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Meeting global food demand sustainably: Insights from Uruguay´s Campos Ecosystem in South America

Ayala, W; Pereyra[1], F; Rovira, P; Savian, J

National Institute of Agricultural Research of Uruguay (INIA Uruguay), Ruta 8 km 282, Treinta y Tres, Uruguay, CP 33000; [1]PhD student until October 2024, UdelaR, Uruguay

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Abstract

The Campos ecosystem is in central-eastern Argentina, southern Brazil and Uruguay. It is described as one of the largest areas of native grasslands in temperate-subtropical environments. However, it faces challenges as a food supplier in an increased global food demand. The main threats are the reduction in the area due to competition with cash crops and forestry and climate change effects. Uruguay produces food for 30×10^6 people representing 10 times its own population. Native grasslands are the main feed source for livestock in extensive ecosystems and complement intensive pastures in crop-livestock systems. In this scenario, INIA Uruguay has been evaluating different levels of land use intensification to quantify productive, economic and environmental impacts through a series of long-term experiments (LTE). In a three-year period, four systems were tested, contrasting different levels of intensification in land use combined with different strategies for beef cattle rearing and finishing. Feeding resources included a combination of improved pastures, native grasslands and supplements. The objective of this contribution is to describe productive potential in herbage, crops and livestock production, and identify tools and key results to improve sustainable management practices in terms of achieving 400 kg LW/ha/year. Data obtained showed differences in the productivity obtained in the livestock and agriculture phases. The adjustment of management practices will provide tools to improve productivity and efficiency, minimize risks and identify mitigation and adaptation approaches to sustain future world food demands. Also, science-based information generated by LTE contributes to assisting public policy decision-makers and risk managers aligned to international commitments agreed by Uruguay in relation to the climate change agenda.

Introduction

The grasslands of Rio de la Plata region cover 76 Mha (Soriano et al. 1992), including the Campos ecosystem (approximately 65% of the area), an area that is declining over time (Carvalho et al., 2021), by agriculture and afforestation interventions. The main economic activity in this region is the extensive livestock production based on the use of native grasslands. In Uruguay, the extensive livestock production occupies 10 Mha of productive area. Cattle introduction in Uruguay dates to 1611, when the Spanish colonizer Hernandarias delivered the first herd of cattle (Barrios 2011). After 400 years of intervention, the ecosystem is still recognized for its potential as a food producer, maintaining a high biodiversity of plants, birds and mammals (Bilenca and Miñarro 2004). Because of climate change, the variability in precipitation and frequency of extreme dry and wet events is reported, as well as long-term warming in this region (Malhi et al., 2020). To attend to the increase in food demand, the redesign of systems should include practices focusing on enhancing productivity, animal welfare, system resilience and mitigation of vulnerability, soil health, including carbon sequestration, and reduction of greenhouse gas emissions through management practices (Jaurena et al. 2021).

In 2018, INIA Uruguay developed an agri-environmental platform, including seven long-term experiments (LTE) on the country's main production systems (Leoni et al. 2024). In the eastern region there are three LTE: a) "Sustainable intensification of rice rotations", located in the Paso de la Laguna Experimental Unit of INIA Treinta y Tres since 2012; b) "Extensive sheep production systems on native grasslands, since 2021, and c) "Sustainable intensification of livestock-agricultural systems" since 1995, b and c placed in the Palo a Pique Experimental Unit of INIA Treinta y Tres. The LTE are being designed to respond to problems in current and future scenarios and understand processes and cause-effect relationships. They help assess the impacts of climate variability and management practices on animals, herbage biomass, crop productivity, species diversity, availability of soil resources, quality of water, environmental footprints, and economic outcomes, among other factors. The LTE constitute an efficient research platform for researchers, producers and public policy makers (Leoni et al. 2024). The objective of this paper is to report information about herbage, crop and animal productivity from the LTE nominated as "c": Sustainable intensification of livestock-agricultural systems". This LTE compares four pasture-crop rotation systems with different degrees of land-use intensification during the 2019 – 2022 period for rearing and/or fattening processes in cattle (Pereyra et al. 2022) and identify key decisions to improve systems management.

