



Short Communication

Effects of *boom and bust* grazing management on vegetation and health of beef cattle used for wildfire prevention in a Mediterranean forest

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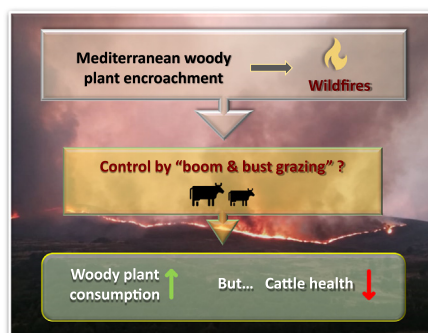
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HIGHLIGHTS

- The manipulative field study points toward new European Agro-environmental policies.
- The “boom and bust grazing” management may affect Mediterranean vegetation structure.
- Cattle feed on flammable plant taxa.
- Mediterranean forest fails to provide the energetic requirements of cattle.
- The “boom and bust grazing” management needs further research.

GRAPHICAL ABSTRACT



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ABSTRACT

Humans and wildfires have historically driven landscape structure in the Mediterranean basin. The Iberian Peninsula is not an exception to that rule, and therefore, farmers, researchers, and governments seek alternative tools to minimize the loss of biodiversity and wildfire risks. Extensive livestock including beef cattle is currently promoted as a suitable management tool by European agro-environmental policies yet pieces of evidence exist regarding the reciprocal effects between cows and Mediterranean woody vegetation. In this work, we performed a field manipulation to evaluate whether free-ranging beef cattle without supplementary feeding, at high density (2 livestock units (LU)/ha) for a short period of time i.e. “boom and bust grazing” management, are able to adapt their grazing preferences to the Mediterranean woody vegetation without health impairment, and prevent from bush encroachment and wildfires. For our purposes, a native herd of 14 adult cows was kept captive without supplementary feeding in a 14 ha enclosure covered by Mediterranean vegetation for two months (April–June 2016). Plant and cattle fecal and blood samples were collected to assess diet composition (plant cuticle microhistological analysis), fecal nitrogen and protein contents of consumed plants, and the nutritional status (non-esterified fatty acids) of cattle. Our results showed that cattle adapted their feeding habits toward a more woody diet including potentially flammable taxa but with some detrimental effects on health status. Hence, cattle cannot control woody vegetation for long periods of time without supplementary feeding. Further research should be oriented to explore other alternative approaches to minimize the health impairment of cattle used for control flammable vegetation in Mediterranean regions.

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1. Introduction

In the late 1990s, there has been a growing interest for the use of free-ranging livestock for the management of vegetation structure to prevent bush encroachment and halt the loss of biodiversity and wildfire risk in the Mediterranean basin (Etienne et al., 1996). Although cows are considered grass feeders (Hofmann, 1989), some research has indicated its ability to feed on Mediterranean woody plants, in particular at moderate to high densities (e.g. Henkin et al., 2005; Schoenbaum et al., 2017). The European agro-environmental policies have promoted the use of beef cattle to reconcile agricultural land use and wildfire prevention (Bernués et al., 2011). However, the toxicity and poor quality of the edible phytomass of many Mediterranean woody plants, along with the low productivity of some Mediterranean grasslands, encourage farmers to use supplementary feeding and recurrent technological intervention (Brosh et al., 2006; Bartolomé et al., 2011). Previous studies appointed that these management practices minimize the ability of cattle to control woody vegetation in Mediterranean landscapes (Provenza et al., 2003; Schoenbaum et al., 2017).

Some authors (e.g. Provenza et al., 2003) have suggested the use of short-duration grazing at high stock densities, called “boom and bust grazing”, with limited or no use of supplementary feeding to force cattle to feed on a broad array of plants including more woody plants. However, we currently lack empirical comprehensive data on the impact of browsing in Mediterranean scrublands on diet quality and health status of these large ruminants (Casasús et al., 2005), and hence support for the current European agro-environmental policies. We, therefore, empirically study by using a multidisciplinary approach, some specific short-term effects of the “boom and bust grazing” management on cattle health and consumption of Mediterranean woody vegetation. We aim to provide relevant insights to evaluate the environmental utility of this management and eventually help to design more efficient monitoring protocols and agro-environmental policies focused on halt bush encroachment and wildfire risk in Mediterranean forested areas.

