Running head: Computer models for beef systems. Using computer models to assist planning beef production: experiences in Brazil*

Uso de modelos de computadora para ayudar a planificar la producción de carne: experiencias en Brasil

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Summary

Brazil is a major beef producer and exporter with most of its production obtained from tropical grazing systems based on *Urochloa* (*Brachiaria*) pastures and Nellore (*Bos indicus)* animals. Despite of major differences to the production systems of developed countries, adaptation of foreign models has been the most successful strategy to develop our own decision support systems (DSSs). In Brazil, DSSs have been more straightforwardly developed and adopted in feedlot operations, probably due to the easier tuning of the available models and the better information and control related to feedlots. An example of successful Brazilian computer model for feedlots is RLM, which includes a model of animal growth based on NRC adjusted for Nellore and crossbred animals. Further, RLM includes a modified feed intake equations, a Brazilian feed library and diet optimization methods for least cost of dry matter or minimum production cost. The development of computer models for our grazing conditions has been comparatively slower. Greater changes in model structure and parameter values were required as most process-based grazing system models have been developed based on temperate or rangelands pasture species. Brazilian research on pasture production, feed intake and diet selection seems more distant to modeling, possibly due to the absence of a reference model to help driving the experimental procedures. From the manager perspective, planning occurs on a longer time horizon in grazing systems and much more risk is associated to the effects of variable climate conditions on the dynamics of pasture production and quality. Besides, higher costs and lower accuracy in monitoring the pasture may also discourage adoption. However, great interest by the Brazilian extensionists and farmers has been perceived for Invernada, a dynamic DSS model recently released Brazilian for grazing systems. Experiences with Invernada training courses indicated that adoption may be slowed down due to the higher complexity of this tool compared with feedlot DSSs and due to the lack of acquaintance of the users with other similar tools. Drivers and future options for the development of DSSs for beef production are discussed.

Key words: computer models, livestock planning, beef production, feedlot, grazing systems.

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Introduction

Managing beef production systems aims at making the best use of resources to achieve an objective (Parker et al., 1993) or the maximum satisfaction of the owner (Olson, 2004). According Keating and McCown (2001) Management System is a key component of farming systems and is defined as a compartment which monitors and fit controlled inputs and outputs of Production System. Computer-based decision support systems (DSSs), are tools that may provide valuable information from data available in order to improve and facilitate management (e.g. Donnelly et al., 2002; Cros et al., 2004; Sorensen et al., 2010).

The wide availability of personal computers today have turned applicability of DSS feasible for on-farm decision making, although adoption rates are still limited in relation to the original expectations (McCown, 2002; Sorensen et al., 2010). There are, nevertheless, perspectives of new challenges and opportunities for DSSs as result of the fast and continue development of monitoring tools (particularly remote sensing and other on-farm electronic sensors), databases and computers. It is even expected that information and decision support systems may become essential as the scope and complexity of farm management growths with new environmental issues and technological options (Sorensen et al., 2010).

One of the approaches most widely applied to develop DSSs for planning purposes is mathematical modeling, particularly applications of mathematical programming and process-based dynamic models.

Until the 90's, about all computer-based tools for on-farm beef decision support were developed by teams in North America, Europe and Oceania. The adoption of those foreign tools was negligible in Brazil, particularly regarding dynamic simulation models of production processes. The NRC system (NRC, 1996) and diet optimization software were, however, successfully adopted by nutrition companies and consultants in Brazil.

It was only in the late 90's that software for ration balancing and animal performance predictions on feedlots were developed and released in Brazil [e.g. RLM (Lanna et al., 2011); Super crac (TDSoftware)]. A grazing system model for the Brazilian conditions became available just in 2011, with the release of Embrapa Invernada.

Nowadays, RLM is the DSS most used by feedlot beef cattle industry in Brazil (Millen et al., 2009; C. Costa Júnior, University of São Paulo, 2011, personal communication). Furthermore, over 2.200 users made download of Embrapa Invernada since their publication in February 2011. Experiences with RLM and Invernada development and adoption will be further discussed in the following sections.

