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Efficiency and stability in subtropical beef cattle grazing systems in the northwest of Argentina

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ABSTRACT

The objective of this work was to evaluate the efficiency and stability of cow–calf, fattening and whole cycle beef cattle agro-ecosystems from the subtropical region of Argentina. For this purpose, an agro-ecosystem model consisting of a production and a management system was developed. Flexible management rules were incorporated. This simulation-based study compared potential trends of different agro-ecosystems under different animal body sizes and several management options traditionally applied in the region. The experiment aimed at estimating productive, energetic and economic efficiency and stability. The results showed that whole cycle and cow–calf systems were more stable but less productive than fattening systems. Within each agro-ecosystem, as body size increased, energetic and economic efficiency and stability decreased. Systems dynamics and multi-criteria approaches allowed recognizing tradeoffs among indicators, and main differences between agro-ecosystems. Further investigation is required to generalize these findings to other system structures, particularly when economic aspects are taken into account in decision making processes.

1. Introduction

Given the complexity of animal production systems in subtropical and semiarid regions, scientists are increasingly relying on the use of simulation models as decision aids (Diaz-Solis et al., 2006). These agro-ecosystems include a myriad of important variables including climate, soil, and vegetation, as well as current range productivity, stocking rate, and market conditions, all of which influence management decisions. In the sub-humid and semiarid rangelands of northwestern Argentina, characterized by high rainfall variability, producers operate cow–calf, fattening and whole production systems. An issue for agriculture in many variable environments may be whether the best adaptive strategy is to choose a more specialized system or a system with greater diversity (Browne et al., 2013). This choice determines the structure and therefore the behavior of the system (Morecroft, 2007; Sterman, 2000). The behavior of a system can be described by emergent properties like efficiency and stability (Feldkamp, 2004; Viglizzo and Roberto, 1998).

The question for beef cattle systems of the northwest of Argentina is: which agro-ecosystem structure shows better behavior as measured through its efficiency and stability? A multi-criteria approach considering productive, biological and economic aspects is necessary to assess this complexity (Giampietro, 2004).

The environment has a strong influence on beef cattle efficiency and stability, although there is little consensus regarding the existence of optimal mature cattle body size for specific production environments. Cattle size, maturing rate and milk production are important parameters in beef cattle production (Pang et al., 1999). The existence of optimal body size for specific environments has been investigated by numerous authors (Dickerson, 1970; Echols, 2011; Johnson et al., 2010). Body size can be represented by the frame size as a set of size-age points that gradually change in a particular animal until reaching a plateau at maturity (Arango and Van Vleck, 2002). Frame size is directly correlated with weight at maturity, animal growth rate, feed intake, nutritional requirements, reproductive efficiency, age at puberty, birth weight, pre-weaning gain and weaning weight (Menchaca et al., 1996; Olson et al., 1982; Vargas et al., 1999). With highly variable and dynamic physical and economic environments, one may consider variability of cow size as an asset to cow–calf producers (Echols, 2011).

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Lack of consideration of the type of agro-ecosystem, the environment and the frame size effect could restrict the improvement in efficiency and stability of beef cattle agro-ecosystems in Subtropical regions.

Thus, the objective of this work was to evaluate the efficiency and stability of cow–calf, fattening and whole cycle beef cattle agro-ecosystem from the subtropical region of Argentina. For this purpose, a dynamic simulation model was used to compare potential trends in performance of the systems under different frame scores and several management options traditionally applied in the region.

2. Materials and methods

2.1. Study area

Beef cattle agro-ecosystems in the northwest of Argentina are highly varied, ranging from extensive pastoral systems dominated by smallholder producers and semi-subsistence production, to large-scale, commercially oriented industrial production systems. The rainfall regime varies in space and time, determining occasional extreme conditions of droughts and floods over wide areas. Annual precipitation varies from 300 to 1000 mm. Grazing systems based on tropical pastures is a distinctive feature in medium and high intensified systems in the northwest of Argentina. Main tropical grasses used are: *Chloris gayana*, *Panicum maximum* and *Cenchrus ciliaris* (Ricci, 2006). Mostly, beef cattle systems keep all animal categories on pastures. Hay, silages and grains (as concentrates), and, to a much lesser extent, industrial feeds or by-products are provided, particularly when pasture availability, quality, or both do not meet animal consumption needs or nutrient requirements (Arelovich et al., 2011). Braford and Brangus biotypes are extensively used to increase the productivity of cattle in subtropical areas. Most farms perform whole-cycle production, running the cow–calf operation and finishing the animals in the same area. Carrying capacity of these agro-ecosystems typically ranges from 0.3 to 2 AU/ha. The degree to which this general description fits into agro-ecosystems varies from farm to farm.

