Journal of Plant Studies; Vol. 4, No. 1; 2015
ISSN 1927-0461 E-ISSN 1927-047X
Published by Canadian Center of Science and Education

Influence of Stocking Rate on Forage Quality and Diversity in Pyrenean Subalpine Grasslands: Can They Recover if Abandoned?

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Received: Janaury 7, 2015 Accepted: February 25, 2015 Online Published:

doi:10.5539/ URL: http://dx.doi.org/10.5539/

Abstract

Can subalpine grasslands recover their pristine conditions if they are abandoned? Since the mid-20th Century, the process of abandonment in European subalpine grasslands due to the decrease in the stocking rate has triggered changes in the forage quality and ecological characteristics of pastures. In this paper we explain the changes (and tendencies) in forage quality and biodiversity in grasslands of *Festuca eskia* Ramond ex DC from the Aigüestortes National Park (Spanish Pyrenees) that were quasi-abandoned for some years and regained their stocking rate at the beginning of the 21st Century without great changes in climatic and edaphic conditions during the period. Results show a decrease in forage quality (measured as the content of crude protein, phosphorous, fat and pastoral value) and in specific richness at the beginning of abandonment and a regain when the stocking rate was restored. The changes in the variables studied over the period of loss and recovery of grazing show a direct relation to the changes in the functional groups.

Keywords: grazing, *Festuca eskia*, specific richness, forage quality

1. Introduction

Pyrenean alpine and subalpine grassland has been used for grazing for many centuries (Montserrat & Fillat, 1990). Grazing communities are not strictly natural but they are very stable semi-natural communities. This grassland has exceptional value as a biodiversity reserve and a carbon sink, provides protection against erosion, is a cheap and efficient source of forage with high nutritional quality, and keeps the hills open for recreational activities (Komac et al., 2014). However, these values can only be maintained by preserving grazing (Sebastià et al., 2008). The stocking rate decreased drastically in most European mountain grasslands in the mid-20th century (Silva et al., 2008). At the beginning of the 21st Century (at our site) the number of heads on the pastures has increased again and some of the former characteristics have been recovered. These results have been observed in pastures of *Festuca eskia* in the Aigüestortes National Park, Spanish Pyrenees, where *F. eskia* pastures cover 11% of the total area.

One of the main principles of rangeland management is the so-called pastoral paradox that "grazing improves the pasture" (Anonymous, 2008). This statement is based on experience: a pasture that is overgrazed or grazed with the wrong type of animal or at the wrong time can be detrimental. Loss of forage quality occurs because some species are favoured, or the production decreases because the soil is too exposed. However, absence of grazing or undergrazing is also detrimental (Fanlo et al., 2000; Jones & Evans, 2001). The disappearance of livestock from pastoral ecosystems leads to a new reorganization of species: the species diversity changes and the forage quality decreases. In fact, the pastoral paradox should read: “good grazing improves the pasture”; in other words, well-managed grassland will lose forage quality and specific diversity when it is abandoned. Grassland is considered to be well managed when the demand of the stocking rate, in kilograms of dry matter, is similar to the production per hectare offered at the time of grazing. Many studies have examined the interaction between livestock and biodiversity, particularly in Mediterranean conditions (Seligman et al., 1989; Noy - Meir, 1995; Sternberg et al., 2002; Koukoura & Karmiris, 2004; Papanikolau et al., 2010), but few indicate the exact stocking rate supported (Caballero et al., 2009). They tend to use imprecise expressions such as “light, moderate and heavy” or “moderate, heavy and very heavy” grazing intensity. Our hypothesis was that in grasslands with a long history of grazing it is possible recovery their pristine conditions changing the soported stocking rate. The objective of this work is to outline the changes in biodiversity, forage quality and dry matter production when subalpine grasslands are abandoned and subsequently recover their stocking rate.

2. Method

This study was conducted during three summer periods (2002, 2008 and 2012) in a homogeneous *F. eskia* pasture from the Spanish Aigüestortes National Park, at 2185 m a.s.l. (42°32'0.22"N - 1°4'59.12"E) with a SE orientation and a 15% slope, where two plots of 30 m x 20 m were established. On each plot two quadrates of 1 × 0.5 m were randomly harvested every three weeks (from June to September) to calculate the dry matter (DM) aboveground production and chemical nutritional components. A linear transect of 20 m (randomly placed on the plot) was also done for botanical composition measurements. In all samplings, we avoided cutting the same patch of ground more than once. The plots were located in the same zone in 2008 and 2012 in order to detect any effects of the change in stocking rate. Botanical composition was determined by the point-quadrat method (1 point every 20 cm; 100 points per transect) (Godall, 1953). The specific contribution was defined according to the Daget and Poissonet method (Daget et Poissonet, 1971).

