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Life cycle assessment of beef cattle production in two typical grassland systems of southern Brazil

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ABSTRACT

The importance of animal production in the overall context of human activity is undisputed and influences food supply, job security, income producing, as well as landscape and local ecosystems conservation. This relevance enhances the charges by society as the environmental impacts of various activities, especially in relation to ruminant production amid the current problems of climate changes. In this context, we analyzed the main environmental impacts of two typical beef cattle production systems from southern Brazil, namely the extensive system (ES) and the improved system (IS), and identified the components that have the greatest environmental impacts using the life cycle assessment method. The basis of the system construction was a cattle herd that originated from 100 weaned heifers, four weaned calves, and the progeny of these cattle during their productive life (12 years), and the land areas, external inputs, and other natural resources and technologies necessary to the operations. The functional unit was the production of 1 kg of live weight. The values of greenhouse gas emissions, land use, and freshwater depletion in the ES were higher compared with those values obtained for the IS (22.52 and 9.16 kg CO_2 equivalents; 234.78 and 21.03 m^2a; and 0.217 and 0.0949 m^3, respectively). These variations were attributed to the permanence time of the animals in each system and to the quality and production of the pastures. The ES presented lower potential impacts than the IS on metal depletion and soil acidification (0.000519 and 0.0536 kg Fe equivalents; and 0.0028 and 0.0038 kg SO_2 equivalents, respectively) mainly due to the pasture improvement practices and the salt supply to the animals. Moreover, the values of freshwater eutrophication and fossil depletion were higher in the ES than in the IS (0.00383 and 0.00219 kg P equivalents and 0.0042 and −0.1255 kg oil equivalents, respectively). While the pasture nutrient loss from runoff and leaching defined the values of eutrophication, the introduction of legumes compensates the use of fossil fuels. The diversity of the results provides a better understanding of the environmental impacts of different production systems and of regional singularities.

1. Introduction

The recent environmental problems present negative consequences for humanity and have alerted different agents and sectors of society to the finiteness of natural resources. Although these consequences have been touted for a few centuries, these questions have only recently been assimilated as equally or more important than the economic performance of activities. Discussions on the sustainability of different human activities have been highlighted (Robèrt, 2000), especially with regard to beef cattle production and the impacts of this activity on plant-animal dynamics (Blanco et al., 2007; Medeiros et al., 2007; Pedroso et al., 2004; Santos et al., 2006) and to global warming, acidification, eutrophication, and resources use.

To select the most appropriate production practices, an analysis of the sustainability of the systems are necessary. Tools that can determine whether different activities have adequate sustainable development principles can facilitate this analysis. Production activities should be environmentally correct, socially just and economically viable (Robèrt, 2000). To evaluate production systems based on these principles, the life cycle assessment method (LCA) can be used, due to amplitude with respect to categories and

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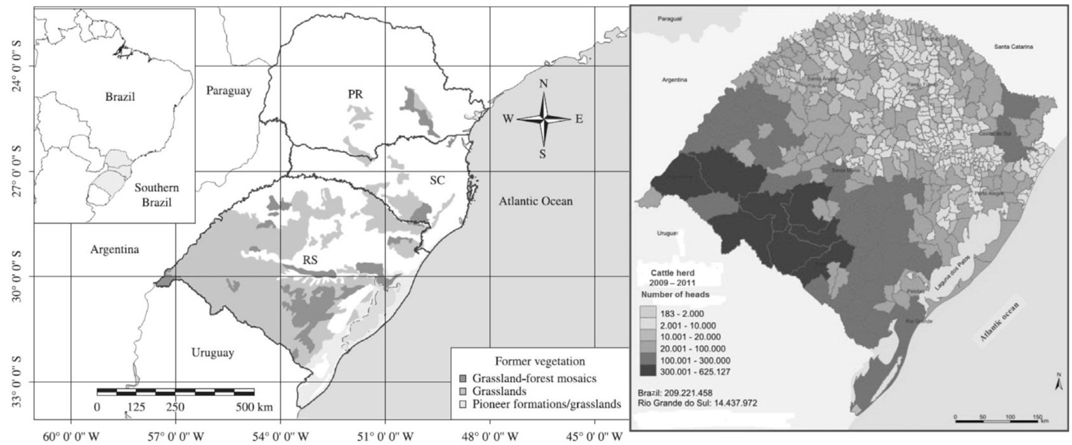

Fig. 1. Region characterized.
Source: Pillar et al. (2012) and IBGE (2011).

indicators of environmental impact, global spread, and scope (Goedkoop et al., 2009). Some works have applied LCA on different beef production systems (Beauchemin et al., 2010; Nguyen et al., 2010; Ogino et al., 2007, 2004) or scenarios (Beauchemin et al., 2011). Factors such as the geography and the adopted time scale (Casey and Holden, 2006) punctuate the flexibility of this analysis and the care necessary for interpretation.

