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High impact grazing as a management tool to optimize biomass growth in northern Argentinean grassland

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ABSTRACT

Grasslands are the main source of feed for cattle in Argentina. Standing dead biomass accumulation threatens efficient resource use. The effect and timing of high impact grazing by cattle as a management tool to remove excess standing dead biomass was studied in grasslands of North Eastern Argentina. High impact grazing (HIG) was introduced monthly on adjacent paddocks over the course of the year and its effects were studied for 12 months following the treatment. Dynamics of biomass re-growth and accumulation of green and standing dead biomass were studied. HIG generally improved the green to total biomass ratio and reduced the overall biomass in the paddocks. Strong seasonal dynamics in the biomass growth rates strongly influenced the effects of timing of the HIG. All sub-plots subjected to HIG showed a growth pattern anti-cyclic to control, with an active growth phase during autumn when the biomass in the control sub-plots decreased. Best results in terms of standing dead biomass reduction and dead to green biomass ratios were achieved after HIG in winter. HIG in autumn, however, reduced fodder availability and reduced next year's grassland's productivity. We propose strategically (carefully) timed HIG not only as an alternative method to reduce standing dead biomass, but also as a pathway to sustainable intensification by providing green forage at levels equal or even higher than those achieved under continuous traditional grazing.

1. Introduction

Regular disturbances such as fire and continuous grazing have shaped Argentina's grassland structure (Carnevali, 1994). In the northern province of Corrientes, having a strong tradition of cattle ranching, net primary productivity (NPP) of C_4 grasses is high in summer but relatively low in winter (Bernardis et al., 2005b; Martín et al., 2011; Royo Pallarés et al., 2005). Therefore, farmers stock their rangelands adjusted to the availability of winter fodder, which in turn results in very low stocking rates (Calvi, 2010). As a consequence, high standing dead biomass pools build up in large grassland areas in north-western Corrientes (Kurtz et al., 2010). Standing biomass decreases net photosynthesis and energy capture decreasing net production; nevertheless it accumulates annually, independent of the season (Fidelis et al., 2013) and acts not only as a grazing deterrent (Balph and Malecheck, 1985; Moisey et al., 2006) but also reduces live weight gain of large herbivores through decreased palatability and low overall forage quality (Mingo and Oesterheld, 2009). Due to these reasons, the overall animal production for northern Argentinean grasslands is low (Royo Pallarés et al., 2005). Recently published data indicated that over the last 60 years cattle live weight gain neither not change in Corrientes (Calvi, 2010) nor or in Argentina (Elizalde and Riffel, 2014; Hidalgo and Cauhépé, 1991), suggesting that a considerable production potential of these rangelands remains unutilized.

There is a wide range of possible treatments to reduce unproductive and low quality standing dead material. It comprises from mechanical elimination e.g. with knife-rollers, choppers,

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mowers and plows (Adema et al., 2004), targeted weed grazing (Frost et al., 2012), goat grazing (Lovreglio et al., 2014), and very often the use of fire (Bernardis et al., 2008; Fernández et al., 2011; Toledo et al., 2014). However, both fire and mechanical options have their disadvantages, namely increased burning risk (Fidelis et al., 2013; Thomas, 2006), bush encroachment (Dudinszky and Ghermandi, 2013), reduced species recruitment and weed germination (Franzese and Ghermandi, 2012), biodiversity loss (Azpiroz et al., 2012; Podgaiski et al., 2014), soil compaction (Hamza and Anderson, 2005; Jung et al., 2010; Schrama et al., 2013) and reduced water infiltration (Chyba et al., 2014). Nevertheless, fire is the most frequent and easy-to-use management tool in tropical grasslands and savannas (Oesterheld et al., 1999; Pausas and Ribeiro, 2013). Recently, burning has been forbidden both in Argentina (Argentina, 2009) and in the Corrientes Province (Corrientes, 2004).

High impact grazing (HIG) or the "herd effect" was proposed as a management option for restoring and maintaining grassland ecosystem functions (Savory, 1983, 2005) and as a means of improving the plant productivity (Savory and Parsons, 1980). Although sometimes controversially discussed (Briske et al., 2013; Teague et al., 2011), HIG has been shown to stimulate plant growth in some grassland ecosystems (McMillan et al., 2011) and create productive grazing lawns with high fodder quality (Cromsigt and Olff, 2008; Hempson et al., 2014; McNaughton, 1984).

HIG has multiple effects; it removes shading by dead biomass, including plant defoliation, nutrient removal and re-distribution through excreta, enhancing nutrient cycling and the mechanical effect of trampling. Although most of the aforementioned effects and issues are known, information of HIG effects on above ground biomass dynamics is surprisingly scarce and for some grassland ecosystems not considered so far. Up to date, the herd effect method generated a strong controversy in the scientific community (Briske et al., 2008, 2011, 2013; Dunne et al., 2011; Joseph et al., 2002). Only few studies analysed the effects of HIG on the above ground biomass; Jacobo et al. (2000, 2006) found positive effects of rotational grazing to control standing dead material; Striker et al. (2011) found for flooded grasslands that the Graminiods share was increased after HIG, while the aboveground net primary productivity (ANPP) was not significantly affected. Since most grassland ecosystems are characterized by pronounced climate seasonality, the timing (i.e. HIG in spring, summer, autumn, or winter) will likely affect biomass growth dynamics during the months following HIG. If properly timed, we assume considerable shifts in green to dead biomass ratio and rangeland productivity and thus positive effects on animal production as well.

