Available online at www.sciencedirect.com
ScienceDirect
Agriculture, Ecosystems and Environment 119 (2007) 383–395
Agriculture Ecosystems & Environment
www.elsevier.com/locate/agee

Emergy evaluation of grazing cattle in Argentina's Pampas

G.C. Rótolo [a,*], T. Rydberg [b], G. Lieblein [c], C. Francis [c,d]

[a] National Institute of Agricultural Technology, Agricultural Experimental Station Oliveros, Route 11, km 353, 2206 Oliveros, Argentina
[b] Swedish University of Agricultural Science, Box 7047, SE-75007 Uppsala, Sweden
[c] Norwegian University of Life Sciences, P.O. Box 5003, 1432 Ås, Norway
[d] University of Nebraska Lincoln, P.O. Box 830910, Lincoln, NE 68583-0910, USA

Received 18 December 2005; received in revised form 8 August 2006; accepted 16 August 2006
Available online 5 October 2006

Abstract

Argentina has a tradition of grazing livestock and the Pampas region produces 61% of the total beef cattle, with more than 80% allocated to internal consumption. Potential for expanding exports has created incentives for increasing production, yet national decisions should include an assessment of natural resources and environmental impacts of the grazing system. The aim of this study was to evaluate the complete system of grazing cattle in Argentina's Pampas in an environmental and economic context. Emergy analysis is used to assess the potential for long-term, sustainable cattle production including indicators of performance and environmental sustainability, with focus on all sources of input energy and the energy value of outputs. Rainfall contributes 61% of the total emergy to the grazing system. Natural pasture depends most highly on local renewable resources (85%) and less than 4% on purchased inputs. In contrast, sowed pasture and maize are 41 and 35% dependent on purchased inputs. Results showed the grazing system to be environmentally sustainable with a low impact on the environment. Yet specific subsystems where grazing cattle depend for part of the cycle on improved sowed pasture or on maize have a relatively high dependency on external inputs and moderate use of local non-renewable resources. Natural pastures have the highest environmental sustainability and the lowest load on the environment, due to low losses of soil organic matter. Appropriate management strategies are available for grazing livestock systems, yet government regulations need to provide incentives to ensure future production stability and economic returns while minimizing adverse effects on the environment. One method to achieve this is recognizing and rewarding farmers for the emergy contributions of the environment.

Keywords: Beef production; Pastures; Ruminant management; System evaluation; Production efficiency

1. Introduction

The sound management of natural resources and development of procedures for the integrated study of human and natural processes are among the most important and complex problems facing humanity (Brown et al., 1995). One large challenge is to include an assessment of natural resources and environmental impact during the evaluation of agricultural production activities. Neither the discipline of economics nor ecology alone adequately addresses the problems that world society currently faces (Brown et al., 1995). It has been difficult to deal with the consequences for nature and society with narrow disciplinary strategies and techniques. It is necessary to use a wider approach that combines biophysical and social methods and criteria, recognizing them as critical elements of the whole system (Brown et al., 1995; Ikerd, 2005).

Emergy analysis is an environmental accounting method based on a holistic systems concept, and includes tools to evaluate a system considering both nature and society, where human society is coupled and evolving within its natural context. Emergy is defined by Odum (1996) as the available energy of one kind that has already been used, directly or indirectly in each step, to make a product or provide a service. Emergy analysis was developed as a tool to inform

* Corresponding author. Tel.: +54 3476 498 010/011/021x52; fax: +54 3476 498 804x29.
E-mail addresses: gloriarotolo@yahoo.com.ar, grotolo@correo.inta.gov.ar (G.C. Rótolo).

0167-8809/$ – see front matter © 2006 Elsevier B.V. All rights reserved.
doi:10.1016/j.agee.2006.08.011

environmental policies and to evaluate quality of energy resources in the dynamic of complex systems (Brown and Ulgiati, 1997). In agriculture, emergy analysis has been used in studying agroecosystem behavior as a whole. It has been applied in evaluation of the efficiency of resource use in different production systems (Andresen et al., 2000; Lagerberg, 2000; Beck et al., 2001; Bastianoni et al., 2001; Lefroy and Rydberg, 2003; Ortega et al., 2003; Martin et al., 2006). It has also been applied to evaluate different size and scales of equipment on farms such as traction from horses or tractors (Rydberg and Jansén, 2002) and the ecological integrity and ecosystem health (Campbell, 2000).

