Challenges and opportunities for livestock production in natural pastures: the case of Brazilian Pampa Biome

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Introduction

Pampa is one of the six officially recognized biomes in Brazil, and represents 2.07% (176,496 km²) of its territory. Much less mediatic than other biomes such as Amazonia and Cerrados (Overbeck et al., 2007), Pampa was only officially acknowledged as such in 2004.

Pampa natural grasslands is part of the Río de la Plata natural grasslands (Carvalho et al., 2008), the largest natural grassland biogeographic unit in South America, and one of the largest in the world. The Río de la Plata natural grasslands occupy an area of 70 million ha (Figure 1), between eastern Argentina, Uruguay and Rio Grande do Sul, Brazil (Soriano, 1991; Pallares et al., 2005).

Figure 1. Natural grasslands from Río de la Plata. A. Pampa Ondulada, B. Pampa Interior, C. Pampa Austral, D. Pampa Inundable, E. Pampa mesopotámica, F. Campos del Sur, G. Campos del Norte. From Soriano (1991).

The vegetation cover comprises grasses and herbs mainly, but small shrubs and trees occur as well (Berreta, 2001). According to Boldrini (2002), Pampa has around 3000 vascular plants, being 450 grasses and 150 legumes considered as forage for domestic grazing animals. This natural vegetation richness has been the foundation of domestic herbivorous feeding since their introduction in Southern Brazil in the XVII century. It has been the main forage source for beef cattle and sheep, the central economic activity that takes place in the region. This rich biodiversity is enlarged by 385 species of birds and 90 terrestrial mammals (Bilenca & Miñarro, 2004).

All those regions have been seriously threatened in the last 50 years. Brazilian census registered that from the 14.078 million ha with natural grasslands in 1970, only 10.524 million ha survived in 1996 (IBGE, 1996). Current estimation sets remaining natural vegetation cover around 33.8% of the original cover, so natural grasslands actually comprise less than 6 million ha (Hasenack, 2007). Bilenca & Miñarro (2004) indicated that natural grasslands are not only decreasing in Brazil, but also in Argentina and Uruguay, at rates of 11.9, 3.6, and 7.7%, respectively. Considering the recent census from 1996 to 2006 the average reduction has reached incredible 440,000 ha per year (Nabinger et al., 2009).

There are many symptoms of ecosystem services degradation in Pampa. More than 50 forage species, 16 mammals and 38 birds, among others, have been classified in different levels of threat (MMA, 2005). Landscape fragmentation, loss of biodiversity, biological invasion, soil erosion, water pollution, and land degradation are among recognized consequences (Carvalho & Batello, 2009).

The causes that are threatening natural grasslands in this part of the world were examined by Carvalho et al, (2008). They are very similar for all countries in facing the classical global production versus conservation dilemma. The expansion of the agricultural border and overgrazing are frequently in the basis of the phenomena. Regarding agricultural expansion, soybean and forestry are the main recent agricultural initiatives threatening natural grasslands. Carvalho & Batello (2009) estimated a reduction of 250,000 ha of Pampa natural grasslands only in 2002, when soybean reached its higher prices. In Uruguay, agricultural surface was doubled between 2001 and 2006 at expenses of natural grassland reduction (Díaz et al., 2006). Baldi & Paruelo (2008) also considered the expansion of agricultural boarder as the main cause of natural grasslands area suppression, reaching around 50% in some Argentinian Pampa regions.

Considering overgrazing, this is a global trend and reasons are complex reflecting biological, social and economical factors (Hanselka & Landers, 1993). Costa & Rehman (2005) explored the overgrazing behaviour of cattle ranchers in Brazil, and concluded that the cattle ownership sense (cattle asset value) and its benefits in terms of security and liquidity were in the main reasons for overgrazing. Besides, the objective of maintaining the ownership of land was significantly related to stocking rate decisions, illustrating the importance of this issue in determining the degradation of grasslands in Brazil (Costa & Rehman, 1999).