Forage parameters of the biomass were analysed using the near-infrared spectrometry method (Marten et al. 1989) after drying to obtain the crude protein (CP), digestible protein (DP), fats (EE), lignin (ADL), fibres (brute fibre [BF], acid detergent fibre [ADF] and neutral detergent fibre [NDF]), ash, 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). Data from transects were used to obtain the specific richness, Shannon and Pielou indexes, and functional groups and to calculate the pastoral value (PV) according to the Daget and Poissonet method. The supported stocking rate (SSR: animal units per hectare) during the three-month grazing period each year was calculated directly in the field as the number of animals present and the time of grazing on the pasture. Climatic records of the experimental period (monthly means of temperature and precipitation) were obtained from the nearest official meteorological station (Espot, about 10 km away). Data were evaluated by an analysis of variance, using the STATISTICA 6 statistical package. A repeated-measures ANOVA was used to test the effect of SSR after the normalization of the data. The least significant difference (LSD) and the Sheffe test were used to compare means following any significance ($P < 0.05$) with STATISTICA 6.0 (StatSoft 1995).

3. Results and Discussion

3.1 Independent variables: climatic conditions and SSR.

Temperature and precipitation are key environmental factors affecting biomass production on all kinds of grassland (Le Houérou & Hoste, 1977; Deshmukh, 1984; Ospina et al., 2011; Fiala et al., 2012; Yang et al., 2013), and monthly temperature and precipitation during the growth period are especially important. We found no significant differences in the monthly averages during the experiment but the total precipitation was greater in the first year than in the other two. Curiously, there was no increase in temperature over the ten years but there was a continual decrease in total precipitation in summer (Table 1).

Table1. Climatic conditions and supported stocking rates during the period of pasture growth (May to September)

year	F(2,12)	1st (2002)	2nd (2008)	3rd (2012)
Monthly average temperature (ºC)	18; $p < 0.841$	16.08 ± 1.85	17.06 ± 3.47	16.44 ± 2.34
Monthly average rainfall (mm)	0.68; $p < 0.524$	88.08 ± 44.96	66.2 ± 48.08	58.64 ± 28.61
Total rainfall (mm)		440.4	331	293.2
SSR ($AU \cdot ha^{-1}$)		0.72	0.18	0.61

Total rainfall corresponds to these five months. The grazing period was three months (late June to late September). SSR (supported stocking rate), AU (animal unit). Means (±SD) and F values.

The SSR in animal units (one animal unit is equivalent to a 500-kg cow) per hectare during the grazing period (three months) showed a great decrease from the first year of sampling to the second and a considerable increase from the second to the third, almost returning to the initial situation (0.72; 0.18 and 0.61 respectively).

3.2 Dependent Variables

3.2.1 Dry Matter Production

The value obtained is directly related to the total rainfall during the growth period. This was reflected in the significant difference in the quantity of DM produced in different years (Table 2), the largest production being in the year with the highest total rainfall (2002). The values obtained are similar to those of other locations in the Pyrenees (Domenech et al., 2011) with the same plant communities. They are also similar to those of Chinese grasslands (Yan et al., 2015), where biomass production was directly related to spring-summer rainfall in many different grasslands.

Table 2. Evolution of dry matter (DM) production and forage nutritive values in the biomass of *F. eskia* pasture

year	$F(2,60)$	1st (2002)	2nd (2008)	3rd (2012)
Production (kg of DM.ha^{-1})	14.65; p<.0003	4147.76±1392.19a	1283.44±245.38b	1495.67±37.28b
Pastoral value (1 to 100)	87.79; p < 0.000	19.67±2.36a	5.38±0.80b	15.21±1.64c
CP	45.61; p<.0000	9.28±1.68a	5.57±0.78b	6.52±1.07b
DP	27.31; p < 0.000	5.34±1.15a	3.34±0.69b	3.95±0.65b
EE	88.66; p < 0.000	2.97±0.29a	1.67±0.23b	1.75±0.58b
ADL	58.70; p < 0.000	9.21± 0.90a	5.41±1.51b	6.62±1.45c
CF	3.94; p < 0.024	32.95±2.55a	33.75±1.74a	31.64±1.15b
ADF	6.76; p < 0.002	41.22± 2.35a	41.24±1.72a	39.08±1.06b
NDF	18.70; p < 0.000	65.33±3.85a	71.38±2.57b	68.85±2.77c
Ash	99.97; p < 0.000	7.92±1.21a	4.23±1.07b	3.71±0.91b
Calcium	13.05; p < 0.000	0.52±0.17a	0.40±0.07b	0.31±0.10b
Magnesium	0.93; p < 0.400	0.13±0.17	0.11±0.02	0.08±0.02
Phosphorous	43.57; p < 0.000	0.16±0.04a	0.07±0.01b	0.10±0.03c

Pastoral value was obtained by means of transects (n=18). The remaining parameters, DM production, CP (crude protein), DP (digestible protein) ash, Ca, Mg, P, EE (fat), ADL (lignin), CF (total fibre), ADF(acid detergent fibre) and NDF (neutral detergent fibre) are content in % of DM analysed by the NIRS method (n=64). Observed means (±SD) and F values.

