

**UNIVERSIDADE ESTADUAL PAULISTA – Unesp**

**CÂMPUS DE JABOTICABAL**

**ECONOMIC EVALUATION, STRATEGY AND PREDICTION STUDIES OF  
RESULTS INTO BEEF CATTLE PRODUCTION USING DIFFERENT  
SCENARIOS**

**Eliéder Prates Romanzini**

**Zootecnista**

**2019**

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SCENARIOS**

**Eliéder Prates Romanzini**

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**Coorientador: Prof. Dr. Ricardo Andrade Reis**

Tese apresentada à Faculdade de Ciências  
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para a obtenção do título de Doutor em  
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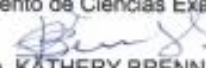
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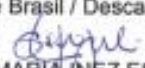
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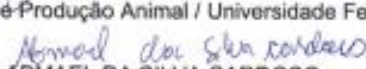
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## **DADOS CURRICULARES DO AUTOR**

**ELIÉDER PRATES ROMANZINI** – filho de Aparecido Donizete Romanzini e Lucélia Perpétua Alves Prates Romanzini, nascido em Palestina, São Paulo, no dia 04 de outubro de 1989. Em fevereiro de 2007 ingressou no Curso de Graduação em Zootecnia, na Universidade Estadual Paulista “Júlio de Mesquita Filho” – Unesp - Câmpus de Jaboticabal, sendo monitor da Disciplina Zoologia, sob orientação da Prof<sup>a</sup>. Dr<sup>a</sup>. Maria Célia Portella, graduando-se em março de 2012. Em outubro de 2012 se tornou bolsista de Treinamento Técnico Nível - 3 da FAPESP, sob orientação do Prof. Dr. Ricardo Andrade Reis, onde se manteve até dezembro de 2013. Em março de 2014 ingressou no Curso de Pós-Graduação em Zootecnia, em nível de Mestrado, na Universidade Estadual Paulista “Júlio de Mesquita Filho” – Unesp – Câmpus de Jaboticabal, onde foi bolsista CNPq, sob orientação do Prof. Dr. Américo Garcia da Silva Sobrinho até fevereiro de 2016. Em agosto de 2016 ingressou no Curso de Pós-Graduação em Zootecnia, em nível de Doutorado, na Universidade Estadual Paulista “Júlio de Mesquita Filho” – Unesp – Câmpus de Jaboticabal, onde foi bolsista CNPq, sob orientação do Prof. Dr. Euclides Braga Malheiros e coorientação do Prof. Dr. Ricardo Andrade Reis, treinamento este que se finaliza com a confecção desta Tese.

“Jesus continuou dizendo: ‘Não fique perturbado o coração de vocês. Acreditem em Deus e acreditem também em mim. Existem muitas moradas na casa de meu Pai. Se não fosse assim, eu lhes teria dito, porque vou preparar um lugar para vocês. E quando eu for e lhes tiver preparado um lugar, voltarei e levarei vocês comigo, para que onde eu estiver, estejam vocês também. E para onde eu vou, vocês já conhecem o caminho.’”

**João 14:1**

“Porque perdem a saúde para juntar dinheiro, depois perdem o dinheiro para recuperar a saúde. E por pensarem ansiosamente no futuro, esquecem do presente de tal forma que acabam por não viver nem o presente nem o futuro. E vivem como se nunca fossem morrer... E morrem como se nunca tivessem vivido.”

**Professor Gretz**

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## ECONOMIC EVALUATION, STRATEGY AND PREDICTION STUDIES OF RESULTS INTO BEEF CATTLE PRODUCTION USING DIFFERENT SCENARIOS

**ABSTRACT:** Brazilian beef cattle has been under pressure to obtain better results, which drives owners to use specific practices and management, which will allow the maintenance within livestock. This study aimed to evaluate use of artificial intelligence, specifically artificial neural networks (ANN), to predict future results both forage and animal productions. Determine between a lot of rearing and finishing phase scenarios of beef cattle production using tropical pastures, how was the best scenario considering economic results. Evaluate between different nitrogen fertilizers levels, how was there obtained best economic indexes. The ANN was better than regressions normally used to predict forage production (mean values obtained by ANN use were 0.84, 0.78 and 0.75 for forage mass, leaf and stem percentages, versus 0.74, 0.39 and 0.50 obtained using multiple linear regression) and animal (0.72 [ANN] and 0.67 regression). Into study about scenarios, the best results were obtained when used mineral mix just (profitability of 26.3%, simple payback period equal to 11 cycles and internal return ratio of 9.30%) during rearing phase of beef cattle. During finishing phase, the best results occurred when weather variables allowed by pasture handled, the use of higher stocking rate (3.18 AU ha<sup>-1</sup>) into area. The evaluation of economic results caused by different nitrogen fertilizer levels. Allowed to say that was possible to observe that there was linear increase both on costs, and gross revenue, caused by added of nitrogen per hectare. The treatment 180 kg N ha<sup>-1</sup> year<sup>-1</sup> obtained good economic indexes when compared to other. The profitability was 17.76%, and net present value, with 12% taxes during ten years of evaluation, US\$ 1,854.35 were results of this treatment. Concluded that ANN can be used to predict livestock results with fitting accuracy; between different scenarios we recommend correct pasture handled practices, what results in forage with high quality and consequently the mineral mix use during rearing phase of beef cattle is enough and it is economic practicable compared to supplementation. This pasture handled, if correctly developed and with great weather conditions, could result higher forage quantity residual to be used during finishing phase. This higher availability resulted higher stocking rate, increasing the activity revenues. About nitrogen fertilizer levels used on pastures fertilization, it is recommended the level 180 kg N ha<sup>-1</sup> year<sup>-1</sup>, which obtained best economic indexes. These indexes if associated to responses of other researches (nitrogen efficiency use) developed into same area, during the same period, authenticate the recommendation.