Decision support for feedlots

Models to calculate nutritional requirements and optimize ration formulation are among the best examples of successful decision support tools in beef production. Input data required (e.g. animal breed, live weight, gender, feed composition, etc) was available at low cost and time demand besides having an acceptable of precision. Also those systems were very consistent with the existing knowledge of nutrition taught in universities. Despite the language barrier, some models, particularly the NRC for beef cattle (NRC, 1996), were found to be useful and widely adopted by nutritionists.

Those models require feed composition data, which would imply in higher costs and time demand. However, DSSs as the NRC for beef cattle software soon integrated feed libraries with expected nutritional values for a collection of feeds. Although the original NRC feed libraries included most of the feeds used in the Brazilian feedlots it was not complete. Brazilian bromatological laboratories have then provided feed standards for conditions (Tedeschi, et al., 2002; Valadares Filho et al., 2002). Valadares Filho also developed tables of feed composition available online with regular updates (available at http://cqbal.agropecuaria.ws/webcqbal/index.php).

Experiences with the NRC beef nutritional requirements model in Brazil made identification of opportunities for software development and change requests quite clear. Among them were incorporating tropicalized feed library and model parameters and a friendlier user-interface in Portuguese.

Supercrac and RLM (Rações de Lucro Máximo - Maximum profit rations, with versions in Portuguese, English and Spanish – Lanna et al., 2011) are two DSSs which can be reported successful cases in the Brazilian market. Supercrac focus on least dry matter cost ration formulation which implements the NRC model for estimation of nutrient requirements (i.e. optimization constraints). RLM includes, besides least dry matter, least production cost optimization through parametric linear programming (Glen et al., 1980). This is very important when defining most profitable diets in a wide range of grain/roughage prices ratios (Lanna et al., 1999).

RLM also made adjustments to the NRC model, particularly for Nellore animals, including a re-parameterized dry matter feed intake equation (DMI, Almeida, 2005). The resultant DMI equation [DMI (kg/d) = $(SBW^{0.75}*(0.2039*NE_m - 0.03844*NE_m^2 - 0.07376))/NE_m$] was modeled using meta-analytical data from animals evaluated in experimental institutions. Sequentially, the DMI equation was evaluated using a different data set from Nellore young bulls. The Almeida equation accounted for 77.2% of variation in actual DMI and had less overprediction bias compared with NRC 1984 and 1996 equations (1.3% vs. 6.1 and 3.2%). Further, actual intakes and the predicted estimates did not differ from each other (based on *t* test, p>0.10).

According to NRC (1996) fat provides small quantity of energy to the rumen microorganisms, thus TDN correction it is necessary when fat level is highest than 3.5% (DM basis). RLM includes TDN fat fit (TDN_{fit}) to predict more accurately the bacterial crude protein synthesis (BCP), as follow: TDN_{fit} (%) = TDN – (Fat – 3.5)*2.25, and BCP (g/d) = (13%*NDT_{fit}*DMI*10)/100. In the previous equations, TDN is multiplied by the factor 2.25 to diets with fat concentration highest than 3.5%, and 13% is assumed to BCP synthesis averaged percentage, according to NRC, respectively.

Most recently, Hoffman (2007) evaluates RLM updating the model considering: Almeida DMI equation; Brazilian feed library, maintenance energy requirements fit (differences of *Bos indicus* and crossbreeds, previous nutrition over compensatory gain, ionophores and antibiotics). RLM updated was evaluated using independent experimental results published in Brazilian Journals (n = 21) and commercial feedlots (n = 892 pens) of Brazilian Central Region to two features: DMI and shrunk daily BW gain (SBWG). In general, RLM accounted for 67 or 68 and 30 or 53% of variation in actual DMI and SBWG in experimental or commercial situation, respectively. Moreover, RLM predicted data in experimental and commercial feedlot situation had equal or less bias compared with NRC (1996) for both features evaluated. According Hoffman (2007) in commercial feedlots, the SBW bias probably was influenced by orts, compensatory gain and frame size. In order to exemplify the orts influence over bias, when the SBW was predicted from data set with "real" DMI (i.e. removing orts) the residual was improved (SBW observed = 1.35, SBW predicted on DMI observed = 1.49, and real DMI = 1.37). Nowadays, RLM penetration in the feedlot industry is associated to several features, but parameterization in order to improve the model accuracy and precision based on experimental studies is extremely relevant.

