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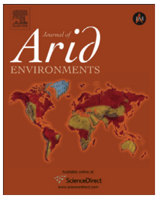

Continuous moderate grazing management promotes biomass production in Patagonian arid rangelands

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ABSTRACT

Domestic grazing effects on primary productivity and community structure are controversial in rangeland ecology and frequently misunderstood. Although directly related with secondary production, biomass stock and biomass production at species level (biomass composition) has been relegated in field studies, especially in arid rangelands co-dominated by woody species. We estimated grazing effects on aboveground biomass in a temperate mixed grass-shrub steppe of Patagonia. We compared exclusion of sheep with two levels of continuous grazing: moderate (light) and intensive sheep grazing in an average precipitation year. Total green biomass (productivity) was twice as high in moderately grazed paddocks as in those without grazing and intensively grazed pastures, while standing dead grass biomass stock only decreased in intensive grazing. Shrub biomass was not modified by grazing management. In addition, grazing modified grass specific biomass composition, thus diminishing biomass quality in intensively grazed areas. This work provides evidence that in arid rangelands, continuous moderate grazing management could be an effective tool to increase productivity compared to grazing exclusion. Furthermore, moderate grazing would not cause major undesired changes in species composition. However, a potential risk of land use intensification exists because intensive grazing could decrease biomass production as well as promote negative composition changes.

1. Introduction

Grazing by domestic livestock is the most common and widespread land use in arid rangelands (Milchunas and Lauenroth, 1993; Oesterheld et al., 1999; Asner et al., 2004) and is identified as one of the major causes of desertification (Brown et al., 1997). However, estimating its impacts on primary production and community structure has been a controversial topic in rangeland ecology (Belsky, 1992; Milchunas and Lauenroth, 1993; Oesterheld et al., 1999; Briske et al., 2008; Wu et al., 2013). In general, maintaining domestic grazing through time (i.e. years) under confined areas (fenced) reduces the forage value of rangelands due to depletion of some preferred species and their replacement by non-preferred species (e.g. James et al., 1999; Tobler et al., 2003), along with productivity and vegetation cover decline and soil erosion increase (Milchunas and Lauenroth, 1993; Brown et al., 1997). Nonetheless, in some rangelands, wild or domestic herbivores can promote productivity and preferred species compared to ungrazed situations, creating grazing lawns of high forage quality (Cargill and Jefferies, 1984; McNaughton, 1984; Posse et al., 2000; Cingolani et al., 2005). In arid grasslands, neutral, positive and negative plant species responses to grazing have been recorded, although species richness has not shown significant changes (Fensham et al., 2010, 2014). Grazing intensity could be an important mechanism which determines the impact of herbivores on vegetation responses (Oesterheld and Semmartin, 2011). Hence, evaluating different grazing intensities can help to refine grazing management practices in order to promote biomass production without undesired changes in species composition (Cingolani et al., 2005; Oesterheld and Semmartin, 2011). In particular, woody-grass steppes are challenging because grazing can trigger different and opposite woody-grass ratio responses (Sankaran et al., 2005), from shrub encroachment to shrub decrease (Cipriotti and Aguiar, 2012). In this paper, we estimated biomass production of grass and shrub species in a temperate grass-shrub steppe under different historical grazing intensities.

Coexistence of herbaceous and woody species has relevant ecological implications for ecosystem function, and there has been

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an increasing interest in understanding grass-woody balance (see for a recent review Sala and Maestre, 2014). Primary productivity variation of herbaceous and woody components is one of the major conundrums in rangeland ecology (House et al., 2003). Grazing can differentially affect grass and woody species through direct and indirect effects (Cipriotti and Aguiar, 2005, 2012). Because of rapid grass—woodland transitions, identifying productivity controls of both life forms is especially important in mixed communities (Sala and Maestre, 2014).

Globally, there is more information about grazing effects on community species composition than about grazing effects on net primary productivity and plant biomass (Milchunas and Lauenroth, 1993). Even less information is available on grazing effects of biomass production at species level. In arid mixed rangelands, this is probably the result of the difficulty of estimating biomass of woody co-dominant species (House et al., 2003). Furthermore, the management of much of world's grazing systems is primarily based upon changes in species composition. In general, species composition is estimated along with richness and species abundance. The latter is evaluated through frequency or cover in order to estimate diversity. However we think that, despite the difficulty and the expense of estimation (Byrne et al., 2011), biomass production of dominant species is the key attribute of vegetation that should be managed. The use of plant cover to estimate abundance has generated controversy since plant structure could generate differences in biomass that are not captured with cover, especially in ecosystems co-dominated by grass and woody species (Montès, 2009; Oñatibia et al., 2010). In this sense, grazing management should be based on biomass composition, which is what herbivores select and consume.