**Key Words:** artificial neural network; multivariable analysis; net present value; profitability.

## AVALIAÇÃO ECONÔMICA, ESTUDO DE ESTRATÉGIAS E PREDIÇÃO DE RESULTADOS DA BOVINOCULTURA DE CORTE UTILIZANDO DIFERENTES CENÁRIOS

**RESUMO:** A pecuária de corte brasileira tem sido pressionada no sentido de cada vez obter melhores resultados, o que força os proprietários a utilizar práticas e manejos específicos, os quais possibilitarão a manutenção dentro da atividade. Este estudo teve como objetivos avaliar o uso de inteligência artificial, mais especificamente redes neurais artificiais (RNA), para prever resultados futuros tanto da produção de pasto quanto animal. Determinar dentre diversos cenários de recria e terminação de bovinos de corte em pastagens tropicais, qual foi o melhor cenário no que diz respeito aos resultados econômicos. Avaliar dentre diferentes doses de adubação nitrogenada, qual foi aquela que retornou melhores índices econômicos. As RNA se mostraram melhores que as regressões normalmente utilizadas para prever as produções de pastagem (valores médios obtidos pelo uso das RNA foram 0,84; 0,78 e 0,75 para massa de forragem, porcentagens de folha e colmo, versus 0,74; 0,39 e 0,50 obtidos usando regressão linear múltipla) e animal (0,72 [RNA] e 0,67 regressão). No estudo referente aos cenários, os melhores resultados foram obtidos quando utilizado apenas sal mineral (lucratividade de 26,3%; período de “payback” simples igual à 11 ciclos e taxa interna de retorno de 9,30%) na recria dos bovinos de corte e na terminação, quando as variáveis climáticas possibilitaram via manejo de pastagem o uso de maior taxa de lotação (3,18 UA ha<sup>-1</sup>) na área. Quando avaliados os efeitos das doses de adubação nitrogenada sobre os resultados econômicos foi possível observar que houve um incremento linear dos custos, assim como da receita bruta à medida que mais nitrogênio foi aplicado por hectare. O tratamento 180 kg N ha<sup>-1</sup> ano<sup>-1</sup> obteve bons índices econômicos em comparação aos demais, sendo lucratividade igual à 17,76% e valor presente líquido, com taxas de 12% em dez anos de avaliação, R\$6.174,99. Concluímos que as RNA podem ser utilizadas para a predição de resultados da pecuária de corte com adequada acurácia; dentre os cenários recomendam-se práticas de manejo adequado das pastagens, o que resulta em forragem de qualidade e consequentemente o uso de sal mineral durante o período de recria dos bovinos de corte se torna viável economicamente frente à suplementação, esse mesmo manejo das pastagens, quando bem desenvolvido e com condições climáticas ideais, resultou em maior quantidade de forragem remanescente para o período de terminação, o que possibilitou maior taxa de lotação, elevando assim as receitas da atividade. Com relação às doses de nitrogênio a serem utilizadas na adubação de pastagens, recomenda-se a dose de 180 kg N ha<sup>-1</sup> ano<sup>-1</sup>, a qual obteve bons índices econômicos, os quais se associados a respostas de outras pesquisas (eficiência de uso do nitrogênio) desenvolvidas na área, durante o mesmo período, validam tal recomendação.

**Palavras-chave:** análises multivariadas; lucratividade; redes neurais artificiais; valor presente líquido.

## CHAPTER 1 – GENERAL CONSIDERATIONS

### 1. Introduction

Brazilian beef cattle production is among the bigger of the world. Numbers can show the importance of this system. Brazil has around 222 million of head what result in 9.5 million tons of equivalent carcass weight yearly (USDA – United States Department of Agriculture, 2017). Values are responsible by keep positive gross domestic product (GDP) on Brazil. The mainly Brazilian product for exportation is *in natura* or fresh meat. During the year of 2017, according to ABIEC (2018, Associação Brasileira das Indústrias Exportadoras de Carnes), Brazil exported until September, close to 1.21 thousand tons of fresh meat. The total of the Brazilian exportation, if summed other products, is close to 1.53 thousand tons what results in about US\$6.28 billion.

If considered that the main production system is pastures (Soares et al., 2015) without the use of technology, so, is possible to say that Brazilian production has a bigger lack to improve yet. However, for this improvement, there are necessary a lot of changes, mainly on concepts used within livestock. Some farmers are very conservator when the matter are new technologies. This scenario causes reduces in productivity and consequently less profitability inside livestock farm. Increasingly the beef producers need insert recent technologies inside the system to keep the positive Brazilian GDP and the improve farm profitability.

In this way, a lot of technologies are available to use. These technologies are since pastures management (as fertilization and use of best forage species), supplementation, cattle breeding genetics improvements until use of some artificial intelligence (AI) (Murase, 2000 and Farkas, 2003) to predict future values. According McClymont (1963) there are a lot of management decisions about livestock, plants and

soil that could change the agricultural ecosystem. Thus, understand more about each system productive is a crucial point to improve the productivity of this farm.

Nowadays, few producers have changed their concepts, what has altered the husbandry standard. These changes created the term “husbandry of precision”, associated with upgrading into system management of animal production using pastures (Carvalho et al., 2009). An example these changes is the use of AI, an innovative technology that could help producers into decision choose even before the occurrence. The use of different AI methods (artificial neural network (ANN), fuzzy logic [Costa, 2009]) allows predicting biological information with a big dataset. However, just to predict results will not improve the productive indexes (Moretin and Toloi, 2006); being necessary use of other technologies parallel as support.

These other technologies are above mentioned, and it is important to keep high productivity. According Reis et al. (2013) is necessary pasture management to allow that forage had adequate nutritional value and produce higher food quantity resulting in higher animal performance; always observing stocking rate during the seasons, to not reduce productivity and the economic efficiency. Therefore, Paulino et al (2008) reported that the use of technologies (fertilization, stocking rate adjusts, and supplementation) could to avoid losses in gain close to 200 g day<sup>-1</sup>.

Therefore, knowing every information and considering that the main specie used into Brazilian tropical ecosystem pastures is *Urochloa brizantha* cv. Marandu (Barbosa, 2006), is necessary to use nitrogen fertilization, supplementation to keep animal performance during the wet and dry season. However, inside this system occurred vulnerability basically due management and technic limitations (Reis et al., 2001). Thereby, according to Calzavara (1980) get or not economic responses previously fixed

is associated to form that farmer executed administrative, technical, financial, commercial, accounting and security function.

Thus, the hypotheses were: 1) is possible to predict results of production system using artificial neural network; 2) supplementation used at different conditions, years, not change the economic responses during rearing and finishing phases of beef cattle production developed in tropical pastures of Brazil; 3) the economic results are no dependent of production system when pastures received diverse levels of nitrogen fertilizer.