Decision support for grazing systems

Modal Brazilian beef production systems present major differences to those of developed countries where most DSSs for grazing systems were developed. Tropical pastures are the base of feeding, comprising over 95% of the total dry matter intake of the herd (Bürgi and Pagoto, 2002). According to the Brazilian National Institute for Geography and Statistic (IBGE), based on the 2006 Agricultural Census data, Brazil has over 172 million ha of grasslands, more than 140 million ha allocated to beef animals (Ferraz and Felício, 2009). Extensive low-input systems predominate (Ferraz and Felício, 2009), with average stocking rates is around 1.08 heads/ha (IBGE, 2011). Grasses of the *Brachiaria* (*Urochloa*) genus are predominant in the pastures. *Panicum*, *Cynodon* and *Penisetum* grasses are adopted in some regions, particularly in the most intensive systems. Zebu breeds, predominantly Nellore, have major contribution to the Brazilian beef cattle genetics (Pereira, 2004).

Some of the particularities of the Brazilian livestock production have been reported as reasons for its competitive production costs (da Silva and Sbrissia, 2000; Ferraz and Felício, 2010). However, these differences also hamper the as-is adoption of DSSs from developed countries. This resulted in the absence of important cases of adoption of foreign DSSs for beef grazing systems up to date.

The Invernada DSS (Barioni et al., 2011a) was developed targeting this gap. It aims at helping farm consultants planning beef production in the stocking and finishing phases and addresses decisions at the tactical level. However, during model development, several issues related to adapt models to the Brazilian conditions were faced.

The main knowledge barrier to the development was modeling pasture production and selective grazing for the major pasture species [*Brachiaria* (*Urochloa*) spp., *Panicum* spp., *Cynodon* spp. and *Penisetum* spp.]. Although Soto (1981) had adjusted thermal sum models for *Panicum maximum* and *Paspalum atratum*, no other important development was made in the 80's and early 90's. It was only the 2000's that a reliable set of information became available for the main pasture species cultivated in Brazil. Among the main contributions are Villa Nova et al. (1999); Moreno et al. (2000); Medeiros et al. (2001); Tonato (2003); Moreno (2004); Rodrigues (2004); Detomini (2004); Lara (2007, 2011) and Cruz (2011).

Tonato et al. (2010) compiled primary data of several of the experiments above and developed a database in order to parameterize models to estimate potential productivity of the main cultivars of the pasture species currently used in Brazil.

Tonato's potential production model was coupled with a soil water balance model and incorporated to the Invernada DSS in 2011. The current perception is that the model produces reliable predictions of seasonal patterns of pasture accumulation rates for the central part of Brazil. However, as it neglects some important information such as soil fertility and grazing management, magnitude of production has to be adjusted for individual production systems (Barioni et al., 2011b). Also, better evaluation in different regions of Brazil is needed as parameter estimation was based on experiments with relatively limited geographic distribution (Tonato et al., 2010).

Modifications of the grazing models described in the literature were also necessary for the Brazilian production systems. The grazing model included in Invernada was developed based on concepts of Woodward et al. (1997; 2001) and Freer et al. (1997) and calibrated using pre and post-grazing evaluations of forage mass and composition *Brachiaria brizantha* cv. Marandu (Gimenes, 2010). The Davis Growth Model (Oltjen et al., 1986) was adopted for predicting animal growth and composition of the animals in Invernada, with parameters estimated also for Nellore animals (Sainz et al., 2004). The NRC model for energy and nutrient requirements with some of the new developments included in RLM was also incorporated to that model.