This is singular in Brazil, where production-oriented policies aiming to give access to land sets a minimum stocking rate to be reach indistinctly by natural and sown grasslands. Unexpected consequence from the current approach is the stimulation of overgrazing by farmers aiming to maintain their ownership (Carvalho & Batello, 2009). Recent stocktaking that focused on beef cattle operations in Pampa was leaded by Nabinger and concluded that the maintaining of land ownership is the most important factor taken into account by ranchers to manage pastures (Sebrae/Senar/Farsul, 2005). Therefore, the attaining of legislation requirements is nearly the only management factor in place, reflecting in low production indices. Mistakenly, the stocking control is assumed to be a measure of production in Brazilian legislation. And unfortunately, stocking rate and individual animal production are negatively correlated, thus the current productivity is very low.

For most of the natural grassland ecosystem around the world, when used all along the seasons by grazing, with a more or less constant stocking density, there is a clear tendency to overgrazing and then to degradation of vegetation. The reason for that is (i) as described above, a general tendency for maximizing the average stocking density for socio-economic reasons, and (ii) the fact that the primary productivity of these ecosystems is submitted to huge seasonal and inter-annual variations leading then to large discrepancies between instantaneous herbage production capacities and instantaneous stocking densities, that provokes vegetation damages during some key periods (winter, dry seasons) as a consequence of over-utilization, while there is under-utilization during other seasons or periods. So successions of over-grazing with under-grazing periods lead to strong modifications of species composition. For example within Pampa region, C3 species over-grazed during winter tend to disappear and to be replaced by C4 species…that leads to accentuate the disequilibrium of herbage production between autumn-winter and spring-summer periods through a vicious cycle. Such an evolution (decreasing contribution of C3 vs C4 species within vegetation) has been also reported within grassland system in Mongolia (Lemaire, pers. comun.).

Other negative occurrences, directly or indirectly related to expansion of agricultural boarder and/or overgrazing, were presented by Carvalho et al. (2008), as such as: desertification, expansion of invasive species (e.g., *Eragrostis plana*), unprescribed fire, among others.

Thus, the central question involved in natural grassland conservation in this region seems to be directly related to a better stocking management to face overgrazing consequences. And since overgrazing decreases animal production, a better stocking management could at the same time make natural grasslands more competitive in relation to other agricultural options. But the point is: can we target natural grassland higher rates of return at the same time aiming to conservation? We think the answer is yes, and we illustrate that focusing on long-term research and other initiatives in the management and conservation of natural grasslands from Pampa biome.

Are conservation and utilization mutually exclusive? The case of Brazilian Pampa

Historically, natural pastures have been considered in Brazil as low productive extensive systems. They are complex, heterogeneous, and challenging for management, whilst humankind usually prefers to deal with homogeneous, surmountable agricultural systems (Carvalho, 2005). The pressure for the use of sown pastures by commercial seed enterprises, jointly with predominant research view by national research institutions, which were oriented to short-term production responses, lead to the main technical intervention proposal for those natural grassland systems: its replacement. Curiously, natural pastures in Brazil did not experienced intensification. They were abruptly replaced by sown foreign species. Cerrado's vegetation is a well-known case.

Against the predominant initiatives from Central Brazil, in the 80's Prof. Maraschin leaded the renewing interest in animal production from natural grasslands in Southern Brazil. At that time, research was mainly production-oriented and the knowledge of animal production potential from natural grasslands was the main research objective. With FAO's support (FAO/Campos Group initiative), the oldest Brazilian grazing experiment was then established and animal/pasture productions were measured according to varying grazing intensities (Maraschin et al., 2007).

The grazing strategy of varying stocking rates according to pasture production was proved to double animal production in comparison with traditional ranching. Maraschin (2001) reached that using moderate grazing intensities, using the forage allowance management concept. The author revealed the plateau for individual animal gain when forage was offered in a quantity four times greater the animal intake potential. Those results were the first local evidence about the remarkable scope for increasing animal production from natural grasslands.

Based on Heitschmidt & Stuth (1991) reasoning and data from Maraschin et al. (1997), Nabinger (2002) illustrated the potential of grazing intensity to alter primary and secondary productivities in Pampa natural grasslands (Table 1).