The objectives of this research were: 1) validate use of artificial neural network to predict forage and animal production into different scenarios; 2) determine the best strategy considering economic analyses of beef cattle during rearing and finishing phase using tropical pastures in Brazil; 3) evaluate economically the beef cattle production system developed in tropical pastures fertilized with four levels of nitrogen fertilizer.

## **2. Literature Review**

### **2.1. Artificial neural network**

The artificial neural network (ANN) model belongs to a powerful class of empirical modeling algorithms that are capable of computing, predicting and classifying data and are more versatile than regression models (Ali et al., 2016 mentioned by Yang et al., 2018). Nowadays, ANN is a technology that has been used some business to predict future results (Farkas, 2003; Brennecke et al., 2011 and Sangoi et al., 2016).

There are a lot of structures of ANN among these is the multilayer perceptron (MLP). Which had its structure showed on Figure 1, where, is possible to see some layers since input until output.

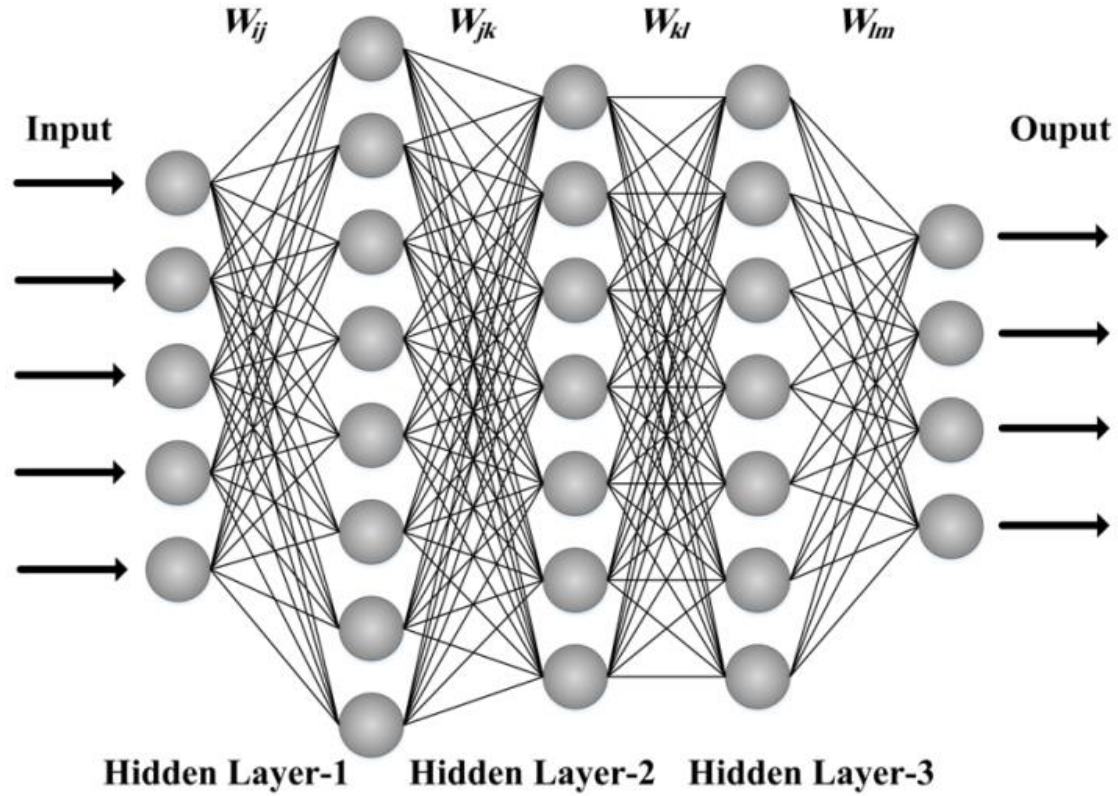


**Figure 1.** Multilayer perceptron neural network model (Hosseini and Samanipour, 2015)

The MLP structure originally used algorithm called “backpropagation”. The backpropagation on ANN has been used to estimate forest biomass (Liu et al., 2008 and Wang et al., 2017) and crop yields, e.g., corn and rice (Panda et al., 2010). However, only limited studies have focused on grassland biomass estimation (Yang et al., 2018). According Pasini (2015) a data set that will be used into ANN analysis needs to be divided into three subsets (for him called training, validation and test set), this practice is important to prevent overfitting during analysis. Overfitting is a problem caused into ANN by knowledge of all data set, so, the ANN will not predict results because it will know these results before to predict. The ANN could be useful in analyzing nonlinear behavior, with the aim of finding casual relationships (Pasini, 2015).

Using this important toll Brennecke et al. (2011) tried to predict the protein fractionation of tropical pastures (*Urochloa brizantha*) according methodology described

by Licitra et al. (1996). These authors reported that ANN can be used to predict the protein fractionation (A, B1, B2, B3 and C). In this way, of use the ANN to predict something, Soares et al. (2015) aimed to estimate the corn production. They used ANN - MLP composed by three layers (one input, one hidden and one output) with backpropagation algorithm and concluded that ANN – MLP was an efficient toll to estimate the productivity of corn grain.

Considering all uses previously mentioned can be said that ANN has been used to determine non-linear relationships among different predictor variables and response variable, what has been called as learning machine. According Sarle (1994) the ANN are used as decision support for different knowledge areas, could be used for process control, standard identification, classifications and predictions. Thus, considering all possibilities described, the capacity of ANN applied in animal science can be understood.

## 2.2. Multiple Linear Regression

The multiple linear regression (MLR) model is often useful model, its composed by a response variable  $Y$ , which is quantitative, and at least one predictor variable  $x_i$ , also quantitative (Olive, 2010). The author represents MLR by model:

$$Y_i = \alpha + x_{i,1}\beta_1 + x_{i,2}\beta_2 + \cdots + x_{i,p}\beta_p + e_i$$

For  $i = 1, \dots, n$ . Where,  $Y_i$  is the response variable,  $x_i$  is a  $p \times 1$  vector of nontrivial predictors,  $\alpha$  is an unknown constant,  $\beta$  is a  $p \times 1$  vector of unknown coefficients, and  $e_i$  is a random variable called the error.