Invernada also includes ration optimization routines (both least cost of dry matter and production). An overview of Invernada's model structure is presented in Figure 1.

Software development was also found to be a challenge. Efficient and modular software architecture was designed for the development (Torres et al., 2007, Figure 2).

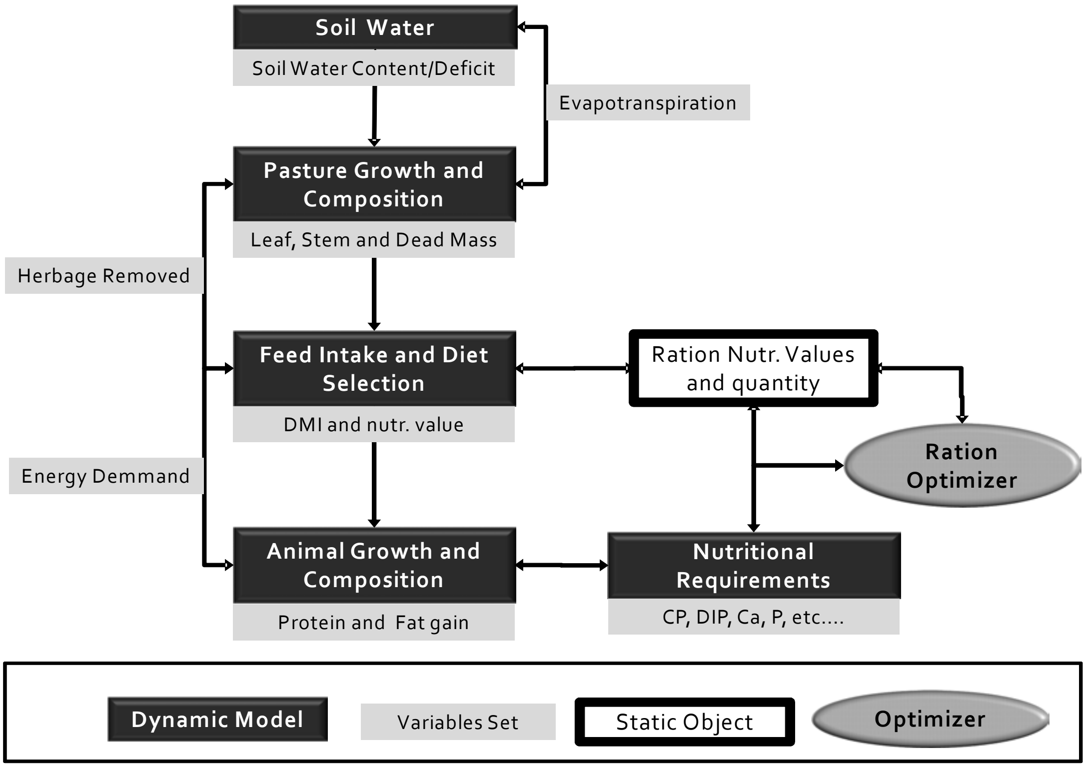

Figure 1: Overview of the Invernada DSS model structure.