Methods

A long-term pasture-crop experiment was installed under no-tillage in Palo a Pique experimental unit of INIA Uruguay (S33° 15´ 54´´, W54° 29´28´) in 1995 (Terra and García-Prechak 2001) and reoriented by Rovira et al. (2019). Four rotation systems with different sequences of pastures and crops are being compared (Table 1) and grazed by different beef cattle categories with the general purpose of producing 400 kg/ha/year of liveweight (LW). The experiment lacks synchronic replications, but all phases of the rotations are present each year, including an area of native grasslands in each system, in an area of 150 has. Paddocks varied from 3 to 6 has each.

Table 1. Cropping and pasture sequences of the 4 pasture–crop rotations evaluated (Pereyra et al. 2022).

Rotation	Purpose	Year of rotation					
		Year 1	Year 2	Year 3	Year 4	Year 5	Year 6
CC	Crop/hay	Oat/Sorghum	Black oat/ Soybean	Wheat/Sorghum			
	Grazing	Oat/Sorghum	Ryegrass/Setaria				
SR	Crop /hay	Idem CC	Wheat + P1	P2			
	Grazing	Idem CC	P1	P2			
LR	Crop/hay	Idem CC, SR	Wheat + P1	P2	P3	P4	
	Grazing	Idem CC, SR	P1	P2	P3	P4	
FR	Grazing	Fescue	Fescue	Fescue	Fescue	Fescue	Fescue

P: pasture, followed by pasture age (i.e., P2: second-year pasture). All pastures, including those following the grain/hay crop phase, were available for grazing. Rotation CC: Continuous cropping; SR: Short rotation; LR: Long rotation, and FR: Forage rotation.

The livestock strategy in each system is the following (Pereyra et al. 2022):

a) In the continuous cropping (CC) rotation, rearing calves (180 to 370 kg/an in 12 months), grazing based on a combination of cool and warm annual grasses (oat or ryegrass – sorghum or *Setaria itálica*) plus a native grasslands pasture (33%).

b) In the long rotation (LR), the rearing and finishing of steers (180 to 530 kg/an in 18 months), grazing strategy based on a combination of *Festuca arundinacea*, *Lotus corniculatus* and *Trifolium repens* mixture during 4 years plus a native grasslands pasture (33%).
c) In the short rotation (SR), rearing heifers (150 to 330 kg/an in 12 months) and fattening cows (450 to 520 kg/an in 5 months), grazing strategy based on *Trifolium pratense* and *Holcus lanatus* and/or *Lolium multiflorum* mixture during two years and an oversown pasture of *Festuca arundinacea*, *Lotus corniculatus* and *Trifolium repens* renewed each five years with the same mixture plus a native grasslands pasture (29%).
d) In the forage rotation (FR), finishing steers (260 to 480 kg/an in 12-15 months), grazing strategy based on a pure *Festuca arundinacea* as a permanent pasture plus a native grasslands pasture (26%).

The native grassland is composed mainly of *Paspalum notatum, Axonopus affinis, Cyperus spp., Coelorhachis selloana, Paspalum dilatatum, Stenotaphrum secundatum, Panicum milioides, Cynodon* dactylon, *Setaria geniculata* and *Axonopus argentinus* (Ayala et al. 1993).

Determinations included pasture growth and botanical composition measured once a month in quadrats of 20×50 cm each in 3 exclosure cages per paddock (adapted from Lynch 1947). Pre- and post-grazing biomass was estimated cutting 6 quadrats per paddock (20x50 cm each). Crop production was evaluated at the end of each growing season. Animal LW, stocking rate, heat stress index, water balance and forage utilization were measured once a month.

Results

Climatic conditions determined a deficit in water balance (356 mm/year, on average). Maximum temperature was 41.4°C and the minimum temperature was −5.1°C, with a marked seasonal pattern. Heat stress index was 62.1±8.3, on average, with a maximum of 81 and a minimum of 41, identifying 6.1% of days with medium heat-stress conditions.