One important information about this matter is that response variable is the one that the researcher wants to predict, and predictor variables are the variables used to predict the first one. Another important information is that quantitative variables takes on numerical values and qualitative variables takes on categorical values (Olive, 2010). Due

to these characteristics, some authors called this model as a standard statistical technique of researcher's toolbox (Nathans et al., 2012). These authors said that MLR is an extension of simple linear regression and it has distinct advantages and limitations.

The use of MLR model to predict results in some research can be linked to some points: simplicity in application, efficiency in computation, ease of interpretation and straightforward interpretation (Thompson et al., 2006 and Hastie et al., 2001). However, this model only can be used to linear relationships between response variable and predictor variables, what reduce the prediction power from this model if compared to models as ANN, which can be used seeking greater predictive power, due the capability of handling both nonlinear and qualitative data.

Bell et al. (2016) used MLR to predict an individual animal's methane yield (g methane/kg dry matter intake) from different composition of diet. These authors said that predictive ability of the model developed was as reliable as other models assessed from the literature. In other hand, Sales (2009) using the same models to predict digestible energy content across feed ingredients and fish species, reported that the multiple linear regression equation developed could not predict apparent digestibility energy contents with an adequate degree of accuracy. So, the choose of what model will be used to predict some results will depend on its accuracy between predicted and observed values, evaluated into different research within each knowledge area.

### **2.3. Brazilian beef cattle production using tropical pastures**

Brazil is a continental country with a lot of kinds weather and vegetable stand. But most of part the territory was inside tropical weather. Ferraz and Felício (2010) reported that Brazilian beef cattle production has a tripod to sustain productivity and indexes, they said that this tripod is compounded by Cerrado-Nellore-*Urochloa* sp. If

considered that Cerrado biome is concentrate into tropical zones, so, into this weather the main cultivated specie to use in beef cattle production is *Urochloa brizantha* cv. Marandu, measured by the seed sold during 90's, something close 70% (Andrade, 2001). The importance of this forage species is due its characteristics (productivity, good nutritional value (if managed correctly)), which support around of 90% of Brazilian beef cattle production (Venturini et al., 2017).

According ABIEC (2018) Brazil has close to 163 million ha of pastures where are keep around 222 million head, just of bovine herd, what result in a stocking rate close to 1.3 AU ha<sup>-1</sup> (AU is animal unit, equal 450 kg body weight [BW]). These numbers showed that Brazilian beef cattle are improving mainly by use of technologies. Technologies utilization increased productivity during the last years. At 1997, the productivity was 2.16 @ ha<sup>-1</sup> year<sup>-1</sup> (@ is equal 15 kg of carcass) and at the last year (2017) the same variable reached 4.01 @ ha<sup>-1</sup> year<sup>-1</sup> (ABIEC, 2018). Even with this increase, Brazil has a lot of opportunities to follow increasing these indexes.

The main Brazilian husbandry system is called as extensive. This nomenclature characterizes a system without use of technologies where animals normally gain weight during wet season and loss weight at dry season caused by seasonality of tropical pastures allowance (Sampaio et al., 2017). To understand better, the weather into wet season is based in high average temperature, rainy, and high humidity. These conditions are fitting to C4 grass development and consequently results in better animal performance. In other hand, dry season has low average temperature, sparse rainy days and low humidity. What resulting in low or none forage development, and in system previously mentioned low animal weight gain, or even animal weight losses.

According Hodgson (1990) the pasture management is the forage's use with knowledge to balance between development and forage intake by animals. Thus, is

possible to obtain animal production, always considering the maintenance and sustainability of system production. If considered the seasonality previously describe and this affirmation, can be observed the necessity of a lot of technologies (fertilization, and supplementation) to keep the animal production into system that use pastures with main food source. These technologies had been studied for some researchers (Romanzini et al., 2017; Barbero et al., 2017; Vieira et al., 2017 and Sampaio et al, 2017) which evaluated use of supplements and fertilization into tropical pastures for beef cattle production.

Barbero et al. (2017) evaluated supplementation effect during post-weaning in finishing phase. They reported that animals fed with supplementation level 0.6%BW and keep in low sward height (15 cm) during post-weaning obtained average daily gain (ADG) equal 0.66 kg bull<sup>-1</sup> day<sup>-1</sup>; animals fed with 0.3%BW and keep in medium sward height (25 cm) gained 0.45 kg bull<sup>-1</sup> day<sup>-1</sup> and animals fed without supplementation but keep into high sward height (35 cm) had ADG equal 0.22 kg bull<sup>-1</sup> day<sup>-1</sup>, these results are very sure to determine supplementation importance, according authors not difference were observed into these results.

### **2.3.1. Nitrogen fertilization into beef cattle production using pastures**

If considered the fertilization inside crops, the forages used to beef cattle production correspond to 1.5% of the fertilization total used in these crops on Brazil during the year 2016 (Heinrichs, 2017). According Cecato et al. (2014) the fertilization practices should be realized during both establishment of pasture and maintenance fertilization. The authors said that the main nutrients used into fertilizer practice are nitrogen (N), potassium (K) and phosphorus (P). Nitrogen fertilization is a punctual technology used into beef cattle production that can improve productivity through increase of stocking rate caused, mainly by higher herbage mass production. However,

this fertilization needs to be done with knowledge because according Martha Júnior et al. (2004), some points (nitrogen source, application's doses and kind of division nitrogen fertilization) should be considered to do this practice.

If considered that the total area of pastures on Brazil is close 150 ha millions being 50% artificial (cultivated) is possible to define that the use of nitrogen fertilizer per area is  $3.46 \text{ kg ha}^{-1}$  in total area and in cultivated areas this use is close  $7.0 \text{ kg ha}^{-1}$  (Heinrichs, 2017) what it makes 520.000 tons. In this way can be observed that the nitrogen fertilization is not high on pastures used in systems of beef cattle production. Therefore, the efficiency of use needs to be high to improve animal productivity. However, some studies had showed that the efficiency is not high (Chagas et al., 2017; Romanzini et al., 2017 and Nascimento et al., 2013). According Romanzini et al. (2017) the nitrogen losses increasing with the increase on level of nitrogen fertilization, what showed that is important knowledge during the process of fertilization.