Table 1. Utilization efficiency of incident radiation for different levels of herbage allowance applied to natural grassland (Nabinger, 2002).

Utilization efficiency of incident radiation	Daily forage allowance (kg DM/100 kg live weight)			
	4	8	12	16
Incident energy/energy in produced DM -%	0.20	0.33	0.36	0.32
Incident energy/energy in live weight gain -%	0.009	0.016	0.017	0.013

The positive consequences of using moderate grazing (daily forage allowance of 12% LW) were highlighted by the transformation of primary and secondary production in fixed energy in relation to available incident energy. The author estimated that the management of forage allowance affects both the pasture production, via an increase in leaf area available for radiation interception, and the animal production, via an increase in the amount of forage consumed and converted to animal weight gain.

Based on the seasonal animal performance variability registered in Maraschin's protocol, Soares et al. (2005) investigated the hypothesis of vegetation structure manipulation by varying herbage allowances seasonally. Using distinct combinations of forage allowances in spring regarding to the rest of the year, the authors first showed animal production per unit area could exceed the ceiling of 200 Kg live weight ha^{-1} $year^{-1}$. With no external inputs animal production could triplicate in relation to traditional ranching, and moderate grazing still proved to be the way for attaining maximum levels of productivity.

At that time the predominant guidance was still the search for productivity records. However, by the end of 90's the questioning about other demanding functions for grasslands and the concept of multi-functionality began to more incisively influence research orientation (Carvalho, 2005). Since then, new questions emerged, and not only the commercial outputs were evaluated, but the production process as well. In this context, the central question became if the same management proved to maximize animal production could also produce long-term sustainability. Thus, soil-plant-animal indicators related to conservation were since assessed.

Concerning vegetation diversity, by using Pielou equity and Shannon diversity indexes, Carvalho et al. (2003) demonstrate 15 years of moderate grazing not only promoted higher animal performance, but enhanced diversity. The number of species (71) and the diversity index (3.510) was greater in the moderate grazing intensity (12%), which showed an equity index of 0.823. More recently, Cruz et al. (2010) demonstrated that plants types associated with strategies of nutrient conservation occurred on areas where grazing intensity was low. Conversely, plant types associated with strategies of nutrient capture occurred on areas where grazing intensity was high. Therefore, the prevailing plant functional type is closely related to grazing intensity. Halford et al. (2008) studied the same vegetation subjected to contrasting intensities of grazing throughout a 20 year period, and confirmed that high long-term grazing intensity significantly modified grassland composition, forming homogeneous overgrazed pastures characterized by a specific species assemblage. On the other hand, lower grazing intensities created more heterogeneous vegetation with grazed and ungrazed areas, but had small impact on floristic composition of grazed areas. Moderate grazing intensities increased vegetation heterogeneity by enhancing species richness (Goret, 2005), creating distinct grazed and ungrazed areas (Halford et al., 2008), and diversifying the occurrence of plant functional types, ultimately enhancing primary and secondary productivity.

So it is clear that seasonal modulation of stocking density is a key management practice for restoring vegetation dynamics and then livestock production capacities of natural grasslands. When harvest and storage of surplus herbage during the favorable season is not possible, owing to the cost of machinery…The only possibility is then to increase the herbage production during the low herbage production period within restricted areas where condition are favorable by adding adequate N and P fertilizers…and then to use these “intensified” areas for reducing the stocking density on the other parts of the land. Then strategic intensification of some restricted areas could be a tool for a more sustainable grazing system within natural grasslands. For that, it is very important to analyse the diversity of the grassland: (i) spatial diversity in relation with soil heterogeneity for determining the potentiality of different grassland areas and their possibility to be or not intensified…and (ii) temporal diversity for forecasting temporal variation of herbage productivity according to season and year to year variation and then to adopt flexible stocking density as a management tool.