In this work, we took advantage of a field manipulative experiment to study the short-term effects of the “boom and bust grazing” management in a beef cattle herd fenced in a Mediterranean woody environment. We specifically evaluated: (I) the ability of beef cattle to adapt their typical grasser behaviour to a more woody vegetation in a Mediterranean forest at a high livestock rate and without supplementary feeding for two months; (II) the impact of the new feeding habits on diet quality; and (III) the impact on the nutritional status of beef cattle.

2. Material and methods

The study was conducted within the Montserrat range, in NE of Spain (central point 41°40′09″N, 01°46′38″E) in 2016. The study area was fenced and consisted of 14 ha at 370–440 m a.s.l. with a mild topography (slopes <15%) integrated by small hills and valleys with multiple aspects except East. Soils are poorly developed (haplic regosols), derived from calcareous conglomerates, sandstone, and marls (Icgc.cat, 2018; IUSS, 2015). The climate is typically Mediterranean with a long-term (1955–1999) average annual mean temperature of 13.3 °C, and an annual rainfall of 610 mm distributed from autumn to spring, with scattered summer storms (Ninyerola et al., 2000). The vegetation comprises 10 ha of a dense planted forest of *Pinus halepensis* Mill., with the understorey saturated with Mediterranean woody plants (e.g. *Erica multiflora* L., *Pistacia lentiscus* L., *Rosmarinus officinalis* L.), and 4 ha of shrubby patches dominated by the same woody species growing in the pinewoods. Among herbaceous plants, Poaceae species predominate (*Brachypodium retusum* (Pers.) Beauv. and *B. phoenicoides* (L.) Roem. et Schultes), plus underlying bryophytes carpets (*Pleurochaete squarrosa* (Brid.) Lindb., *Homalothecium* sp.) on northern or shady slopes.

A herd of 14 adult (>4 years old) cows of the native breed *Bruna dels Pirineus* (130 cm tall to the withers and the top of the hips, and weighing

around 600 kg.) was introduced in the fenced area at the beginning of April. Then, the herd was monitored from the 19th of April (mid-spring) to the 21st of June of 2016 (early summer). Animals were kept with water supply but without supplementary feeding, and under high density: 2 livestock units (LU)/ha. Diet composition and quality including bromatological analyses of plants as well as nutritional and energy status of cattle were studied by collecting plant, fecal and blood samples at the onset (19th of April) and at the end of the experiment (21st of June).

The fecal samples from ten (out of 14) different individuals were taken and kept in sealed plastic bags and then frozen until analysis. The diet composition was analyzed by microscopic identification of 200–240 vegetal epidermic fragments per fecal sample, using the cuticle microhistological analysis (Stewart, 1967). The total 4800 fragments were classified into four major groups: 1. Graminoids (Poaceae, Cyperaceae, Juncaceae, etc.), 2. Woody plants, 3. Forbs and 4. Bryophytes.

Diet quality and nutritional status of different cows (n = 10) were assessed by fecal nitrogen (FN) (Villamuelas et al., 2017). The percentage of FN was estimated using Near-Infrared Reflection Spectroscopy (Lyons and Stuth, 1992) implemented in NIRSystem 5000® by Foss Electric A/S. Fecal samples were air-dried at 65 °C, milled to 0.5 mm, and scanned from 1100 to 2500 nm. Reflectance was recorded at 2-nm intervals and the fecal nitrogen percentage was predicted from the resultant reflectance pattern. The energy status (i.e., energy status = energy intake — energy requirement) of the same ten individuals was assessed by nonesterified fatty acids (NEFA) (Rudik et al., 2004) that has largely been used for monitoring the energetic status of cows (Adewuyi et al., 2005). Blood samples were collected into Vacutainer tubes with C₂K₂O₄ and NaF as a glycolytic inhibitor. At the lab, samples were centrifuged (915 ×g) for 5 min immediately after collection; plasma was decanted and stored at –20 °C until analysis. NEFA assessment was performed by a WAKO NEFA C Kit (Wako Chemicals GmbH, Germany).

