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Sustainability of meat production beyond carbon footprint: a synthesis of case studies from grazing systems in Uruguay

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ABSTRACT

Livestock production has been challenged as a large contributor to climate change, and carbon footprint has become a widely used measure of cattle environmental impact. This analysis of fifteen beef grazing systems in Uruguay quantifies the range of variation of carbon footprint, and the trade-offs with other relevant environmental variables, using a partial life cycle assessment (LCA) methodology. Using carbon footprint as the primary environmental indicator has several limitations: different metrics (GWP vs. GTP) may lead to different conclusions, carbon sequestration from soils may drastically affect the results, and systems with lower carbon footprint may have higher energy use, soil erosion, nutrient imbalance, pesticide ecotoxicity, and impact on biodiversity. A multidimensional assessment of sustainability of meat production is therefore needed to inform decision makers. There is great potential to improve grazing livestock systems productivity while reducing carbon footprint and other environmental impacts, and conserving biodiversity.

1. Introduction

Livestock production is growing worldwide because of the increased demand for animal proteins. Beef cattle production has increased in the last three decades almost 40% worldwide, being the Americas one of the regions that led this development (FAO, 2013). At the same time, the need to reduce the sector's greenhouse gas (GHG) emissions and its overall environmental footprint has become a top priority for industry and policy makers (Gerber et al., 2013). Carbon footprint has become the indicator to quantify the GHG emission intensity, usually expressed from the standpoint of the consumer as kg of CO_2 equivalent (De Vries & de Boer, 2010). A recent FAO report challenged the global livestock sector as a large contributor to climate change representing 14.5% of anthropogenic GHG emissions, and therefore, a sector with major opportunities for mitigation (Gerber et al., 2013). Due to their high cattle numbers the Latin America and the Caribbean have the largest challenges and opportunities.

In Uruguay cattle graze year-round on natural grasslands from the Campos biome (Royo Pallarés, Berretta, & Maraschin, 2005), improved pastures with legumes and P fertilizer added, and seeded pastures (i.e., mixtures of temperate grasses and legumes replacing the native vegetation, also known as ley). Cow–calf systems breed heifers at around 2.5 years of age, and calves are weaned at 6 months of age, and 130 to 150 kg of live weight (LW), with a national weaning rate between 63 and 70% (DIEA, 2013). Backgrounding of steers (from 150 to 350 kg LW) is usually done on native grasslands and seeded pastures. Finishing of steers (up to 500 to 550 kg LW) is also mostly done on pastures, and only 10% of the steers are finished in feedlots. The expansion of agriculture (driven by no tillage soybean production) has reduced the area of grasslands to 70% of the country area, and pushed livestock production to marginal lands, as well as providing opportunities for intensification of livestock systems based on higher inputs and grains. In this context, Uruguay has increased its beef production more than 45% since 1980 (DIEA, 2013), representing currently almost 75% of the GHG emissions of the whole country (MVOTMA, 2010). Therefore, climate change mitigation and adaptation, soil erosion control, grassland biodiversity conservation, and water quality are major environmental priorities for the Ministry of Livestock, Agriculture and Fisheries of Uruguay (MGAP, 2013).

The range of beef carbon footprint estimates among production systems in Uruguay is large (Becoña, Astigarraga, & Picasso, 2014; Modernel, Astigarraga, & Picasso, 2013), so that there is a high potential for reducing GHG emissions. In beef cow–calf grazing systems, using forage efficiently by optimizing forage allowance is a key mitigation option that can increase beef productivity and reduce carbon footprint

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per kg of beef and per ha (Becoña et al., 2014). In beef backgrounding–finishing systems, confinements (feedlots) have lower GHG emissions than grazing systems, and improving productivity of grazing systems can greatly mitigate GHG emissions (Modernel et al., 2013).

Carbon footprint studies in the beef sector worldwide have identified GHG mitigation opportunities at global and local scales for tackling climate change (some examples are shown in Table 1). Improving efficiency of beef production, through increasing animal intake quantity and quality, increasing reproductive efficiency, and daily weight gain, may result in significant reductions of GHG emissions from ruminants. Furthermore, in beef grazing systems, grazing efficiency could play a central role in GHG emission mitigation (Herrero et al., 2013).

Despite the major contribution of carbon footprint to the understanding and mitigation of GHG emissions, sustainability of food production is a much broader concept than carbon footprint. Furthermore, there is little recognition of the role livestock grazing systems play in storing carbon, protecting biodiversity and utilizing marginal land that cannot be used for crops. Therefore, the literature on sustainability and life cycle assessment (LCA) can significantly contribute to inform meat industry and policy makers. The objectives of this paper were to quantify carbon footprint using various metrics and several other environmental variables: fossil energy consumption, soil erosion, nutrient balance, pesticide ecotoxicity, and impact on biodiversity, among fifteen beef grazing systems in Uruguay. Our hypotheses were: i) that the carbon footprint of different beef grazing systems will change when using different metrics for assessment and ii) that significant tradeoffs exist among alternative environmental variables, especially between carbon footprint and impact on biodiversity.