It has not been investigated to date if HIG could be a serious alternative management practice for Northern Argentinean grasslands to control standing dead biomass and promote plant growth. The results will be relevant for developing strategies within the concept of sustainable land use intensification with regards to both environmental stability and raising productivity of agro-ecosystems (Garnett et al., 2013).

2. Materials and methods

2.1. Study area

The study was carried out at the Corrientes INTA Research Station (lat 27°40′01″S, long 58°47′11″W), in the Empedrado Department, 30 km South of Corrientes city, Capital of the Corrientes Province, Argentina. Mean elevation at the site is 69 m above sea level, and slopes are less than 0.1%. Local mean annual precipitation is about 1300 mm. There is a slight seasonality of rains; most of precipitation occurs in autumn (33% from March to May) and summer (30% from December to February) and less in spring (24% from September to November) and winter (13% from June to August). The average annual temperature is 21 °C. The annual temperature amplitude of monthly means ranges from 25.6 °C in January to 15.5 °C in July. The mean temperature during the experiment was similar to the average mean temperature. Precipitation amount during the experimental period varied only slightly between years, from June 2012 to May 2013, total precipitation was 1345 mm, and evapo-transpiration 1150 mm. From June 2013 – May 2014, precipitation was 1233 mm and evapo-transpiration 1107 mm (Fig. 1)

Soils have a sandy-loam texture and belong to the Treviño series (Aquic Ariudoll, Escobar et al., 1996) which covers approximately 37,250 ha in north-western Corrientes. Soils remained humid or very humid for most of the time every year, mostly due to both, the high precipitation and the clay layer located at approximately 40–90 cm depth (Bt horizon). The pH varied from 5.6 to 6.0, up to 7.0 to 7.4 below the Bt layer. Soil organic matter varied from 1.2 to 1.7% in the upper part, being as low as 0.3% at 90 cm (Escobar et al., 1996).

2.2. The dominant vegetation

Dominant tussock species were paja colorada (*Andropogon lateralis* Nees), paja amarilla *Sorghastrum setosum* (Griseb.) Hitchc. (ex *S. agrostoides* Speg. Hitchc.) and *Paspalum plicatulum* Michx. Among grass bunches, other short grasses develop, pasto horqueta (*Paspalum notatum* Flügge), *Axonopus affinis* Chase, *Eleocharis nodulosa* (Roth) Schult., *E. viridans* Kük. ex. Osten. and *Leersia hexandra* Sw. are the most frequent grass and grass-like species. Legumes are rather infrequent, with *Desmodium incanum* DC. being the most widely spread perennial legume and *Vicia epetiolaris* Burk. being the annual most frequent species growing and flowering in late winter and spring (Vanni and Kurtz, 2005).

2.3. Experimental layout

The experiment was established on a 24 ha natural grassland area which is part of the research facility of the Institute of Technical Agriculture (INTA) Corrientes. Before, the area was traditionally managed with continuous grazing at an intensity of 0.5 animal units per ha. Four adjacent paddocks of 6 ha each were separated with permanent electric fences. Three of them were used as replicates (R1–R3) for the HIG treatment experiment, and the fourth paddock was defined as control with continuous grazing with no HIG. The HIG treatment followed a monthly sequence; therefore each replicate paddock was divided into 12 sub-plots of 0.5 ha each, used for monthly HIG. The experiment started in July 2012, when the first sub-plot (50 m width, 100 m length) was enclosed with mobile/temporal electric fences and subjected to three days of HIG. For that purpose a mixed 75-animal herd of Braford, Hereford, and Brahman cattle breeds was used, representing an instantaneous grazing intensity of 150 animals ha^{-1} (approximately 30,000 kg of animal biomass ha^{-1}). During the first day the herd was allowed to graze ad libitum and the second day the cows were moved/driven around within the sub-plot to ensure an impact as homogeneous as possible until all vegetation was trampled down. After HIG, the mobile sub-plot fences were removed and the HIG herd was driven to the remaining two 6 ha paddocks to carry out the HIG at the particular sub-plots. All four 6 ha paddocks were continuously grazed throughout the experiment with 3 non-lactating cows each, to resemble the average stocking rate of 0.5 animal unit ha^{-1} in Corrientes Province (Calvi, 2010; Kurtz and Ligier, 2007). These cows were also crossbreeds Braford, Hereford, and Brahman. According to mean temperature, monthly precipitation, daily reference evapo-transpiration and relative humidity the impact month were classified to represent an annual season namely spring (September, October, November),