Soil quality parameters were assessed in this long-term protocol, and have strengthening the significance of positive effects of moderate grazing on natural pastures. Bertol et al. (1998) showed organic matter, water infiltration rate and some macronutrients (e.g., Mg, Ca) are found to be higher at moderate grazing. The authors reported that high grazing intensities decreased organic matter in the upper layer of the soil, from 3.6 to 2.4%. Considering total carbon stocks, Salton et al. (2008) described carbon stocks were inversely related to grazing intensity. When not only the quantity of carbon was considered, but also its lability, then the carbon management index, one of the most important soil quality parameters, indicates moderate grazing to produce better results after 22 years of grazing effects (Conte et al., 2011). Carbon associated to microbial biomass did not differed, but microbial biomass activity was positively related to grazing intensity (Matsuoka et al., 2008). Regarding soil physical parameters, Conte et al. (2011) found soil density to increases linearly with increasing grazing intensity. All those reference reinforce moderate grazing promotes soil quality parameters.

Guterrez et al. (2006) applied the same treatments in another experiment, and showed how grazing intensity impacts carbon stocks after a few years grazing (Figure 2). Again, moderate grazing was able to promote higher carbon stocks.

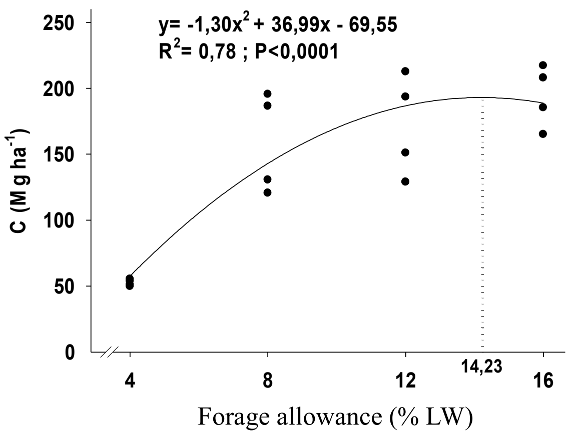

Figure 2. Carbon stocks from the upper 40 cm layer of natural grasslands according to grazing intensities (Guterrez et al., 2006)

Regarding animal parameters, Maraschin et al. (1997) showed moderate grazing with 12% daily forage allowance was the better compromise between individual animal daily gain and live weight gain per unit area. However, cause-effect relationships were not enough assessed to allow for comprehensive animal well-being at grazing. Carvalho et al. (2009) demonstrated in natural grasslands subjected to high grazing intensities, it is common that the prevailing plants species have resource capture strategies and avoidance mechanisms to resist grazing. The size and structure of such plants result in little “exposure” of the acquired carbon, making more difficult the process of herbage capture by the grazing animal. Under these conditions, daily grazing time can easily exceed 600 minutes (Pinto et al., 2007). The authors found grazing time increased 67 minutes for each centimeter decrease in sward height. Bite mass and intake rate are optimized in those natural pastures when pasture height in grazed areas is around 10.0 and 11.5 cm for ewes and heifers, respectively (Gonçalves et al., 2009b). Gonçalves et al. (2009c) presented other ingestive behavior parameters indicating the quality of the pastoral environment. Under intake limiting conditions, both cattle and sheep visit a larger number of feeding stations, harvesting fewer bites and remaining less time on each feed station. In this sense, Mezzalira et al. (2011) demonstrate moderate grazing enhance animal selectivity, and very recently Da Trindade (2011) reported higher daily intakes for animals at moderate grazing in the same long-term protocol. Once again, moderate grazing promotes better animal performance because it enhances “foodscape quality” (*sensu* Searle et al., 2007) at the same time.

Final comments

It is now accepted that production is no longer considered the only target for pastoral ecosystems (Carvalho & Batello, 2009). The quality and the long-term sustainability of the production processes became crucial, and the multi-functionality of rangelands is now a matter of target (Carvalho, 2005). Natural grasslands and their intrinsic biodiversity value are a public good (Soder et al., 2009). However, for natural grasslands of Southern Brazil, conservation must occurs by private farmers that are obligate to survive selling commercial products.