For this study a database from the Animal Research Institute of Semiarid Chaco (IIACS) which belongs to the National Institute of Agriculture Technology (INTA, Argentina), was used. The data set included information that referred to different agro-ecosystems (cow–calf, fattening and whole cycle), climatic records (1973–2012) and soil characteristics of the systems considered. Main information of these agro-ecosystems include animal body weight, animal growth rate, body condition score, forage growth rate, total forage growth, forage quality, stocking rate, forage management, herd management, inputs (i.e., feed concentrates) and main outputs. The information covers the Depressed Saline Plain of the Province of Tucumán (Argentina). The mean annual precipitation is 880 mm (concentrated from October to March) with an inter-annual coefficient of variation of 35%. Mean monthly rainfall and standard deviations are shown in Fig. 1. Mean annual temperature is 19 °C, ranging from 25 °C in January to 13 °C in July. The climate is subhumid with a well-defined dry winter season (April to October).

2.2. Model overview

The model developed is deterministic, so that its outputs are primarily the result of the initial farm conditions, weather inputs during the simulation sequence, and the farm management strategy (Romera et al., 2006). The only stochastic components in the model are weather, pregnancy length, aborts and deaths. It allows the simulation of the stages of breeding, stocking and fattening either independently or as an integrated process within a production system. The agro-ecosystem model consists of a production and a management system (Feldkamp, 2004). The first part comprehends biophysical processes, named pasture growth, soil–water availability, animal growth, animal reproduction and animal feed intake. The second part of the agro-ecosystem model includes processes regulated by human intervention, i.e., management model (Fig. 2). We adapted several preexisting submodels: forage (McCall and Bishop-Hurley, 2003); animal (Feldkamp, 2004); feed intake (Freer et al., 1997) and soil–water (Cros et al., 2003).

The management model uses environmental and system information to evaluate criteria regulating the flows and determining the occurrence of processes. Therefore, the management model acts as a link between the production system, the inputs and criteria given by the user into the agro-ecosystem model (Feldkamp, 2004). The model is driven by decision rules entered by the user, which allows the representation of many different kinds of management options that respond to changing farm conditions (Romera et al., 2004).

2.3. Simulation model

The modeling methodology used to develop the mathematical model was system dynamics (Morecroft, 2007; Sterman, 2000), and it was programmed using Powersim Studio 8® model development platform. Powersim Studio 8® is an object-oriented graphical programming language designed specifically for modeling dynamic systems (Costanza et al., 1998; Smith et al., 2005). It requires identifying the system's variables, named stocks, flows, auxiliaries and constants; and establishes the appropriate connections among them. Variables defined as indexed variables or arrays hold several values, and their dimension and structure are defined by the user introducing the range and/or the sub ranges of the array. The array feature allows representing individual objects with particular attributes,

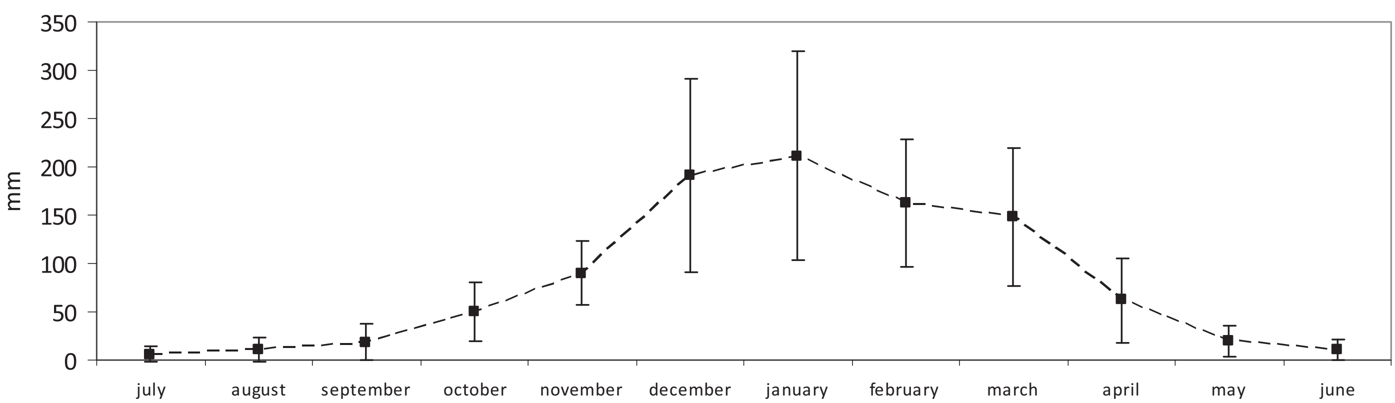

Fig. 1. Monthly mean precipitation (mm) for the series 1973–2012 in the Depressed Saline Plain of Tucumán Province (Argentina). Whiskers show ± standard deviation.

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