Our objective was to study sheep grazing effects on aboveground biomass in a mixed grass and shrub steppe of Patagonia. We estimated biomass (total, green and standing dead) and density of dominant grass and shrub species in the peak of production during early summer. Our assumption was that green biomass in peak production may be considered a good proxy of aboveground annual productivity in these sites, which present a brief and pronounced growing season as was proposed by Sala and Austin (2000). Our general hypothesis was that continuous and intensive domestic grazing history reduces total biomass production due to intense and sustained defoliation. By grazing history, we refer to more than a decade of grazing; under this time span plant demographic dynamics develop and community changes occur. Due to sheep selectivity, we expect a higher effect on preferred species and, along time, a biomass and density decrease. However, if grazing intensity is moderate, this reduction caused by defoliation could be compensated through two different mechanisms. On the one hand, grazing can promote an optimization process, increasing the productivity of defoliated species (McNaughton, 1979) and, on the other hand, depending on less preferred species response (higher abundance or not), total biomass production may increase or be maintained. Because of this possible positive effect of grazing on plant biomass, we propose that domestic herbivore exclusion will not necessarily raise biomass production.

2. Materials and methods

2.1. Study site description

We worked in a grass-shrub steppe area of 300 km^2 located in South Central Patagonia, Chubut province, Argentina, including the Rio Mayo INTA Experimental Station and privately owned neighboring rangelands (lat 45º24′ S, long 70º15′ W). This steppe is mostly used for wool production and has been grazed by sheep for more than one hundred years. Grazing management is extensive, in large paddocks (frequently around 1000 to 5000 ha), continuously grazed (Golluscio et al., 1998). Mean monthly temperature is between 2 °C in July and 14 °C in January. Average annual precipitation is 154 ± 44 mm, and most rainfall occurs between May and September. Few dominant perennial grasses and shrubs contribute approximately 96% of total biomass (Fernández et al., 1991), and mean aboveground net primary production is 560 kg ha^{-2} yr^{-1}, half of which corresponds to grasses and half to shrubs (Jobbágy and Sala, 2000). The dominant grass species are *Pappostipa speciosa* Trin. et Rupr., *Pappostipa humilis* Cav., *Poa ligularis* Nees ap. Steud and *Bromus pictus* Hook. The dominant shrub species are *Mulinum spinosum* Cav. Pers, *Adesmia volckmannii* Philippi and *Senecio filaginoides* De Candolle. Sheep and native herbivores are very selective and select their diet from these dominant grass and shrub species.

2.2. Grazing treatments

We worked in a group of paddocks distributed over a 150 km^2 homogenous plateau. We studied three grazing management treatments: ungrazed (exclosure > 20 years), moderately grazed and intensively grazed fields. Grazing management has not experienced changes during the last decade. During dry years, only moderate grazed paddocks experienced planned reduction in sheep numbers. Each management treatment was represented by three different paddocks or fields (replicates), except the exclosure treatment for harvesting grass biomass. The moderately grazed treatment correspond to paddocks (around 1000 to 1200 ha) where stocking rate has been around 0.2 sheep ha^{-1} yr^{-1} for more than two decades. This grazing pressure could also be defined as continuous (year round) light grazing. The intensively grazed pastures were paddocks (around 1200 to 1500 ha) where the stocking rate over the last 20 years was about 0.4 sheep ha^{-1} yr^{-1} year round (Cipriotti and Aguiar, 2005). In grazed pastures, we avoided areas near watering points or fencing to prevent grazing sampling in areas of local high grazing pressure. To evaluate the non-grazing treatment, we only had one exclosure (8 ha in area) to utilize for destructive sampling. This exclosure was established in 1983. The three replicates of grass biomass were inter-dispersed in this area. We are aware of the implications from inferences based on pseudo replication (Hurlbert, 1984). Therefore, we added two other exclosures, installed in 1954 and 1972, to perform non destructive sampling (shrubs density and biomass, and grass density). In this way we complied with exclusion's management guidelines in the Experimental Field and increased robustness of our inferences. Exclosures installed in 1954 and 1972 were 2 and 5 ha in size, respectively. Because the 1983 exclosure was large, we assumed that grass biomass samples represented a large proportion of the potential variation of excluded plant communities. Additionally, we have measured that exclosures of different ages (three exclosures of this study and two additional exclosures installed in 1994 and 1998) do not differ in several variables associated to grass aboveground biomass (grass total and specific density, individual plant size, population structure of all dominant grass species and grass total and specific cover (Oñatibia, 2013)). Furthermore, all study sites correspond to the same plant community. Therefore, we assumed that differences in composition and aboveground biomass among treatments can be attributed to grazing effects (Cipriotti and Aguiar, 2005). The grass harvest and shrub study was performed in January, at the end of the growing season (peak of green biomass). Annual water year precipitation of the previous year that included this growing season was 156 mm, similar to an average year.

2.3. Biomass estimation

We sampled aboveground grass biomass in five plots of 1 m^2