Bromatological analyses were performed to determine the quality of seven browsed and grazed taxa: four shrubs (*Erica multiflora*, *Rhamnus alaternus* L., *Rosmarinus officinalis*, *Rubus ulmifolius* Schott) and three graminoids (*Brachypodium retusum*, *B. phoenicoides*, and *Carex* sp.). All these taxa were selected on the basis of previous studies (e.g. Bartolomé et al., 2011) and direct observations. Ten samples (200 g in total) from different sites and individuals within the fenced area were collected and mixed for each plant taxa and date (April and June). Then, three subsamples of each plant taxa and date were used to obtain the percentage of the protein content following the procedures of Helrick (1990) and Van Soest et al. (1991).

To explore whether cattle modified their feeding habits during the study period, we used Generalized Linear Mixed Models (GLMM) including the proportion of plants consumed (assessed by fecal cuticle microhistological analysis), as response variable and plant type (i.e., graminoids, woods and forbs), sampling period (onset vs end) and their two-way interaction as fixed explanatory variables. To control for individual effects, cow identification was included as a random intercept in our GLMM (Zuur et al., 2009). Model selection was based on the Akaike information criterion (lowest AIC) and the Akaike differences (Δ_i) with respect to the best model. When the Δ_i was <2 units, we applied the principle of parsimony to select the simplest model (Burnham and Anderson, 2002). We then estimated the Akaike weight (W_i), that is, the relative likelihood of the model given the data available. Previous to any model interpretation, we checked for evidence of overdispersion of residuals. Our response variable (plant fragments in %) were log transformed to achieve the GLMM assumptions (Zuur and Leno, 2016). Pseudo R² for our set of GLMM was estimated following Nakagawa and Schielzeth (2013). Finally, mean FN and NEFA concentrations, as well as percentages of protein content from comparisons between the onset and the end of our experiment, were performed using Student's *t*-tests. However, due to the reduced sample size for protein content, the *t*-test was based on 1000 bootstrapped replications.

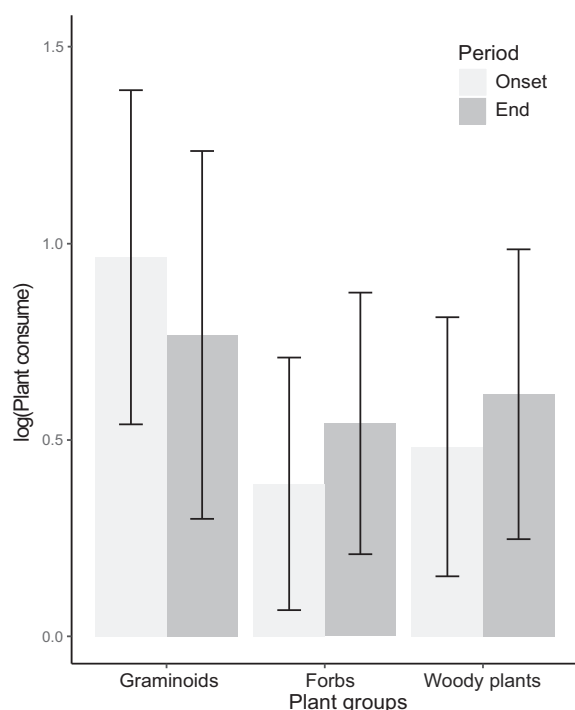


Fig. 1. Feeding habits of a herd of ten adult cows. Percentage of fragments summarised into three informal groups. Bars and whiskers represent mean and standard deviation values, respectively.

GLMM were performed using the “lme4” package 1.1–17 version (Bates et al., 2015), pseudo R² using “MuMIn” package 1.40.4 version (Barton, 2018), and bootstrapping using the “boot” package 1.3–20 version (Canty and Ripley, 2017) of the R software 3.5.1 version (R Core Team, 2018).