3.2.2 Forage Quality

Forage quality can be limited by its botanical composition and particularly by the interaction between species composition and the presence and amounts of chemical components in the biomass. Table 2 shows the values of forage quality variables studied during the sampling. The majority of variables (PV, CP. DP, EE, ADL and phosphorous) increase and decrease together with the SR and in relation to the changes in the proportion of functional groups (floristic composition) (Table 2).

The decrease in PV from the first to the second sampling is related to the increase in the proportion of non-leguminous forbs with poor-quality species such as *Alchemilla flabellata, Euphorbia cyparissias* and *Polygonum viviparum*. However, the increase in PV in the third sampling is related to the greater proportion of Trifolium alpinum. Similar results were found for CP, DP, total fats (EE) and lignin (ADL), and lignin was significantly different in the three years. By contrast, all kinds of fibre, including crude fibre (CF, or total fibres), ADF and NDF, showed an opposite trend: they increased from the first to the second year and after the abandonment. This finding is normal because proteins and fibres have an opposite correlation in the DM of grassland's species (Huston & Pinchak, 1991; Van Soest, 1965). The mineral components such as ash, Ca and

Mg decreased continuously regardless of the stocking rate. However, the concentration of phosphorous in DM was significantly different in the three years and showed the same behaviour as the PV or proteins.

3.2.3 Diversity

Specific richness. Of the total of 33 different species in the three years, 12 (5 grasses, *Agrostis rupestris, F. eskia, F. nigrescens, Nardus stricta, Poa chaii*, and 7 forbs, *Achillea millefollium, Campanula scheuchzeri, Cerastium arvense, Galium pumilum, G. verum, Potentilla* sp. and *Thymus praecox*) were present in all transects and two (the legumes *Lotus alpinus* and *Trifolium alpinum*) were present only in the second and third samplings. This richness is low compared with that of other European subalpine grasslands, in particular calcicolous pastures (Alard & Poudevigne, 2000; Marriott et al., 2004), but also in the same range of acid pastures (Komac et al., 2014; Fanlo et al., 2014). Table 3 shows the yearly averages of transects. The specific richness rose when the SSR fell in the second period and began to fall when SSR rose again. If we compare these values with CP or DP, we can conclude that the new species that appeared in the second period had poor forage quality.

Table 3. Evolution of diversity parameters in the pasture of *F. eskia*

year	F(2,15)	1st (2002)	2nd (2008)	3rd (2012)
S	10.85; $p < 0.001$	13.40±2.36a	18.20±0.80b	16.66±1.64b
H’	1.25; $p < 0.314$	1.99±0.19	2.15±0.11	2.06±0.29
E	0.56; $p < 0.584$	0.77±0.04	0.77±0.05	0.74±0.05
grasses	10.76; $p < 0.001$	47.74±7.65a	33.58±3.85b	34.03±3.18b
legumes	4.65; $p < 0.026$	0a	3.36±3.10b	2.08±3.60b
forbs	7.25; $p < 0.006$	52.26±7.65a	63.05±2.74b	63.88±2.40b

S (species richness), H’ (Shannon index), E (Pielou evenness index), % of grasses, legumes and non-leguminous forbs. Means (±SD) and F values from the transects (n=18).

Diversity index. The Shannon (H’) and Pielou evenness (E) indexes provide more information about plant community composition than simple species richness, because they also take into account the relative abundances of species. In our case there were no significant differences between years; the structure of the plant community was very stable due to the high proportion of *F. skia* (more than 70%) in all periods. It thus acts as a stabilizer.

Functional groups. For the analysis we grouped Poaceae and graminoides into “grasses”, only Fabaceae into “legumes”, and the remaining species into “forbs”. The floristic composition or the “functional groups” showed a decrease in grasses in the second and third years due to competition from the forbs group. The lack of legumes in the first year might be explained by the slight overgrazing that led to their consumption. On this grassland Trifolium alpinum is the most frequent legume, followed by Lotus alpinus, which was present in the second and third periods. The proportion of forbs was negatively related to changes in SSR, rising when the SSR falls and vice versa, because animals prefer to graze on soft species than on the hard F. skia leaves. In general, the study of functional groups may be more appropriate than the study of species as a predictor of ecosystem evolution (MultiSward, 2012).