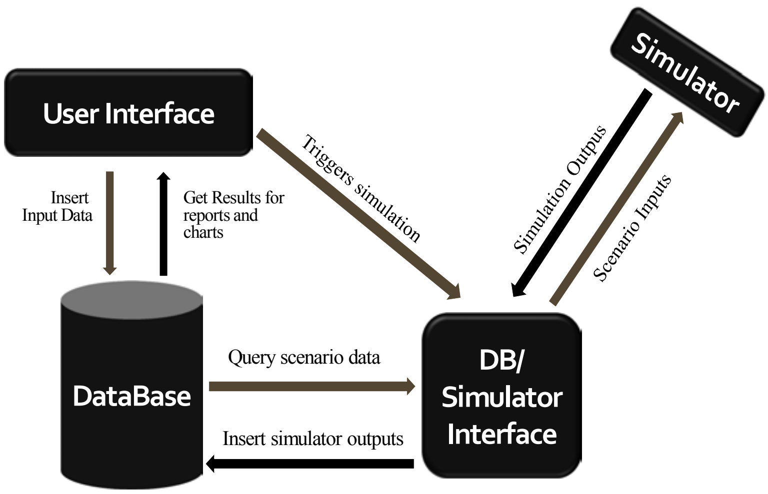

Figure 2: Overview of the Invernada DSS software structure.

Unfortunately users were not included in early stages of the development of Invernada, but four workshops were organized where prototypes and preliminary versions were presented to a partner company, Bellman Nutrição Animal, and to a private farm consultancy office, Boviplan. Typically, those workshops included a short training period, and informal validation of user interface, performance and outputs. Software testing was carried out in a period of two weeks after the workshops. In each of the iteration, change requests were analyzed and a new version produced.

Those workshops revealed that our focus as researchers was much narrower than that of the end-user. First it was felt that problem identification was not very clear in the first moment as researchers focused only in accurate model predictions and the end-user on how the model predictions would be useful to solve their problems. In this respect, the interactions with consultants have enabled us to introduce some useful features to more specific cases such as better evaluation of responses to supplementation (e.g. accounting for the effect of low protein diets; evaluation of generic technologies to change animal intake and performance). For the reason that user evaluation came late in software development, excessive work of redesigning and reprogramming was necessary. Therefore other methods of analysis and development, particularly agile methods (Arroqui et al., 2009) and user-centric software design (Sorensen et al., 2010) should be used in future software development in our group.

In the first six month (march to September/2011) from release over 2,200 downloads have been recorded and geographic dispersion of the visits to the download site show the software (Figure 3) indicate potential user all around the country. The demand for DSS tools for grazing systems, such as Invernada, seems to have a substantial potential.

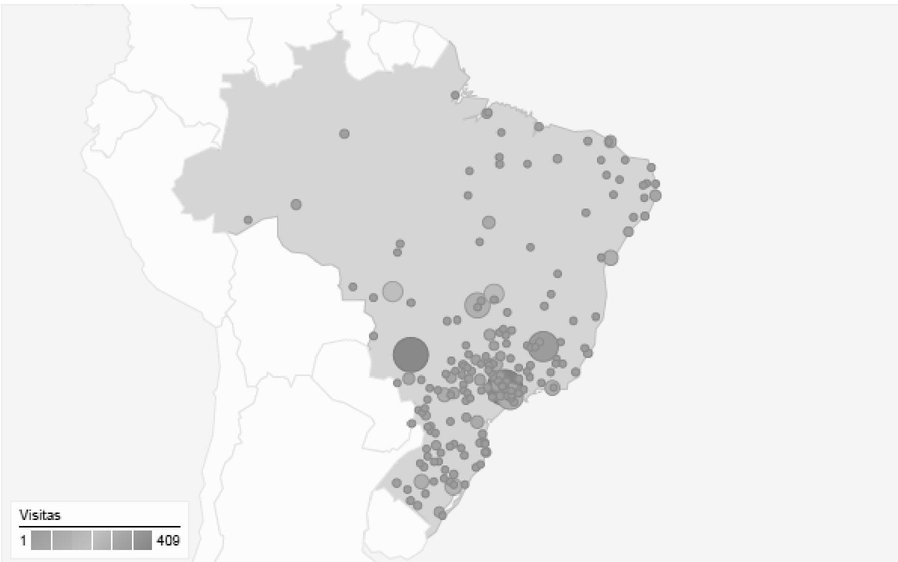

Figure 3: Distribution of Invernada downloads in the Brazilian territory using Google Analytics tool.

Decision support for whole farm systems

Optimization models based on linear programming (LP) or mixed integer linear programming (MIP) are excellent tools for strategic planning, particularly regarding the allocation of farm resources.

