries, there are no natural communities in *stricto sensu;* communities are semi natural with a good stability. The value of this grassland is exceptional (biodiversity reservoirs, chipper production with good nutritional qualities, protective from erosion, suitable for amenities, etc.). However, such values can only be maintained by keeping the farming activity. In this work we present continuous measurements during five years of the effect of *Festuca eskia* in grasslands from the Aigüestortes National Park in the Spanish Pyrenees, where the seasonal stocking rate was decreasing (from 0.72 to 0.18 LU·ha^{-1}·year^{-1}). Results show an increase in species richness (S, 13.4 *vs.* 18.2), biodiversity index (Shannon, 1.99 *vs.* 2.13) and non-legume forbs (7.1 *vs.* 11.4) when stocking rate was diminishing. Forage quality (measured through the pastoral value method, the content in crude protein, fat and phosphorus in the dry matter production) diminished in the same period.

Keywords. Upper timberline grasslands – Forage quality – Grazing abandon – Plant diversity – Pyrenees.

***Conséquences fourragères de la réduction continue de la charge animale dans les prairies subalpines: le cas des pâturages de* Festuca eskia**

Résumé. *Depuis le milieu du siècle dernier, l'abandon de l'activité pastorale est l'une des principales menaces dans les zones de haute montagne de l'Europe. Depuis des siècles, ces communautés végétales ont été utilisées par le bétail et, bien qu'elles soient semi naturelles, elles sont assez stables quant à leur diversité, leur qualité fourragère et leur production, ce qui leur confère une valeur exceptionnelle. Cependant, cette valeur ne peut être conservée (étant donné son caractère semi naturel) que si l'utilisation et la gestion pastorale sont maintenues. Ce travail montre l'effet, sur une période d'échantillonnage de cinq ans, de la diminution de la charge en bétail estivale (de -0,72 à -0,18 UBG·ha^{-1}·an^{-1}) sur différentes caractéristiques du système. Les résultats montrent une augmentation de la richesse spécifique (S, 13,4* vs. *18,2), de l'index de Shannon (1,99* vs. *2,13) et de la diversité des espèces (7,1* vs. *11,4). Simultanément, la qualité fourragère (mesurée selon la méthode de la valeur pastorale, ainsi que par l'analyse des teneurs en matière azotée totale, en graisses et en phosphore dans la matière sèche) diminue pour la même période.*

Mots-clés. *Prairies d'altitude – Qualité fourragère – Abandon du pâturage – Diversité botanique – Pyrénées.*

I – Introduction

Most of European grassland ecosystems, such as the Pyrenean *F. eskia* pastures, have been used for centuries, and have thus maintained high values of biodiversity and forage quality (Humphrey and Patterson, 2000; Leeuw and Bakker, 1986). The abandonment of pastures in the mountain started with remote and badly connected farms, related with the migration process (farmers to cities) and the shift in working activities from the agricultural to the tertiary sector. On the contrary, the stocking rate has increased in pastures near farms. Abandonment (lower stocking rate than admissible) and overgrazing (more stocking rate than admissible) are similarly bad situations for the ecosystem. Our objective was to study the evolution of different variables (related with floristic diversity and forage quality) during a period of seven years in a pasture of *F. eskia* that was being gradually abandoned.

II – Materials and methods

1. Location

This study was conducted in the Aigüestortes National Park (Spanish Pyrenees; 420 35' N, 010 00' E; 2185 m a.s.l.; SE orientation; 15º slope). The climate ("oro-temperate hyper-wet" according Rivas-Martinez *et al*., 2002) does not show significant differences in precipitation during the growth period over the seven sampling years (average of 238.6 mm). The stocking rate changed from 0.72 $LU.ha^{-1}$ in the first year (2002) to 0.18 $AU.ha^{-1}$ in the last year (2008). At the start of experiment, 0.72 AU was slightly higher than the admissible stocking rate calculated by means of dry matter production (0.68 AU), consequently the pasture was a bit overgrazed. The livestock grazed from July to the end of September.

2. Sampling

Two fenced plots of 10 x 12 m were established in a homogenous *F. eskia* pasture. On each plot, two quadrates of 1 x 0.5 m were randomly harvested every three weeks (from mid-June to the end of September) to calculate the dry matter (DM) aboveground production (not used for this paper) and the chemical nutritional components. We avoided cutting the same quadrate more than once in all samplings. Two linear transect of 10 m (randomly placed on the plot) was also used for botanical composition measurements. The plots were located in the same zone every year, but not in the same place, in order to detect any effects of the change in stocking rate.

3. Diversity and forage quality

The botanical composition (present and abundance species) was determined by the point-quadrat method (1 point every 20 cm; 100 points per transect) and the specific contribution was defined according to our works in the same kind of pasture (Fanlo *et al*., 2015; Komac *et al*., 2014). Data from transects were used to obtain the specific richness, Shannon and Berguer Parker indexes (Magurran, 1988), botanical functional groups and to calculate the pastoral value (PV) according to the Daget and Poissonet method (Daget and Poissonet, 1971). Forage parameters of the biomass were analyzed using the near-infrared spectrometry method after drying to obtain the crude protein (CP), fats (EE), lignin (ADL), crude fiber (CF), calcium (Ca), magnesium (Mg) and phosphorous (P) contents in DM by means of an NIR SYSTEM 6500, using a universal calibration obtained in the Catalan Agro-Food Laboratory (accreditation number 157/LE309).