The herbage production showed yields of 5.6±4.2 and 6.0±4.5 t DM/ha/yr for native and oversown pastures. The spring deferment applied contributed to increased biomass accumulation. Short-term pastures (2-yr) produced 8.5±6.3 t DM/ha/yr, 16% higher than the results obtained with long-term pastures (4-yr). Cool annual pastures differ in biomass accumulation being annual ryegrass superior over oat (5.0±1.2 and 2.7±2.1 t DM/ha/yr, respectively). Warm annual pasture like Sorghum and *Setaria itálica* have the potential to contribute with 13 and 7 t DM/ha/yr, respectively.

The feed options available in each system are presented in Table 2. Pasture production differs between FR and CC systems, with pasture levels in the CC system being 25% lower than those in the FR system. The LR, SR and CC include legumes in a proportion of 48, 43 and 33% of the total area of the system, respectively. Legume contribution in mixed pastures declines over time, from 39.5 to 4.9% in a four-year pasture in the LR system and from 39.7 to 21.5% in a two-year pasture in the SR system. In CC legume contribution was 8.2%.

Animals received strategic supplementation when pasture was not enough to prevent LW loss, mainly in winter or summer. The utilization of hay was maximum in LR, followed by SR; representing 15 and 12% respectively of the total biomass offered (pasture + hay). The HSGM was an important component, particularly in the LR system. The LW production differed significantly between systems, being greater in CC and SR, compared with LR and FR. The conversion efficiency did not differ significantly between systems ranging between 14.1 to 19.2 kg of feed per kg of LW produced. Rearing categories exhibit greater conversion efficiency than finishing categories.

Forage utilization varied between 50-60%, 55-62% 48-52% and 35-39% for LR, SR, CC and FR, respectively. Mean stocking rate was 614, 600, 575 and 498 kg LW/ha/yr for CC, SR, LR and FR, respectively (Pereyra et al. 2022).

Table 2: Level and type of pasture, supplements, production and efficiency in each system in 'Palo a Pique' long-term experiment in Treinta y Tres, Uruguay (three-year average), adapted from Pereyra et al. (2022).

System	Feeding options (DM, kg/ha/year)					Production	Efficiency
	Pasture	Hay[1]	PC[2]	HSMG[3]	BR[4]	LW (kg/ha/yr)	(kg feed/kg LW)
Continuos Cropping	5206 b	256	21	122	0	426 a	14.1
Short Rotation	5763 a	790	12	169	0	418 a	15.1
Long Rotation	5399 ab	940	20	616	63	369 b	16.1
Forage Rotation	6867 a	138	0	23	166	310 c	19.2
p-value	0.039	--	--	--	--	0.003	ns

[1] Hay: 6.7% crude protein (CP), metabolizable energy (ME): 5.8 MJ/kg DM; [2] Protein concentrate (PC): 46.5% CP, ME = 10.5 MJ/kg DM; [3] High moisture sorghum grain (HMSG): 8.1% CP, ME: 12.6 MJ/kg DM; [4] Balanced ration (BR): 14% CP, ME: 11.7 MJ/kg DM

The range of productivity of different crops varied between 1.20-2.43, 4.12-6.79, 2.20-3.02, and 0.76-4.02 t/ha/yr for Oat, Sorghum, Soybean and Wheat, respectively (Pereyra et al. 2022). In 2021-2022, oat, sorghum and wheat did not produce grain. In the CC system, crops produced less than those that rotate with perennial pastures (SR, LR), being 23, 9 and 16% lower in the years 2019-2020 and 2020-2021 for wheat, sorghum and soybean, respectively.

Implications and Conclusions

The effects of climate determined variations in the availability of feed resources, demanding the use of supplements to minimize animal LW losses. Native grasslands based on their resilience to stress factors played a strategic role in each system. Match feed demand and supply is a crucial process, requiring to be monitored and introduce stocking rate adjustments. From the animal perspective, the occurrence of heat stress conditions demands special solutions to minimize effects. The synergies between agriculture and livestock production provide low-cost solutions.

The objective of achieving 400 kg LW/ha/year was reached by two of the four systems evaluated (Continuous Cropping and Short Rotation). These systems included the highest proportion of rearing stock with a trend to have the best conversion efficiency rates. Systems that include a pasture phase (Short Rotation and Long Rotation) tend to show high crop production. From the results, there are opportunities to improve efficiency in the different systems tested.

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