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Environmental and economic performance of beef farming systems with different feeding strategies in southern Brazil

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ABSTRACT

Beef production is one of the contributors to emission of pollutants to the environment, and increasingly competes for natural resources. Beef producers can improve their environmental performance by adopting alternative feeding strategies. Adoption of alternative feeding strategies, however, might negatively impact farm profitability. The objective of this study was to evaluate the environmental and economic performance of four beef farming systems with different feeding strategies in southern Brazil: grazing on natural pasture (NP); grazing on improved pasture (IP); grazing on natural pasture and crop residues (CR); and grazing on natural pasture and feedlot fattening (FL). Environmental indicators used to compare these farming systems were global warming potential (GWP), fossil energy use, and land occupation per kilogram live weight (LW). Life cycle assessment (LCA) was used to quantify environmental indicators from cradle-to-farm gate. The indicator for economic performance was operating profit per farm. The IP system had lower GWP (18.7 kg CO_2-eq.·kg^{-1} LW) and land occupation (37 m^2·kg^{-1} LW) than other systems, whereas its fossil energy use (19.3 MJ·kg^{-1} LW) was higher. CR had the highest operating profit (1,567,800 R$·$farm^{-1}$) of the four systems, followed by the IP system (616,400 R$·$farm^{-1}$). Operating profit in the CR system was mainly from crop production (88%). The GWP of the CR system (26.8 kg CO_2-eq.·kg^{-1} LW) was similar to the GWP of the NP system (27.3 kg CO_2-eq.·kg^{-1} LW). Operating profit of the FL system (148,100 R$·$farm^{-1}$) was lower than in the NP system (184,400 R$·$farm^{-1}$). The outcomes of this research suggest that IP is a promising system to improve GWP, land occupation, and operating profit, whereas CR has the potential to improve economic performance of whole farms in southern Brazil.

1. Introduction

Sustainable production of animal-source food has emerged at the top of the global policy agenda for two main reasons. First, the demand for animal-source food is expected to increase, due to population growth and changes in dietary patterns (Gerber et al., 2013). Second, production of animal-source food, such as beef, increasingly competes for natural resources and contributes to emissions of pollutants to the environment (Steinfeld et al., 2006; Gerber et al., 2013).

Brazil is one of the world's producers of beef and faces the above-described challenges (Pashaei Kamali et al., 2014). A number of studies have evaluated the environmental impact of Brazilian beef production (Cederberg et al., 2009; Dick et al., 2015a; Ruviaro et al., 2014). Several studies have assessed the potential of various strategies to reduce the environmental impact of livestock production in different countries (Vergé et al., 2008; Beauchemin et al., 2010; Wall et al., 2010; Bannink et al., 2011; Bell et al., 2011; Dick et al., 2015a; Ruviaro et al., 2014; van Middelaar et al., 2014a, b; de Vries et al., 2015). Two studies focused specifically on Brazilian beef production (Dick et al., 2015a; Ruviaro et al., 2014). These studies proposed several animal husbandry practices and farm management strategies to reduce environmental impact of beef production.

The feeding strategy is one of the main farm management strategies affecting environmental performance of beef production (Beauchemin et al., 2008). Adoption of alternative feeding strategies, however, might negatively affect farm profitability (Hristov et al., 2013). Any strategy that requires additional investments, which do not generate a positive net present value of cash flows is likely to be rejected by livestock producers (Beauchemin and McGinn, 2008; Hristov et al., 2013). Hence, there is a need to consider both environmental and economic performance in analyzing the impact of alternative strategies. Examples of this approach include Wall et al. (2010); van Middelaar et al. (2014b),

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and de Vries et al. (2015). van Middelaar et al. (2014b), for instance, investigated the cost-effectiveness of feeding strategies to reduce GHG emissions from Dutch dairy farming. An assessment of the environmental and economic performance of different feeding strategies for beef production in Brazil is currently lacking in the literature. In southern Brazil, cattle are able to continuously graze on natural pasture throughout the year. Grazing on natural pasture represents the traditional feeding strategy in southern Brazil. (Dick et al., 2015a; Ruviaro et al., 2014). Improved natural grassland or pasture is a relatively new strategy that is becoming popular in southern Brazil. This strategy is expected to increase grass productivity, and also beef productivity, implying environmental and economic benefits. Although this strategy is promoted by governmental extension agencies, its adoption rate has been low (Borges et al., 2014). Integration of crop and livestock production has been adopted recently in southern Brazil and several other regions in this country. Adoption of integration, however, differs in crop species, crop rotation, and rotation phases between crop and livestock farming. Finishing beef cattle based on concentrates, as in feedlots, is not common in Brazil. In 2008, only about 2.7 million animals, corresponding to 6.7% of slaughtered animals in Brazil, were kept in feedlots (Ferraz and Felício, 2010).

The objective of this study is to assess environmental and economic performance four feeding strategies in southern Brazil. Based on four feeding strategies, we defined four beef cattle farming systems: (1) cattle grazing on natural pasture (NP), (2) cattle grazing on fertilized pasture improved with winter grasses and legumes (IP), (3) cattle fed on crop residues and natural pasture (CR), and (4) cattle raised on natural pasture and finished in a feedlot (FL). Results of this study are useful for policy makers in Brazil to design policies to reduce the environmental impact of beef production without compromising operating profit and competitiveness.