III – Results and discussion

All the means obtained in the experiment are shown in Table 1. Species richness and diversity values (S and H') are significantly higher when pastures are being left and Berguer-Parker's dominance index is minor. The number of species is low, but it is within the same range as other acidic pastures (Komac *et al*., 2014). For the analysis of "functional groups" we have grouped *Poaceae* and graminoides as "grasses", only *Fabaceae* as "legumes" and the rest of species as "forbs". Number of different "grasses" doesn't show significant difference between the different years, "legumes" vary with no clear pattern and "forbs" increase in number. The increase in "forbs" causes the increase of Shannon and a decrease in the dominance values. These results are the contrary to when Mediterranean pastures are abandoned, as functional diversity decreases (Peco *et al*., 2012).

Quality assessment of grassland through pastoral value method is based on the presence of good forage species (values 4 or 5) and their proportion (Daget and Poissonet, 1971). Most of the species in our pastures have a medium quality (3) a low quality (2 and 1) or none (0). It is important to point

out that the mentioned method (VP) considers *F. eskia* as a species with no value. This is the reason why values are very low in general. The decreasing VP over time is related to the increase of "forbs" with no forage value. The nutrient contents obtained by means of the NIRS method show a similar result to those of the VP. The decrease of the stocking rate produces a significant reduction of the CP, EE, P and a tendency in Ca in the pasture biomass. Variations of CF are difficult to explain; they may be related to the increase of "forbs", and the latter with the decrease of LAD.

Table 1. Supported stocking rate over the trial duration and observed means (± SD) from plant richness, Shannon, and Berger-Parker indices, grasses, legumes and forbs proportions, Forage quality (pastoral value, crude protein, crude fibre, lignin, fat, phosphorus and calcium in % of DM) (n = 35 for diversity variables; n = 145 for forage quality)

Year	2002	2004	2005	2006	2008
Supported stocking rate AU.ha^{-1}.year^{-1}	0.72	0.60	0.50	0.21	0.18
Diversity parameters					
Richness (S)	13.40 ± 1.89c	11.80 ± 1.93d	14.33 ± 1.4c	16.83 ± 1.51b	18.20 ± 2.38a
Shannon-Weber (H')	1.99 ± 0.19b	1.82 ± 0.20c	1.84 ± 0.11c	2.26 ± 0.15a	2.15 ± 0.11a
Berguer Parker (d)	0.37 ± 0.05b	0.40 ± 0.06b	0.47 ± 0.02a	0.28 ± 0.03c	0.28 ± 0.03c
Grasses	6.30 ± 0.67	5.70 ± 0.48	6.22 ± 0.83	6.00 ± 0.63	6.00 ± 0.70
Legumes	0.00	0.90 ± 0.31a	0.88 ± 0.33a	0.16 ± 0.40b	0.60 ± 0.54a
Forbs	7.10 ± 1.66b	5.0 ± 1.63c	7.22 ± 0.9b	10.66 ± 2.06a	11.40 ± 2.07a
Forage quality parameters					
Pastoral Value (range 0-100)	19.67 ± 2.36a	14.65 ± 3.59b	10.45 ± 2.77c	9.36 ± 0.69c	5.38 ± 0.80d
Crude protein (CP)	9.28 ± 1.68a	7.26 ± 1.26b	6.05 ± 0.66c	6.19 ± 1.64c	5.57 ± 0.78d
Crude fiber (CF)	32.95 ± 0.55ab	32.13 ± 0.36b	34.00 ± 0.34c	33.43 ± 0.38ac	33.75 ± 0.44ac
Lignin (ALD)	9.21 ± 0.9a	9.32 ± 0.63a	6.62 ± 0.26b	5.22 ± 0.13c	5.41 ± 1.51c
Fat (EE)	2.97 ± 0.29a	2.66 ± 0.37b	1.69 ± 0.33c	1.34 ± 0.43d	1.18 ± 0.23e
Phosphorous (P)	0.16 ± 0.04 a	0.12 ± 0.02b	0.09 ± 0.01c	0.10 ± 0.02c	0.07 ± 0.01d
Calcium (Ca)	0.52 ± 0.03a	0.41 ± 0.01b	0.33 ± 0.01c	0.32 ± 0.01c	0.4 ± 0.07b

Values in the same row followed by different letter are statistically different for $P \leq 0.05$ (LSD test).

Plant biodiversity losses due to abandonment entail a loss of animal and fungi diversity; this tendency could be reverted by going back to traditional management, and hence an increase in stocking rate (Fanlo *et al.*, 2015; Humphrey and Patterson, 2000). But this would only be possible in the case of mountain farmers receiving an economic compensation, in order to avoid polarization of agricultural activities. This would also allow having a feedback between conservation measures and field farming systems (Beaufoy, 1998).

IV – Conclusions

The decrease in the number of animals in upper timberline grasslands over the years produces a loss of quality and an increase in the specific richness. The interrelation between the variables studied (stocking rate, forage quality and biodiversity) shows an inverse relation between the stocking rate and the forage quality and plant biodiversity. These results prove the actuality of the old pastoral paradox: "good grazing management improves grassland"; at least from the pastoral point of view.

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