The intensification of beef cattle production, that could be increased using nitrogen fertilizer, could to change the farm productivity level. Manetti Filho, Hernandez and Caramori (2014) reported data from other research about productive index according intensification levels into beef cattle chain. These authors showed that a system without technologies into system obtained a stocking rate equal  $0.5 \text{ AU ha}^{-1}$ , animal production equal  $120 \text{ kg animal}^{-1} \text{ year}^{-1}$ , when some intensification start to be used into this system, as maintenance fertilizer, the index changed to  $1.5 \text{ AU ha}^{-1}$  and  $180 \text{ kg animal}^{-1} \text{ year}^{-1}$ , respectively. Following the intensification, if used an intensive fertilizer, the same index could be  $4.5 \text{ AU ha}^{-1}$  and  $221 \text{ kg animal}^{-1} \text{ year}^{-1}$ , respectively. So, the reported by Manetti Filho, Hernandez and Caramori (2014) allow to say the intensification importance into beef cattle chain.

## **2.4. Economic evaluation**

Every production system needs to be economic viable to have its use considered by producers. According to Barbosa & Souza (2007) the lack of costs information does not allow to producer to know how much the system is profitable or how variables should be changed to reduce costs and improve this system profitability. In this way the husbandry needs to more studies about economy to define each condition that can results more profitability.

Production costs are every monetary expenditure occurred during the production period. The knowledge of these costs allows to control and to organize the farms always aiming the less cost, what would result higher profitability (Santos et al., 2009). Therefore, the profitability of beef cattle production is directly related to productive efficiency and costs. However, a lot of farms of beef cattle production are managed with empiric methods, without to know efficiency levels and production costs (Cinemre and Ceyhan, 2006 and Bravo-Ureta et al., 2007). According Carvalho and Zen (2010) Brazilian beef cattle costs are lower than other production countries, this help the farm's economic results but just this not is enough to keep these farms inside chain.

Pini et al. (2014) evaluated different beef cattle systems and these authors reported that rearing and finishing phase farms had the main cost represented by animal purchase, according they this cost is close 60% of cost total operating. Carvalho and Zen (2010) reported that into finishing phase using feedlot system, feeding represent the second higher cost, about 20%. If thought that finishing phase when developed grazing uses big quantities of supplement, levels between 1.5 and 2.0% BW, so, the costs with fed will be high too.

Côrrea et al. (2010) reported that increase on intensification into systems, caused by some factors as fertilization, animal supplementation, increase the system complexity

and cause changes into costs structure. These changes caused higher risks, which is necessary to improve profitability, sure if the system management was appropriate. In this way, Keat, Young and Erfle (2014) reported a concept about production function, where they say that an increase on input inside some chain will result higher production until a point. After this point, the increase on inputs do not change production (Figure 2). The beef cattle production needs to understand these concepts to use and increase animal index until the limit what probably will result best economic responses.

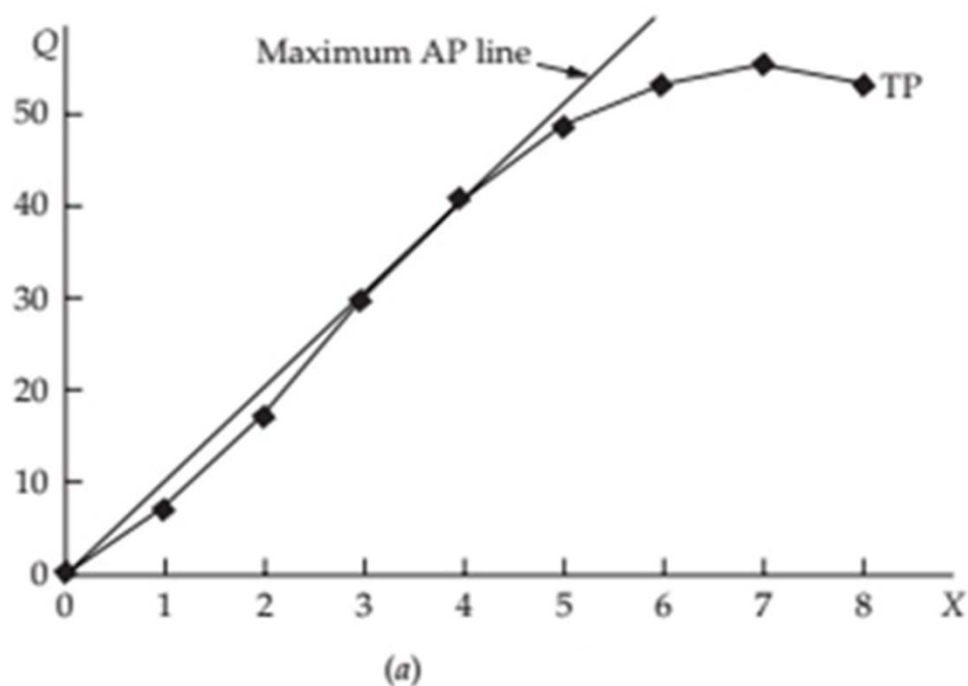


**Figure 2.** Production function curve between (a) Input x Q (Total Production – TP; Adapted from Keat, Young and Erfle (2014)).

A research from Lupatini (1996), mentioned by Cecato et al. (2014), showed the production function curve on millet pasture. The author evaluated five levels of nitrogen fertilizer (0, 100, 200, 450 and 600 kg ha<sup>-1</sup>) and obtained benefit equal US\$393.70; US\$515.81; US\$612.91; US\$734.70 and US\$653.17 for levels previously mentioned. The results showed clarity that increases on nitrogen fertilizer levels increased benefit until 450 kg ha<sup>-1</sup> and after this level, the benefits decreased independently of fertilizer

level. So, with this example can be explained the production function curve previously showed.

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## CHAPTER 2

O artigo a seguir está redigido  
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Scientific Reports

## **Use of artificial neural networks to predict the production of tropical pastures and animals in Brazilian beef cattle system**

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**Running title:** Artificial neural network in Brazilian livestock systems

**Keywords:** artificial intelligence; *Urochloa brizantha*; intensification level

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### **ABSTRACT**

Aimed in this research compare artificial neural networks (ANNs) and multiple linear regression (MLR) to predict the forage (forage mass, leaf, and stem percentages) and animal (average daily gain) production. Two datasets were used in each evaluation.