In Brazil, several mathematical programming models have been developed and applied to the optimization of beef systems (e.g. Balverde, 1997; Veloso et al., 2009). Those models can provide optimized strategies taking into account stocking rates, quantity of supplements, financial loan and risk, among others. Unfortunately, none of them have led to the development of a tool available for the end-user yet.

Whole farm systems simulator based on biological processes are still not available in Brazil. Comparing to the existing mathematical programming models, a whole farm simulator may have the advantage of allowing more detailed description of the biological processes related to production and environmental impact. In comparison to Invernada, a whole farm systems simulator would have the advantage to enable simulations of crop-livestock and other mixed systems besides a better description of the whole farm business.

Perspectives for future development

Agricultural systems modeling is a growing field in Brazil and our research team foresees considerable opportunity to improve the beef cattle production efficiency, increase the profit and reduce environmental impact through the adoption of decision support systems. In our evaluation, some of the most active streams of research DSSs for beef production are:

1. Evaluation of environmental impact, particularly greenhouse gases (GHG) net balance in beef production systems;
2. Developing whole beef cattle farm systems DSS;
3. Using new technologies of data acquisition (GPS, sensors and mobile computers) and communication to monitor individual animal performance to provide inputs for simulation models.

In stream 1, a large research project, with more than 300 members, led by Embrapa called PECUS (Sustainable Cattle Farm. Successful Cattle Operations, Embrapa SEG 011.006.001) has the objective of quantifying GHG net balance aiming at supporting the selection of mitigation alternatives and implementation of public policies. In that project, dynamic models of processes related to GHG fluxes will be incorporated to the Invernada simulator.

The PECUS project will also include stream 2 research through the development of Mixed Integer Programming Model of a beef cattle production system. The goal of this model is to establish optimal strategic plans for beef production systems by applying a bioeconomic model incorporating environmental constraints and evaluating GHG mitigation policies, such as carbon credits and governmental incentives.

This model aims to maximize the producer's net revenue at the end of planning period taking into account: land areas allocated to each activity in the production system, pasture production and grazing animals intake, pasture production decline, supplementation and pasture recovery policies besides the credit and dynamics of financial resources. The GHG emissions will be attached in the model as a constraint, but also will be studied the financial return by CO_2 equivalent abatement by means of governmental incentives and carbon credit.

In stream 3, another multi-institutional research project, including the University of São Paulo and Embrapa was conceived with the objective of optimizing the economic slaughter endpoint of Nellore steers using online monitoring of individual performance and a dynamic model (Embrapa call (SEG MP2

01/2011) and FAPESP[1]. To achieve this, there will be an effort to improve a mechanistic dynamic animal growth model and composition, parameterized from experiments based on evaluation of genotypes adapted in the Brazilian conditions, particularly Zebu germplasm. A second aspect is the integration of monitoring technologies to evaluate the growth of individual animals in real time with the dynamic simulation model in order to allow, through dynamic filtering (Oltjen and Owens, 1987) fitting model parameters to individual animals. Finally optimization methods will be applied to support decision making by cattle producers, slaughterhouses and consultants.

Concluding remarks

The development and application of DSS for beef production in Brazil is much more recent than that in several developed countries. However considerable level of adoption is noticeable with the release of the first DSSs in Brazil. This makes us optimistic about the future of DSSs for beef production. Demands and opportunities for improvement of current systems are expected to be driven by user feedback, evolution of scientific knowledge, data availability (particularly with online monitoring methods and remote sensing) and improvement of software development methods.

Environmental issues will also demand new models and DSSs for beef as those may have to be included in planning and evaluating production systems in the future. In that case, besides farmers and extensionists, the government may become an important client of such solutions.

Also, opportunities generated by new technologies, particularly regarding remote sensing and real-time monitoring are expected to drive development of DSSs for beef systems in the future.

[1] FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo) is the São Paulo Research Foundation

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