3.3 Correlations Between the Studied Variables

The correlation analysis of variables and between years showed some differences. Correlations explain the reciprocal relationship, especially a structural or functional correspondence between two variables and their simultaneous change in value in grasslands. Some differences in correlations between years are consistent with the changes in the floristic composition and forage quality (Table 4).

Two pairs of correlations were maintained over the three years, regardless of the changes in the SSR: specific richness (S) was always positively correlated with the percentage of forbs, and CF was positively correlated with production (DM). These results are in agreement with other values from alpine and subalpine grasslands (Fanlo et al., 2014) and are characteristic of them.

Table 4. Correlations between studied variables: functional groups (% of species by transect), biodiversity (S, richness, by transect), forage quality (P, phosphorous; CP, crude protein and CF, crude fibre in % of DM) and production (DM in kg·ha^{-1}). All values are significant at $p < 0.05$

		Functional groups			Specific richness	Forage quality			Production
Year		grasses	legumes	forbs	S	P	CP	CF	DM
1st (2002)	grasses	1							
	legumes	-	-						
	forbs	-0.99	-	1					
	S	-0.74	-	0.74	1				
	P	NS	-	NS	NS	1			
	CP	NS	-	NS	-0.55	0.43	1		
	CF	0.66	-	-0.66	NS	NS	-0.60	1	
	DM	NS	-	NS	NS	NS	-0.83	0.52	1
2nd (2008)	grasses	1							
	legumes	-0.71	1						
	forbs	NS	NS	1					
	S	-0.67	NS	0.93	1				
	P	NS	0.99	NS	NS	1			
	CP	-0.81	0.65	NS	NS	NS	1		
	CF	NS	NS	NS	NS	NS	NS	1	
	DM	NS	NS	NS	NS	NS	NS	0.92	1
3rd (2012)	grasses	1							
	legumes	-0.75	1						
	forbs	NS	NS	1					
	S	NS	NS	0.99	1				
	P	NS	NS	NS	NS	1			
	CP	NS	NS	-0.99	-0.99	0.95	1		
	CF	NS	NS	-0.97	NS	NS	-0.97	1	
	DM	NS	NS	0.62	NS	NS	NS	0.66	1

Other correlations were dependent on the changes in the level of grazing: CP was only correlated positively with legumes and negatively with grasses when the SSR fell. CF was negatively correlated with forbs when the SSR was high and specific richness (S) was also negatively correlated with total protein (CP). The negative correlation with forbs in the 1st and 3rd samplings was due to the fact that the forbs present were soft species such as *Cerastium arvense, Galium verum, G. pumilum, Hieracium micranthum* and *Campanula scheuchzeri*. This result indicates low protein content in our grasses and forbs.

Only in the 3rd sampling did the production in DM show a positive correlation with the number of forbs. In general, when the production rose, the forage quality, measured by the percentage of CP, fell due to the dilution of the protein in the plant's tissue when it grew (negative correlation) and an increase in the cellular walls and CF (positive correlation) (Justes et al., 1994). These results clearly show the influence of SSR on floristic changes (number and kind of species) and of these on the forage quality of the pasture.

3.4 Final Remarks

Permanent mountain grasslands are important ecosystems as they provide a variety of goods and services to support flora, fauna, and human population worldwide. Preserving grazing on these extensive grasslands is a challenge for the future because it avoids the loss of forage quality, maintains diversity and allows the grasslands to act as effective carbon sinks (Soussana, 2005).

Our study shows that It is possible to recover the quality and diversity of a grassland that has suffered a relative abandonment if the initial stocking rate is restored, and if the period of undergrazing has been short (10 years or less), and no woody species have colonised the grassland and reduced its grazing quality. These results agree with one of models of Cingolani et al. (2005) where systems with long evolutionary history of grazing have developed resilience mechanisms that allow reversible shifts in floristic composition with changes in grazing intensities. In the European framework the recovery of SSR in a lot of mountains only it is possible with an exhaustive application of the measures for "aid to farmers in Less Favoured Areas" where agricultural production or activity is more difficult due natural handicaps, like mountains. Nevertheless and in some grasslands very colonized by woody plants, the recovery needs a previous cleaning (mechanic or by means of controlled fire) with the consequent amount of expenses.

Acknowledgments

To mountain farmers by maintained live these grassland ecosystems and to the National Park workers.

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