3. Results

The model including the interaction between plant type and the period best explained the feeding habits of our herd of cows (Wi Period * Plant type = 1, R² = 25.8, Table 1 and Fig. 1). Plant type explained most (13.1%) of the observed variability in the feeding habits whereas changes between sampling periods explained 3.5%. That indicates that changes in the plant consume between periods significantly varied among all the plant types ($p < 0.05$). For example, cattle increased the consumption of woody plants and forbs (by 15.5 and 4.4% in the use respectively) whereas the use of graminoid plants decreased (by 19%) over time (Appendix A). Overall, cattle consumed a wide array of species common to the understory layers including bryophytes (Appendix A). In detail, the first target plants in spring were three graminoids, *Brachypodium phoenicoides*, *B. retusum*, and *Carex* sp. Secondly, two woody plants, *Rhamnus alaternus* L. and *Rubus ulmifolius*, which doubled the percentage of protein of the graminoids (Table 2, Appendix A). Several sclerophyllous shrubs (e.g. *Erica multiflora*, *Olea europaea* L.,

Table 2

Percentage of protein (mean ± standard deviation) obtained at the bromatological analysis of three samples per taxa and date. Significant differences ($p < 0.05$, bootstrapped t-student test) in protein content between dates were observed in all plant taxa.

Taxa	Woody/herbaceous	Protein (%)	
		19th April	21st June
<i>Brachypodium phoenicoides</i>	Herbaceous	7.6 ± 1.01	5.0 ± 0.84
<i>Brachypodium retusum</i>	Herbaceous	7.6 ± 0.46	5.1 ± 0.47
<i>Carex</i> sp.	Herbaceous	10.3 ± 0.64	8.2 ± 0.47
<i>Erica multiflora</i>	Woody	5.2 ± 0.56	5.1 ± 0.49
<i>Rhamnus alaternus</i>	Woody	12.8 ± 0.63	11.5 ± 0.55
<i>Rosmarinus officinalis</i>	Woody	9.7 ± 0.50	6.0 ± 0.53
<i>Rubus ulmifolius</i>	Woody	15.7 ± 0.27	11.4 ± 0.35

Phillyrea angustifolia L., *Pistacia lentiscus* and *Viburnum tinus* L.) were also consumed yet mainly at the end of the study period.

The bromatological analysis by bootstrapped t-test showed a significant ($p < 0.01$) decreasing tendency in the percentage of protein in every analyzed planta taxa but *Erica multiflora* (Table 2, Appendix B). Likewise, at the end of the field experiment, the FN of cows decreased by 1.6 times ($t = -3.5$, p -value = 0.006) confirming the consumption of less nutritious plants (Table 3). Along the same lines, NEFA concentrations in the herd increased two-fold ($t = -3.5$, p -value = 0.006) after two months without supplementary feeding (Table 3).

4. Discussion

We confirm the prediction regarding the implementation of the “boom-bust grazing” management (Provenza et al., 2003). Cattle, without supplementary feeding and under high density, increased the consumption of sclerophyllous woody plants over two months while fenced in a Mediterranean forest. As expected in grazing animals (Hofmann, 1989), cattle initially focused on herbaceous plants and some shrubs with high protein content (e.g. *Rhamnus alaternus* and *Rubus ulmifolius*). Moreover, cattle also browsed a large series of woody plants including taxa avoided in similar Mediterranean environments under similar or even higher livestock rates but with supplementary feeding (Bartolomé et al., 2011). In fact, after two months, cattle increased the consumption of several woody taxa (e.g. *Erica multiflora*, *Olea europaea*, *Pistacia lentiscus*) despite their low quality (Silanikove et al., 1996 and references therein). Cattle only seemed to avoid the dominant tree species (*Pinus halepensis*) probably due to the scarcity of saplings (i.e. young *Pinus* individuals with accessible branches), which otherwise are consumed in other Mediterranean areas (Pfister et al., 2008). Cattle also consumed bryophytes, not by chance, given that mosses grow close to the ground (<3 cm height) and possess deterrent chemical components that exert detrimental effects on nitrogen absorption (Ihl and Barboza, 2007 and references therein). This result might reveal the lack of optimal resources or overgrazing (Ihl and Barboza, 2007). Thus, without supplementary feeding, cattle might effectively modify forest structure by changing, in the short-term, the density of different understory vegetation strata including woody and mossy vegetation.