In this context, this review brings support that conservation and utilization are not mutually exclusive. Competitive levels of livestock production can be attained with good ecosystems functioning and services indicators. The capital point is the use of moderate grazing, which means, in the case of Pampa natural grasslands, a grazing harvesting efficiency of no more than 30% of the grazed preferred species production (Da Trindade, 2011).

The opportunities to livestock production based on natural grasslands are illustrated in the Figure 3.

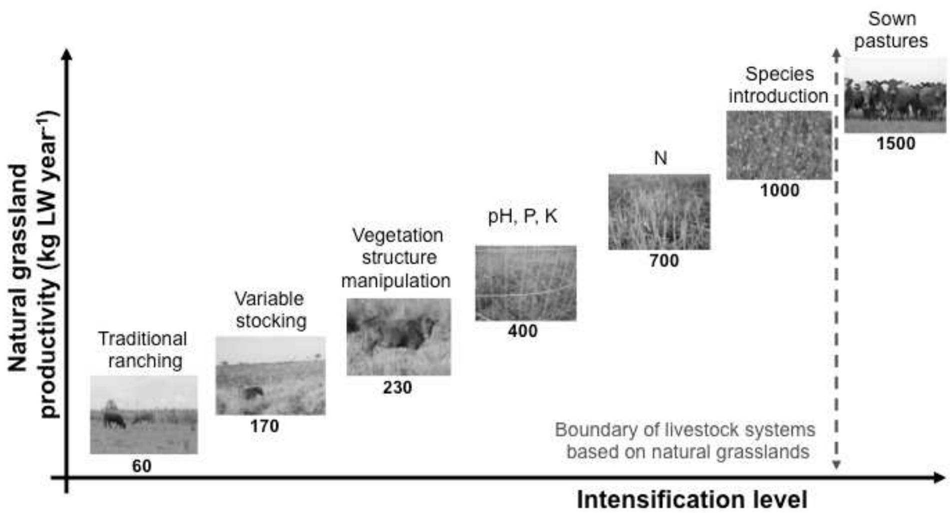

Figure 3. Livestock production opportunities based on Pampa natural grasslands with different levels of anthropogenic intervention (adapted from Carvalho, 2001 and Carvalho et al., 2008).

Past and recent experiences proved different levels of intensification can hugely enhance livestock production in natural grasslands. With no external inputs livestock production, illustrated by beef production, can triplicate by using moderate grazing in order to manipulate sward structure to maintain favorable grazing environments (sward height of 12 cm and less preferred species/tussock cover less than 30%). Adding external inputs and maintaining proportionally moderate grazing (in relation to pasture production) this productivity can be increased ten times if nitrogen fertilization is applied. Obviously vegetation diversity is negatively affected. Maintaining all these technical interventions and introducing temperate annual species, as overspreading Italian rygrass, the production system remains based on natural vegetation, less diverse, feeding all year long and reaching 1,000 kg live weight ha^{-1} year^{-1}. Pampa natural grasslands allow for those huge intervention levels because of its singular resilience.

We believe livestock production systems should be diverse in those different options. A better grazing distribution and forage budget can be planned integrating different levels of intensification, including the integration of crops. Instead of be viewed as a threat, crops should be viewed as an opportunity. Obviously depending on how crops, sown and natural pastures are spatio-temporally organized.

Carvalho & Batello (2009) explored the basis of De Haan (1997) approach and proposed several measures to mitigate the negative effects and to enhance positive effects from the production versus conservation dilemma in natural grazing systems. In general, property, financial, institutional and information measures are proposed, from altering legislation up to being paid for ecosystem services and certificated animal products. However, we must comprehend that education is core to all initiatives.

Finally, there is no more room for romantic arguments to support natural grassland conservation. They need to feed animals and sell commercial products to maintain stakeholders in the field. Natural grasslands can economically compete with other agricultural options, but production systems are better with natural grasslands and crops in synergistically conceived in diverse production systems. For such a proposal, there is need to redefine the frameworks within which natural grassland management are proposed in relation to other agricultural options, in order to enhance the overall agricultural sustainability at regional scales. In this context, it is urgent that natural grassland management and conservation initiatives should enlarge its classical approach.

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