2. Materials and methods

2.1. Description of the systems

Beef production cycle in Uruguay can be divided in cow–calf and finishing stages. The first one includes the reproduction process, producing calves of 150 kg live weight (LW) on average that would enter the meat production stage. Finishing includes an initial phase where the animal grows from 150 to 350 kg LW on average (backgrounding) and the fattening phase, going from 350 kg LW to slaughter weight (500 kg LW on average). Farms can specialize in breeding (cow–calf farms), finishing, or both (complete cycle farms). The most common management in farms based on natural grasslands include high stocking rates, with consequent overgrazing (Carvalho & Batello, 2009) and low forage allowance (i.e., kilograms of forage every 100 kg of animal LW, Sollenberger, Moore, Allen, & Pedreira, 2005) which limits livestock production. Other forage sources used by farmers are improved grasslands (natural grasslands oversown with legumes) and seeded pastures (i.e., ley) mostly comprised by exotic perennial species such as Fescue (*Festuca arundinacea* Schreb.), white clover (*Trifolium repens* L.) and birds foot trefoil (*Lotus corniculatus* L.). In both cases phosphorus and nitrogen fertilizer are applied. Seeded pastures achieve acceptable yields until 3 to 4 years, when a crop is sown as part of a crop–pasture rotation. Annual fodder crops in winter (ryegrass and oats) and summer (sorghum fodder) are used.

In order to represent a wide range of beef producing cycles in Uruguay, this study compared 15 beef production cycles, which were the combination of three cow–calf systems and five finishing systems. The boundary of our study is the primary production phase (i.e., farming systems), not the entire beef value chain.

The three cow–calf systems were averages of groups of farms previously identified through statistical clustering of seven production and environmental variables from 20 cow–calf farms, as described in Becoña et al. (2014). The three more contrasting clusters of cow–calf systems were included in the analysis for this paper. The "low performance" cow–calf farms (LP) had the lowest forage production allowance and high stocking rates and poor herd reproductive parameters. The "intermediate performance" cow–calf farms (IP) had an intermediate stocking rate and forage production allowance, resulting in better reproductive performance, but a low efficiency in heifer raising, and intermediate beef productivity. Finally, the "high performance" cow–calf farms (HP) had high beef productivity and excellent reproductive performance, sustained by high stocking rates on optimal forage production allowance, resulting in minimal carbon footprint.

The five finishing systems were identified based on previous published literature and expert opinion, as combinations of two typical backgrounding and three fattening systems (Modernel et al., 2013). Backgrounding systems were based on grazing, either native grasslands (G) or seeded pastures (P). Fattening was based on grasslands (G), seeded pastures (P), or feedlot (F). Five different combinations of these background–finishing stages were included in the analysis of this paper: G–G, G–P, P–P, G–F, and P–F.

A summary of each system's nutritional characteristics and productive performance is presented in Table 2. Nutritional requirements were used to calculate the relative area for each system needed to produce the required amount of feed, using national technical coefficients

Table 1
Comparison of grasslands and pasture based beef systems carbon footprint (kg $CO_{2e}\cdot$kg LW^{-1}) from various studies.
Modified from Becoña et al. (2014).

Beef system	Feed base	Mean	Country	Reference
Cow–calf	Native grasslands	28.7	Uruguay	Becoña et al. (2014)
	Native grasslands and improved pastures	20.8		
	Native grasslands and seeded pastures	16.0		
	Mixed hay and pasture	10.4	Canada	Beauchemin, Henry Janzen, Little, McAllister, & McGinn (2010)
	40% legume pasture, grass hay, and wheat	10.5	USA	Pelletier, Pirog, & Rasmussen (2010)
Finishing only	40% legume pasture, brome pasture, grass and alfalfa hay	8.7	USA	Pelletier et al. (2010)
Backgrounding–finishing	Native grasslands	16.7	Uruguay	Modernel et al. (2013)
	Native grasslands–seeded pastures	13.0		
	Seeded pastures	9.5		
	Native grasslands–feedlot	10.5		
	Seeded pastures–feedlot	6.9		
	Pastures and supplements	19.3	Australia	Peters et al. (2010)
	Native grasslands	42.6	Brazil	Ruviaro, de Léis, Lampert, Barcellos, & Dewes (2014)
	Improved natural grass	20.2		
	Native grass/ryegrass	29.6		
	Improved grasslands/sorghum	23.4		
	Cultivated ryegrass and sorghum	20.0		
	Native grass suppl. with protein mineralized salt	33.3		
	Native grass suppl. with protein energy mineralized salt	23.4		