For each dataset, a multivariable analysis was developed to understand possible interactions. Subsequently, all inputs were designed for use in ANNs. The results showed that there was no formation of groups in each dataset. Next, we perform an analysis to determine the best model ANN or MLR results, considering the correlation between the predicted value and the observed value, and the results are compared using an F test. Other evaluations are performed for ANNs, more specifically for structures. The inputs and the number of hidden layers were analyzed to define the best structure for the prediction of future results. Significance level was considered at level 5.0%. It was found that ANN is better than MLR for predicting results for both the dataset forage ( $p < 0.0001$ ) and animal products ( $p < 0.0001$ ). For the inputs used in each ANN, there are differences in terms of the animal production ( $p < 0.0001$ ), with the higher prediction values (0.72 and 0.67 for ANN and MLR, respectively). In other words, the number of hidden layers for both datasets were not different ( $p = 0.063$  and  $p = 0.431$ , for forage and animal production, respectively). Hence, ANN, with a specific structure for each evaluation, is a potential tool for prediction of results for forage and animal production.

**Keywords:** artificial intelligence; *Urochloa brizantha*; intensification level

## BACKGROUND

The livestock production index is required to improve year-on-year to ensure positive gains, and thus profitability. In this industry, it is important to consider the use of tools that predict future results, which could help entities to make real-time decisions regarding planned actions. The most important characteristic of Brazilian beef cattle production is the source of food, i.e., the tropical forage. Throughout the countryside, there is a wide variety of species and genera, but the highlight is tropical forage grasses

with C4 photosynthetic metabolism. Azevedo et al. [1] reported that approximately 80% of the cultivated pastures in Brazil comprise the *Urochloa* grass species, and the most commonly cultivated crops are *U. decumbens*, *U. brizantha*, *U. humidicola*, and *U. ruziziensis*.

The knowledge of the specific forage utilization enables the development of management techniques according to the requirements of each crop. Therefore, an understanding of the production process of the main source of food is an important requirement for animal suppliers, considering the quantity and quality of their source of food, the tropical forage [2]. In order to meet the accurate amount of animal feed required during all seasons, several tools have been employed to predict future biological results. Some examples of these tools are artificial neural networks (ANNs) and fuzzy logic [3]. Both of these approaches can be used to solve complex problems, such as biological problems, using big data. However, according to Morettin and Toloi [4], the prediction of future results will not by itself improve the livestock index. Thus, it is important to augment this prediction with appropriate system management. In this way, the 21<sup>st</sup> Century has been referred to as “farming 4.0,” which involves using technology in the entire production chain (livestock and agriculture) to improve the index and consequently all results (productive, environmental, financial, and social).

Considering that there are several kinds of models to predict the productivity of farming systems (potential, limited, and reduced productions; [5]) it is important to determine how all of the factors will be used in the determination. These factors can be divided into genetic characteristics, light, and temperature (used for potential productivity models); these last three as well as the water and available nutrients (used for several productivity models) and all of the above-mentioned factors in addition to the presence of weeds and disease (used for reduced productivity models). Some studies were developed

to evaluate ANNs as a tool in the prediction of forest results [6, 7, 8] and animal production results [9, 10, 11]. This is because according to Pasini [12], ANNs were developed and used for several purposes in many fields related to contemporary scientific research. However, to the best of our knowledge, there are no studies that employ ANNs to predict forage production using tropical grasses and animal performance in grazing systems.

Therefore, our research aims to verify the use of ANNs to predict forage production (forage mass [fm], and leaf [%l] and stem [%s] percentages), and animal production (average daily gain [ADG]) using datasets obtained in tropical conditions. Our hypothesis considers whether it is possible to predict the results of livestock systems using ANNs.

## METHODS

### *Ethical statement*

All experimental procedures involving animals in this study were performed in accordance with the relevant guidelines (Protocol CEUA #12703/15) as approved by the Ethics, Bioethics, and Animal Welfare Committee of the UNESP, Jaboticabal.

### *Dataset*

The data used to evaluate the forage production (forage mass, leaf and stem percentages) were obtained from experiments that were developed at the São Paulo State University, “Júlio de Mesquita Filho” (Unesp) (Jaboticabal, São Paulo, Brazil), where the typical climate is the subtropical humid type, with dry winters and wet summers. Pastures were seeded with *Urochloa brizantha* (Hochst.) Stapf. cultivars Marandu and Xaraes, and both were managed using a continuous grazing system, and the variable stocking rate and

sward height were varied between 15 and 35 cm according to studies developed between 2013 and 2017. It was worked 410 records pertaining to forage production, with 94% from Marandu grass and 6% from Xaraes grass.

For the other evaluation, animal production (ADG) data that were employed were obtained from experiments that were developed at the same University, where animals were kept during the rearing phase in pastures that had been seeded with both of the previously mentioned grasses. These experiments were performed between 2016 and 2017, and two animal breeds were used (Nellore and  $\frac{1}{2}$  Nellore  $\times$   $\frac{1}{2}$  Aberdeen Angus), were worked around 900 records, 83% of which were from Nellore, and 17% from  $\frac{1}{2}$  Nellore  $\times$   $\frac{1}{2}$  Aberdeen Angus.

Climate data were used in both datasets (Table 1) and were obtained from the Department of Exact Sciences (São Paulo State University, “Júlio de Mesquita Filho” (Unesp) (Jaboticabal, São Paulo, Brazil)), and the observations were made at the Agroclimatological Station of Unesp - Campus Jaboticabal.

| Input number    | Variable                  | Forage Production | Animal Production |
|-----------------|---------------------------|-------------------|-------------------|
| 1               | Rainfall                  | X                 | X                 |
| 2               | Photoperiod               | X                 | X                 |
| 3               | Temp. Maxima              | X                 | X                 |
| 4               | Temp. Minima              | X                 | X                 |
| 5               | Rainy Days                | X                 | X                 |
| 6               | Humidity                  | X                 | -                 |
| 7               | Stocking rate             | X                 | X                 |
| 8               | Nitrogen Fertilizer Level | X                 | X                 |
| 9               | Supplementation Level     | X                 | X                 |
| 10              | Forage Crop               | X                 | X                 |
| 11              | Sward Height              | X                 | X                 |
| 12              | Animal Breed              | -                 | X                 |
| 13              | Forage Mass               | -                 | X                 |
| 14              | Leaf Percentage           | -                 | X                 |
| 15              | Steam Percentage          | -                 | X                 |
| 16 <sup>‡</sup> | Average Daily Gain        | -                 | -                 |

**Table 1.** Inputs used for development of Forage (Forage mass, Leaf and Stem percentage) and Animal (Average Daily Gain) Productions\* prediction models. \* Models studied to Forage (Forage mass [fm], Leaf [%l] and Stem [%s] percentages) and Animal (Average daily gain [ADG]) productions. <sup>‡</sup> ADG used just in principal component analyses (PCA, into Figure 2).