Livestock production is the world's largest user of land either directly through grazing or indirectly as a source of fodder and feed grains (Steinfeld, 2004). It is an important activity in sustainable agricultural practices linked to cultural traditions and an important food source. There is an expected growth in livestock production in developing countries as incomes rise and meat consumption increases.

Argentina is the fifth largest producer of cattle in the world, contributing 2.5 million tonnes or 4.7% of world production (FAO, 2002). Nearly all the cattle are raised through grazing, with only 1.2% finished in corrals (INDEC, 2002). A majority of the cattle slaughtered is consumed domestically, 87% in 2002 (FAO, 2002), although in recent years Argentina has been pushed to expand exports in fresh meat from cattle.

Grazing through the whole year produces meat with less cholesterol than the meat produced through feedlot (García et al., 1996). Opportunities for export meat produced through grazing are appealing to farmers and the government, and efforts to increase production have been growing (Latimori, 2004). Several studies examined the use and management of natural resources through grazing with minimal external inputs, assessing productivity, profitability and/or sustainability. Examples include analysis of use of specific natural resources (García and Santini, 1996; Agnusdei et al., 2001), efficiency of fossil energy use (Gingins and Viglizzo, 1981), environmental impacts (Viglizzo and Roberto, 1997; Viglizzo et al., 2001), or production stability (Viglizzo and Roberto, 1985).

This study was designed to evaluate the grazing cattle system in Argentina's Pampas within the region's environmental and economic context. Emergy analysis is used to assess the environmental support for cattle production and then calculate indicators of performance and environmental sustainability. This analysis provides an insight on what factors are important to maintain the current system and what practices should be modified. We also provide results that indicate why decision makers should seek strategies to recognize ecosystem services and ensure the future economic welfare and environmental integrity of the region.

2. Materials and methods

2.1. Study location and grazing system

The complete cycle of grazing cattle for meat production in Argentina's Pampas Region was chosen for study. The Pampas, in the central-eastern region, produces 61% of the beef cattle in Argentina and includes 65% of the farms dedicated to livestock, of which 35% run the complete production cycle (SENASA, 2002).

2.1.1. Climate, soils, and vegetation

Rainfall ranges from 1200 mm year^{-1} in the eastern part to 500 mm year^{-1} in the west (Garbulsky and Deregibus, 2004). The region enjoys a temperate climate, where autumn and spring are rainy but there is often lack of rain during summer (Castaño, 2003). The average temperatures are from 6 to 10 °C in winter to 21 to 26 °C in summer, thus there are 60–120 days where forage production is very low (Castaño, 2003). Soils are mainly Molisols, with a deep accumulation of loose, windblown materials (loess), resting upon granite and other ancient crystalline rock, mostly free of stones (Soriano, 1992). The land is flat with some undulations in the northeast, some hills in the southeast, and a big depression in the Salado river basin (Soriano, 1992). The vegetation structure corresponds to a prairie in humid years and to a pseudo-steppe during dry periods, but autochthonous species have been substituted by meadow and crops (Soriano, 1992; Ruiz et al., 2000).

2.1.2. Grazing system

The study system was the livestock component within an 11-year rotation of mixed production (6 years cropping–5 years livestock) as shown in Fig. 1. The prototype system for study was a farm that had a size of 500 ha, average for the Pampas Region (INDEC, 2002). On this farm, 300 ha are sowed in cropping each year and 40 ha sowed to annual pasture or winter cereal for grazing. As the focus of attention for this study is cattle for meat production, cereal grain for sale is not considered as an output of the system, but the maize (*Zea maize* L.) subsystem was evaluated since it is a feed for the animals.

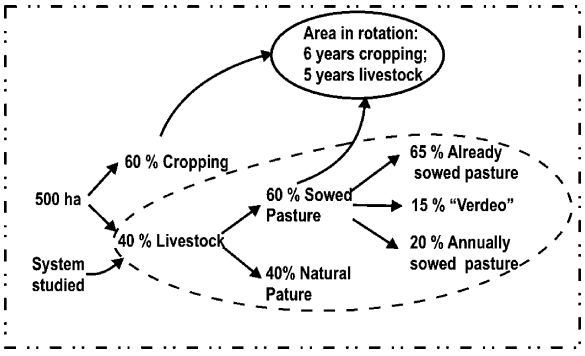

Fig. 1. Overview of land utilization system with grazing cattle and cropping system (*verdeo* refers to cattle grazing cereals in winter).