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Grazing supplementation and crop diversification benefits for southern Brazil beef: A case study

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ABSTRACT

Profitability and environmental benefits of beef cattle raised on natural pasture or combined with soybean in tropical biomes need to be better evaluated. The objective of this research was to simulate and evaluate three common pastured beef grazing systems in southern Brazil, estimating profitability and the environmental impacts of carbon footprint (CF) measured as kg of CO_2 equivalent per kg of body weight produced (BWP), water footprint (kg of water used/kg of BWP) and energy footprint (MJ of energy used/kg of BWP) using the Integrated Farm System Model version 4.2. Simulations were run for Angus beef cattle raised on natural pasture (NP), natural pasture with low levels of grain supplementation (NPS), and NPS combined with soybean production (NPSC). Net animal weight produced (kg/ha/year) increased 7.9% for NPS and NPSC when compared with the NP system. Natural pasture production costs per hectare were lower (US$ 114) than that of NPS (US$ 126) and NPSC (US$ 233), while NP had a net return per hectare only 2% greater than NPS. Even though the gross income from animal sales was 5% higher in NPS than NP, the elevated cost of purchased feeds reduced net return per hectare. While costs were higher for NPSC, diversifying with soybean production, a high value commodity for cash sale, was profitable resulting in 44% and 47% greater net return per hectare than NP and NPS, respectively. Natural pasture with low supplementation (NPS) decreased CF by 2% when compared with NP due to faster weight gain from supplementation despite higher emissions from feed production. Furthermore, CF was also 6% lower for natural pasture combined with soybeans (NPSC) compared with NPS. However, the energy and water footprints and erosion increased with the greater use of both purchased feed and inputs required for feed and cash crop production. It can be challenging to increase beef cattle productivity and diversification to lower GHG emissions while minimizing water and energy use and soil erosion.

1. Introduction

Beef cattle production is one of the most important agricultural systems in Brazil with 212 million head (IBGE, 2014) distributed over an estimated total pasture area of 174 million ha, mostly in extensive pasture. Due to its potential to produce food, the United Nations (FAO, 2010) indicates that Brazil is one of the countries with the greatest potential to meet 70% more global food demand by 2050.

The Brazilian beef industry is under pressure to mitigate climate change, particularly from cattle production which is responsible for ~25% of Brazil's greenhouse gas (GHG) emissions including methane (CH_4), nitrous oxide (N_2O) and other relevant gases (Cardoso et al., 2016). However assessing the environmental sustainability of a production system should not be evaluated solely by GHG per kg of meat or product produced, but also other impacts such as water and energy use (Ridoutt et al., 2014). Furthermore, for an agricultural production system to be considered sustainable, profitability is of paramount importance.

In the southern Brazil state of Rio Grande do Sul, beef production takes place on natural pasture in one of the six Brazilian biomes, the Pampa Biome, which extends to Argentina and Uruguay. Rio Grande do Sul has 14.3 million cattle, which is approximately 8% of Brazil's herd (IBGE, 2009). Pampa Biome beef production involves an extensive farming system that has about 450 grass species and > 150 legume

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species (Boldrini, 1997) characterized by high nutritional quality in spring and summer and low nutritional quality in autumn and winter. Therefore, it is important to determine the relationship between environmental impact, beef and crop productivity and net return or profit for different beef production systems in southern Brazil.

The objective of this research was to use a whole-farm modelling approach using the Integrated Farm System Model (IFSM) software (Rotz et al., 2015b) to assess the profitability and evaluate environmental impacts of three beef production systems in Rio Grande do Sul state in southern Brazil. This is the first time IFSM has been used to model beef production in Brazil. All three systems modeled involve beef cattle raised on natural pasture. The baseline system, using just natural pasture, is compared to two systems using low grain supplementation. While the second system involves no row crop production, the third system includes soybean production solely for cash crop sales.

2. Material and methods

Three beef production systems in Rio Grande do Sul state were simulated using the Integrated Farm System Model, version 4.2 (Rotz et al., 2015b). IFSM simulates pasture and crop growth, feed production and use, animal growth, and the deposition of manure nutrients from cattle to the land to predict the environmental impacts, production costs and profit of agricultural production systems (Rotz et al., 2005, 2013, 2015a,b). Animal care and use committee approval was not obtained for this study because no animals were used.

2.1. Collaborating farm

This simulation study was performed based on a farm located in the central region of Rio Grande do Sul state, in southern Brazil (S 30° 26′ 454″ W 53° 11′ 024″). The climate is subtropical humid "Cfa", according to the Köppen classification. Farm performance was simulated over 25 years (1988 to 2013) of observed weather data collected at the experimental station farm of Universidade Federal do Rio Grande do Sul (UFRGS) in Eldorado do Sul, located in the same central region, 151 km from the cooperating farm. The average maximum and minimum temperatures over these 25 years were 24.7 °C and 13.5 °C respectively, precipitation averaged 1545 mm/year, humidity 81.4%, global radiation was 15.1 MJ/m^2, and average annual wind speed was 1.7 m/s.