Table 1

Model selection for exploring changes in the feeding habits of ten different adult cows by analysing vegetal fragments grouped into three plant types (Woody plants, Forbs and Graminoids) from their respective 20 fecal samples collected in two periods: 10 in April and 10 in June. The Null model only included the intercepts as explanatory fixed variable. K = degrees of freedom of the models, AIC = Akaike Information Criterion, Δi = difference of AIC respect to the best model, Wi = Akaike weight. The percentage of the observed feeding patterns variability explained by both the fixed and random terms (Conditional), by the fix (Marginal) and the random term are also provided. The best model is shown in bold.

Biological model	K	AIC	Δi	Wi	Conditional R ²	Marginal R ²	Random factor R ²
Period * plant type	8	262.01	0	1	25.8	16.7	9.1
Plant type	5	268.15	6.14	0.05	20.3	13.2	7.1
Period + plant type	6	269.13	7.12	0.03	20.7	13.4	7.3
Null model	3	304.08	42.07	< 0.01	–	–	–
Period	4	305.71	43.71	< 0.01	0.2	0.1	0.1

Table 3

Mean $\pm$ standard deviation of ten fecal nitrogen (FN) and non-esterified fatty acid (NEFA) concentrations recorded in ten different adult cows at the onset (19th of April) and at the end of the experiment (21st of June).

Period	FN (%)	NEFA (mmol/L)
Onset	2.76 $\pm$ 0.320	0.14 $\pm$ 0.03
End	1.67 $\pm$ 0.31	0.28 $\pm$ 0.13

In the spring (April), at the beginning of the study, all the studied plants, except *Erica multiflora*, showed higher protein values than those needed for cattle maintenance, considering that the protein requirement for cattle is around 14% for production and 7% for basal maintenance (NRC, 1996). Thus, Mediterranean forests can meet cattle requirements in the spring (Casasús et al., 2005) even though nutritive values of grasses can be reduced by shrubs abundance (Zarovali et al., 2007). In contrast, in early summer (June), Mediterranean plants showed much lower protein contents and some highly consumed taxa, *Brachypodium*, *Erica multiflora*, and *Rosmarinus officinalis*, yielded values under the maintenance threshold. This poor-quality diet might be the cause of the nitrogen content decrease in cattle feces. Although the registered nitrogen values resemble those recorded for extensive grazing cattle (Aldezabal et al., 2011), NEFA concentrations were slightly above the reference values for a cow with adequate nutrition (<0.2 mmol/L, Drackley, 2000). In fact, concentrations in some individuals got close to 0.6 mmol/L, the limit beyond which a severe negative energy balance would be seen (Adewuyi et al., 2005). Thus, if the grazing period was prolonged, the boom-bust grazing management (sensu Provenza et al., 2003) would reduce the woody cover but severely compromise livestock health and herd productivity.

As a conclusion, cattle, without supplementary feeding and under high density, actively graze herbaceous taxa including bryophytes but also browse woody taxa. The consumption of woody taxa responsible for bush encroachment increases over time which in turn might cause a reduction of the shrub understory layer of the forests. Besides, cattle feed on key taxa, like *Brachypodium* spp. and *E. multiflora*, that possess a relatively high percentage of dry matter, and are potentially flammable (Elvira Martin and Hernando Lara, 1989). Therefore, these preliminary results might support extensive cattle as a suitable target for incoming studies focused on the environmental problems linked to land abandonment: bush encroachment and the concomitant increase in wildfire risks. However, further studies will have to address whether the “boom and bust grazing” management significantly modifies the vegetation structure (woody and herbaceous biomass spatial patterns) and the species composition to make Mediterranean forests less prone to wildfires.

Nonetheless, the studied Mediterranean forest failed to truly provide the energetic requirements of beef cattle. The use of the boom-bust grazing management would be constrained to no more than two months to conciliate bush encroachment control, livestock welfare, and herd productivity. Still, further studies are needed on different and complementary options like the use of native breeds (Bartolomé et al., 2011), improving the adaptability of cattle to the Mediterranean woody vegetation (Gutman et al., 2000; Estell et al., 2012) or use non-profitable livestock as an environmental management tool (Bernués et al., 2005). Optimally, future studies should incorporate long-term experiments comprising analysis of cattle body conditions to meet the ambitious goal of sustainable (profitable) extensive grazing systems in Mediterranean regions (Nadal-Romero et al., 2018).

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.scitotenv.2019.02.037>.

Declarations of interest

None.

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