2. Material and methods

2.1. Characteristics of feeding strategies and related farming systems

General characteristics of the four farming systems were based on data provided by an EMBRAPA[1] expert panel (Table 1). The EMBRAPA panel consisted of beef production experts, who were mostly farmers, farm advisors or farm assistants (Malafaia et al., 2014; Pereira et al., 2014). The expert panel provided data for the NP system in southern Brazil in 2012. These data covered the main characteristics of cattle farms in this region, e.g., average farm size, slaughter age and slaughter weight, calving rates, and pasture type. Cattle in this study were all assumed to be of the same breed. The NP system was assumed to be the reference system. System-specific data for IP, CR, and FL were based on literature (Table 1), since these systems are relatively new in Brazil and IP, CR, and FL cover very small percentages of beef production in Brazil. Hence, there were no farm, regional, or municipality data available for these systems.

The main feature of the NP system is the use of large areas of land with little or no subdivision, where continuous grazing is applied year-round, without any feed supplementation. In southern Brazil, natural pasture is dominated by *Paspalum*, *Axonopus*, *Briza*, and *Bromus* species, sparse shrubs, and trees (Dick et al., 2015a). No reseeding, fertilization, and liming are applied on natural pasture. Beef production and farm inputs were computed on an annual basis. Based on EMPRAPA data, we assumed that the NP system had an area of 1200 hectare (ha), which equals the average size of a beef cattle farm in southern Brazil. All farming systems were assumed to have the same land area. Cows were assumed to have an annual calving rate of 70%, and 20% of the calves were retained as replacement heifers. The average live weight at slaughter was 420 kg for females and 440 kg for males (Dick et al., 2015a, b). We assumed that all manure were deposited on pasture, as housing is not utilized for beef production in Brazil. We further assumed that the farming systems were all focused on the export market, which prohibits use of growth hormones, and therefore that growth hormones are not used. Pasture utilization efficiency was defined in this study as the fraction of dry matter (DM) produced on pasture that was actually consumed by cattle (Dick et al., 2015b). Feed intake from pasture was calculated by multiplying the area under pasture by the DM production per hectare and the efficiency of pasture utilization (Table 1). The stocking density was calculated from Dick et al. (2015a).

The IP system is similar to NP, except for its pasture characteristics. The natural pasture was assumed to be improved in IP by introduction of winter grasses (ryegrass and oat) and legumes (clover and birdsfoot trefoil), which improves the nutritional quality of pasture and DM production. Pasture production is especially improved in autumn and winter, and mitigates feed shortages during this period. In addition, rotational grazing is applied instead of continuous grazing to increase pasture quality and DM production (Dick et al., 2015a). Pasture production is also increased by fertilization and liming. Using clover decreases nitrogen (N) fertilizer requirements, as clover has a symbiotic relationship with nitrogen-fixing bacteria. Phosphorus (P) fertilizer, potassium (K) fertilizer, and lime were assumed to be applied (Table 2), but irrigation was not used (Dick et al., 2015a). In the IP system, the calf mortality rate was assumed to be lower than in NP (Dick et al., 2015a). Mortality may be reduced due to increased nutritional quality and pasture

[1] EMBRAPA: Brazilian Agricultural Research Corporation

Table 1
General farm characteristics of the four farming systems.

Farm characteristic	NP[a]	IP[b]	CR[c]	FL[d]
Area pasture (ha)	1200[e]	1200[e]	720[f]	1200[e]
Pasture type	Native[e]	Improved	Native[e]	Native[e]
Area crop land (ha)	–	–	480[f]	–
Yield soybean residues (t DM·ha^{-1})	–	–	2.4[g]	–
Pasture production (t DM·ha^{-1}·yr^{-1})	3[e]	11.5[f]	3[e]	3[f]
Efficiency of pasture utilization (%)	50[h]	70[h]	50[h]	50[h]
Calf mortality rate (%yr^{-1})	4[e]	1[f]	4[e]	4[e]

[a] NP = natural pasture.
[b] IP = improved pasture.
[c] CR = crop residue.
[d] FL = feedlot.
[e] Source: EMBRAPA.
[f] Expert opinion.
[g] Computed based on Pashaei Kamali et al. (2016).
[h] Dick et al. (2015a).

Table 2
Input of seeds, fertilizers, lime, mineral supplements, and concentrate feeds for the four farming systems.

Input parameters	NP[a]	IP[b]	CR[c]	FL[d]
Seeds (kg·ha^{-1}·yr^{-1})	–	Ryegrass: 20[e] Clover: 5[e]	56	–
P fertilizer (kg·ha^{-1}·yr^{-1})	–	50[f]	76	–
K fertilizer (kg·ha^{-1}·yr^{-1})	–	65[g]	76	–
Lime (kg·ha^{-1}·yr^{-1})	–	333[h]	2000	–
Mineral supplements (g·head^{-1}·day^{-1})	49	49	49	49
Pesticides (kg·ha^{-1}·yr^{-1})	–	–	6.5	–
Maize[i] (t·yr^{-1})	–	–	–	32
Soybean meal[i] (t·yr^{-1})	–	–	–	32
Sorghum[i] (t·yr^{-1})	–	–	–	32

[a] NP = natural pasture.
[b] IP = improved pasture.
[c] CR = crop residues.
[d] FL = feedlot.
[e] Reseeding is done every two years.
[f] Phosphorus (P) is applied every two years.
[g] Potassium (K) is applied every two years.
[h] Lime is applied every six years.
[i] Dry matter.