### *Multivariable analysis*

After the composed dataset for forage and animal production were developed a multivariable analyses to understand all interactions, after which all of the inputs were defined (Table 1) for use in the ANN. Factor analyses were obtained using principal component analysis (PCA) [13, 14], and were calculated from the correlation matrix of the variables. Therefore, three groups were developed for each evaluation using a graphic scatter plot. For the forage production, the clusters were composed of a combination of the forage mass (fm), as well as leaf (%l) and stem (%s) percentages (Great [fm > 6t, %l > 50% and %s < 30%]; Normal [5t < fm < 6t, 45% < %l < 50% and 30% < %s < 35%] and Bad [fm < 5t, %l < 45% and %s > 35%]). For the animal production, the clusters comprised the ADG (high gain [ADG > 1.5], medium gain [1.5 > ADG > 0.8], and low gain [ADG < 0.8]).

### *Artificial neural network*

An ANN analysis was developed based on the most commonly used type in different studies [3, 15, 16, 17] namely the multilayer perceptron (MLP) with linear activation function. The algorithm that was used was backpropagation, in which each neural weight must be higher than 1.0 for the prediction to proceed to the next step. Different ANN structures were used considering the hidden layers and number of neurons in each layer. All cases involved the use of five different hidden layers, i.e., 2, 3, 4, 5 and 6 hidden layers. These structures were analyzed with a different number of neurons for each layer, and each combination was repeated five times. For the inputs (Table 1), the criteria were facility on obtaining the field information.

In all cases, the data were divided into two groups, namely training and test groups. This practice is important to prevent the ANN from learning all results and not predicting more, but just providing an answer for each set of information, which is called overfitting. Therefore, the training used 66% of the data, and the test was developed using the other 34%. The choice of data in the dataset was randomized at all times. The analyses resulted in two values, the Pearson correlation (Corr) and mean-square error (MSE). Corr was developed by comparing the predicted value with the observed value, and MSE was the error between these two values (predicted and observed).

To compare the ANN results, the MLR was developed using the same dataset. The MLR was developed considering all inputs used (Table 1) based only on their significance ( $p\text{-Value} < 0.05$ ). Therefore, with the chosen model, the predicted value was determined, which was used to determine Corr and MSE to MLR. These results were determined using five repetitions of the same number of ANNs, and they could be compared with ANN results to determine how to better predict the forage and animal

production. All of the analyses were developed using R Core Team [18] as well as the packages “neuralnet” and “NeuralNetTools.”

### *Statistical analysis*

After performing all of the evaluations, the previously described ANNs for forage and animal production were developed using factorial analysis, which is a three-way interaction, to evaluate differences between the inputs used, an N° hidden layer and model (ANN and MLR), considering the significance of the F test,  $p\text{-value} < 0.05$ . The factorial analysis that were developed were  $5 \times 5 \times 2$  (Input  $\times$  N° hidden layer  $\times$  model) for forage production and  $3 \times 5 \times 2$  for animal production (Input  $\times$  N° hidden layer  $\times$  model) using AgroEstat software [19]. The mathematical model used for these analyses was:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + \delta_{ij} + \varepsilon_{ik} + \omega_{jk} + \tau_{ijk} + e_{ijk}$$

where  $Y_{ijk}$  is the dependent variable  $i$  subject to inputs  $j$  used at the N° hidden layer and at model  $k$ ,  $\mu$  is the overall mean,  $\alpha_i$  is the effect of the inputs  $i$  used = 5 different inputs (forage production) and three different inputs (animal production);  $\beta_j$  represents the effect of the N° hidden layer  $j = 2, 3, 4, 5$  and 6 layers,  $\gamma_k$  is the effect of model  $k = \text{ANN and MLR}$ ,  $\delta_{ij}$  is the interaction between inputs  $i$  used and the N° hidden layer  $j$ ,  $\varepsilon_{ik}$  represents the interaction between the inputs  $i$  used and model  $k$ ,  $\omega_{jk}$  represents the interaction between the N° hidden layer  $j$  and model  $k$ ,  $\tau_{ijk}$  represents the interaction between the inputs  $i$  used and the N° hidden layer  $j$  and model  $k$ , and  $e_{ijk}$  is the residual experimental error.

## **RESULTS**

The factor analysis that was developed for forage production (Figure 1) considered two factors, which account for 41.52% of the data variability. The first factor accounts for 24.58% and the second one for 16.94%. By observing this figure, it is

possible to determine that there no were clusters among the three groups (Great, Normal, and Bad) that were previously created.