In Brazil, farming systems occupy approximately 160 million hectares (IBGE, 2012) and are home to the largest commercial cattle herd in the world. The herd is maintained almost exclusively on pasture with a negligible use of external inputs to production units. The southern Brazil has practiced cattle farming since its colonization, and the economy is heavily based on primary cattle production. The region is in a privileged position, the climatic conditions are favorable for keeping the animals in pastures year around, but nevertheless no LCA studies on whole farm level has so far been developed for a regional beef production (Ruviaro et al., 2012).

This work analyzes the main environmental impacts of two typical beef cattle production systems from southern Brazil: the extensive system (ES) and the improved system (IS). Additionally, it identifies the components and processes that have the greatest environmental impact in terms of (a) global warming, (b) land use, (c) freshwater depletion, (d) metal depletion; (d) fossil depletion, (e) terrestrial acidification and (f) freshwater eutrophication.

2. Methods

Life cycle assessment (LCA) has been described by the definitions of standards ISO14040 (2006) and ISO14044 (2006). Our analysis involves different levels of organization, which are limited to environmental aspects, and does not consider social and economic issues.

2.1. The system boundaries and functional unit

According to IBGE (2011), the southern Brazil has a cattle herd of 27.98 million head, and more than half of these are found in Rio Grande do Sul State, particularly in the Pampa biome (Fig. 1). In this biome, the dominant vegetation is natural grasslands with predominant *Paspalum, Axonopus, Briza and Bromus species*, sparse shrubs and trees. The climate is humid subtropical with well-defined seasons. The frequent soil types are Mollisols, Vertisols and Ultisols, and these are usually well drained with limitations due to low natural fertility, acidity and susceptibility to erosion and degradation. We simulated the representative properties in this ecoregion, which is localized between 29°30′ and 32°30′ south latitude and 52°10′ and 57°40′ west longitude.

The LCA was conducted over several years in order to represent the emissions of the entire cycle, as well as of all components of the beef production. The systems include the following: animals; native grassland and pastures improved by the introduction of winter grasses (ryegrass and oat) and leguminous (clover and birdsfoot trefoil); potassium and phosphorous fertilization, liming, and mowing; supplementation (common and mineral salt); and the resources used to produce these components (minerals, fuels, etc.) and; the transport of different materials, both externally and internally, to the production unit (Figs. 2 and 3). Emissions associated with capital goods (machinery, buildings, etc.) and medicines were not considered.

In the description of the pastures, we considered issues related to the occupation and transformation of land, the energy used to forage production, the mineral flows and other substances that exert potential impacts on environmental parameters. With respect to the water supply to the animals, data related to the use of natural water in the extensive system and the use of troughs in the improved system was considered. In this case, the energy required for water distribution was added to the process. In regard to common or mineral salt supplementation, data were computed on the raw materials, their transportation to the production unit, and on farm supply. The energy used, the estimated impact of the materials, the mechanized operations, and the transportation of the

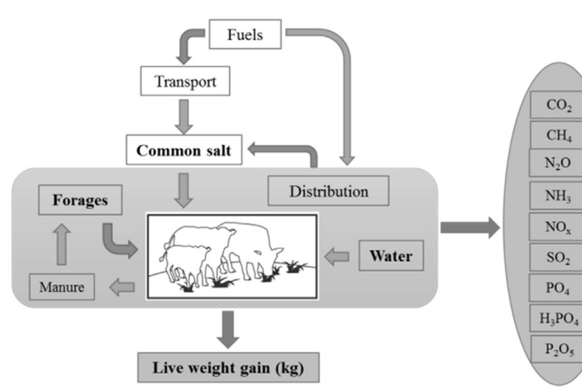

Fig. 2. Systems boundary – extensive system.