The cooperating farm has an Angus beef cattle production system including cow-calf, growing and finished cattle raised on natural pasture, winter pasture (*Lolium perenne* Lam), supplemented on pasture, and natural pasture with diversified rotation with row crops for cash sales. Five year average (2009–2013) production and financial data from this representative farm were used to set up three simulated production systems commonly used in this region. Although the cooperating farm is classified as large (> 500 animals) and beef farms of this size in Rio Grande do Sul make up only 1% of the ~346,000 beef farms in the state (De Sousa e Silva et al., 2014), the cooperating farm had the most comprehensive availability of the myriad of livestock and crop production and management data required to calibrate the IFSM model.

2.2. Simulated production systems

The three systems simulated were: natural pasture (NP), natural pasture with low supplementation of grain (NPS), and NPS combined with appended soybeans for cash sales, not used internally as feed (NPSC). Profits, carbon footprint measured as kg of CO_2 equivalent (eq) per kg of body weight produced (BWP), water footprint (kg of water used/kg BWP) and energy footprint (MJ of energy used/kg BWP) were evaluated for these three representative production systems.

The breed simulated was Angus with a herd composition of 921 cows (30% in first lactation), 193 replacement heifers, 698 stocker cattle, and 171 finished cattle. The number of animals was the same across all three simulations to reduce undesired variability during system comparisons. However, the days required for each animal to reach final live weight (450 kg; Table 1) was different under the three scenarios due to the differences in nutritional quality of diets. IFSM was set up for zero-forage balance to insure accurate comparison, i.e. pasture areas were set to provide no buying or selling of forage on average over the 25-year simulation period.

Table 1
Land area, growing period goals, forage to grain ratio, and level of supplementation for three simulated beef production systems in Rio Grande do Sul State, Brazil.

	Production systems		
	NP	NPS	NPSC
Land area (ha)			
Native pasture	2100	2100	2100
Soybean	–	–	442
Growing period goals (months)			
Age of weaning	7	7	7
Stocker period	11	9	9
Finishing period	11	2	2
Forage to grain ratio	High	High	High
Supplementation level	No	Low	Low
Protein supplementation (% of recommended)[a]	0	95	95
Weight (kg)			
Body weight entering finish period	360	380	380
Final finish body weight	450	450	450

[a] Percent of that recommended to meet requirements of each animal group (NRC, 2016).

The NP simulation used 2100 ha of natural pasture with a pasture utilization efficiency of 60%. The animals were fed with essentially no protein or energy supplementation (Table 1). The growing periods were: age of weaning (7 months), stocker period (11 months), and finishing period (11 months). Fertilizer was not used on pasture. The tractor used for the model farm has 108 hp. (80 kW) at a price of US$ 73,350. The initial investment of perimeter fence was US$ 53,000 with temporary fence valued at US$ 1462. Simulations assumed a machine shed valued at US$ 50,000 and a feed storage shed at US$ 40,000. All other important costs and economic parameters are summarized (Table 2).

NPS also used 2100 ha of natural pasture with a pasture utilization efficiency of 60%. Cows, heifers, stockers, and finished cattle were fed at a supplementation level to meet 95% of recommended protein requirements (NRC, 2016; Table 1) and the weaning period was the same as NP with the stocker and finishing periods reduced to 9 months and 2 months, respectively. Grazing management, initial capital (equipment and building) costs, input costs, commodity prices, capital depreciation schedules and fertilizer prices were the same as the other systems (Table 2).

The NPSC system used the same cattle management, pasture operations and supplementation as the NPS system, however, 442 ha of soybeans were cultivated for cash sales as grain for a total area of 2542 ha. The crop land was rotated with the pasture providing some additional fixed N for pasture growth.

Soybean was planted on or soon after October 25th with a 12-row planter (9.1 m; initial cost US$ 53,100) and the same tractor used in NP and NPS. Fertilizer and chemicals were applied on 15-Oct, 14-Nov, 4-Dec, 20-Dec and 13-Jan. The sprayer with a 9.1 m wide boom (US$ 5850) was attached to the same tractor used for the other operations. Soybean harvest was March 10th using a small, 6-row combine (US$ 240,000). The macro-nutrient fertilizer cost (US$/ha) were lowest for nitrogen (US$ 14.49/kg at 15 kg/ha), highest for phosphorus (P_2O_5) (US$ 91.43/kg at 90 kg/ha) and intermediate for potassium (K_2O) (US$ 34.12/kg at 45 kg/ha). The lime cost was US$ 142.91/ha (3693 kg of $CaCO_3$/ha every 3 years). Seed and chemicals were US$ 128.80/ha. Other financial parameters are summarized in Table 2.

The soil used for all systems was a chromic luvisol with a low