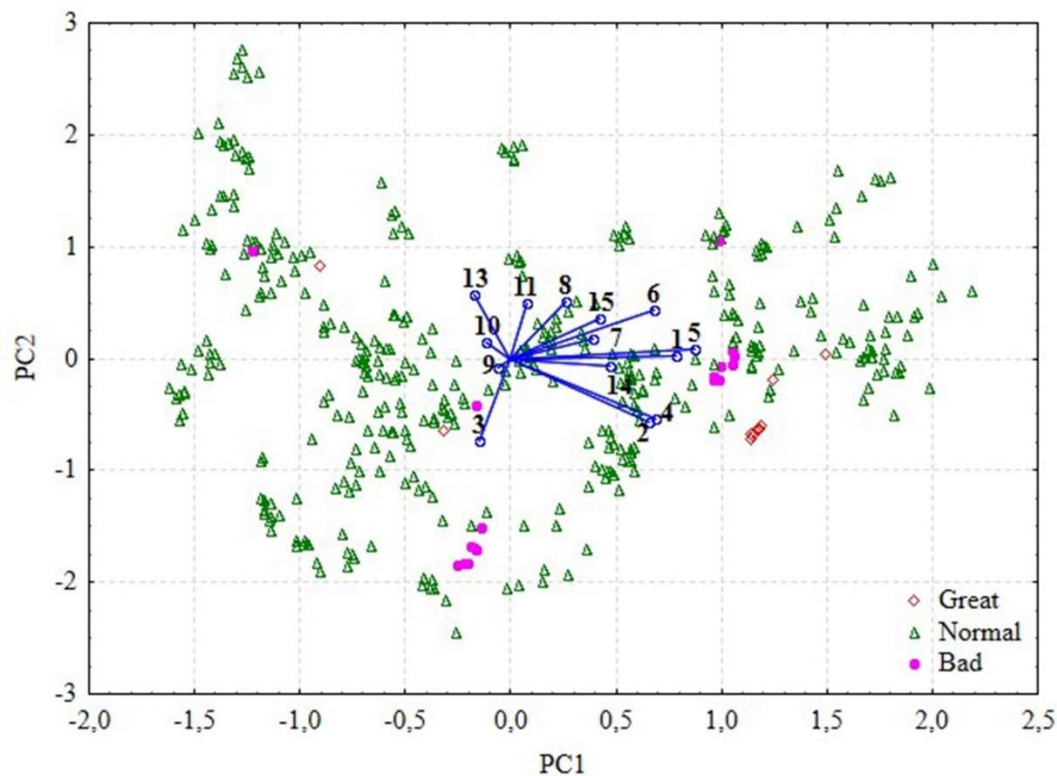


**Figure 1.** Graphical clusters of Forage production, considering combination among forage mass, leaf and stem percentages (Great, Normal and Bad), a merged between clusters and factors obtained by principal components analyses (PCA) from Inputs (Table 1).

In the same figure, it can be observed that the primary group was Normal, with 93.17% of the total. In the same way, but considering another dataset, i.e., animal production (Figure 2), two factors accounted for 47.44% of the data variability, where the first factor was responsible for 27.05%, and the second for 20.39%. In Figure 2, the group distribution not permitted to say that there were clusters. Of the groups in animal production, 63.51% were for animals with medium gain, 25.70% for low gain, and the least was high gain, with just 10.79%.

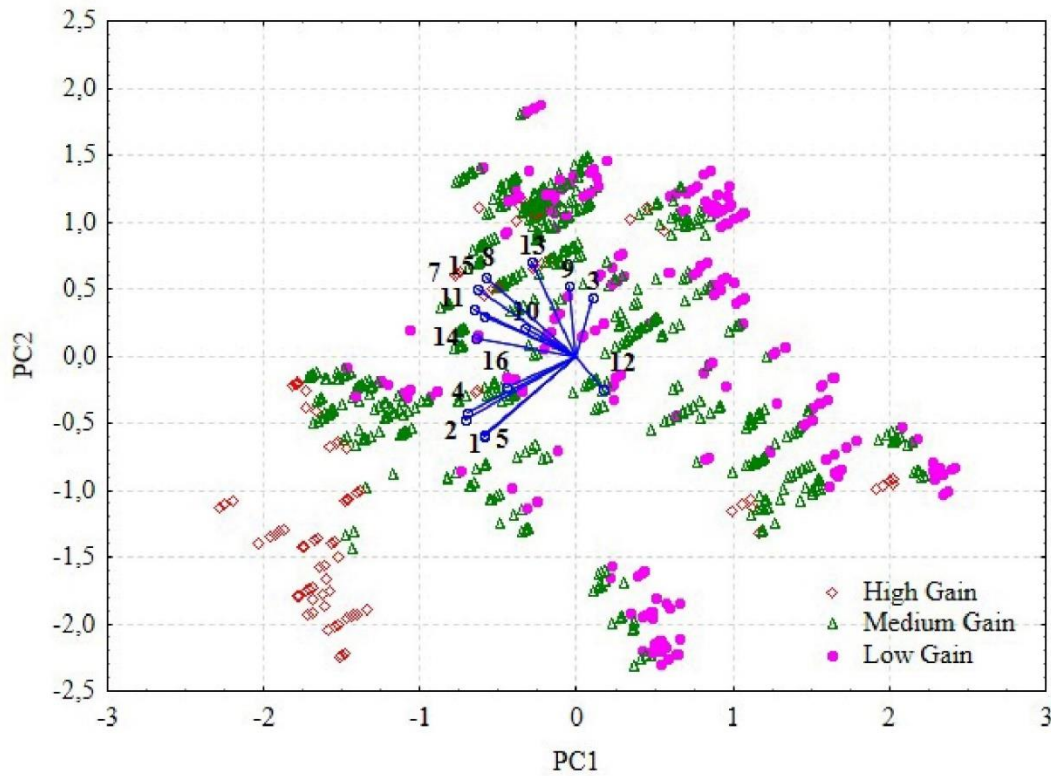


**Figure 2.** Graphical clusters of Animal production, considering average daily gain (High, Medium and Low Gains), a merged between clusters and factors obtained by principal components analyses (PCA) from Inputs (Table 1).

After it was observed that there was no clustering among the data in each dataset (forage and animal production), individual ANNs were developed in each dataset. The Corr and MSE values that were obtained using ANNs and MLR for different inputs (Table 1) and ANN structures (N° hidden layers) are presented in Table 2. The standard observed for all evaluations was that ANNs predict with more efficiency compared to MLR. For all combinations between inputs and ANN structures, the Corr value was higher than ANN (mean values of 0.84, 0.78, and 0.75 for fm, %l, and %s, respectively, versus mean values of 0.74, 0.39, and 0.50 for fm, %l, and %s, respectively for MLR), and consequently, the MSE was lower. For MSE, these values were close to 1.3 t, 0.9%, and 1.1% (for fm, %l, and %s, respectively) for ANN, and 1.9 t, 1.9%, and 1.8% (for fm, %l, and %s, respectively) for MLR.

| Inputs <sup>a</sup> | N <sup>o</sup><br>hidden<br>layer <sup>b</sup> | Total mass        |       |                  |       | Leaf percentage   |       |                  |       | Stem percentage   |       |                  |       |
|---------------------|------------------------------------------------|-------------------|-------|------------------|-------|-------------------|-------|------------------|-------|-------------------|-------|------------------|-------|
|                     |                                                | Corr <sup>c</sup> |       | MSE <sup>d</sup> |       | Corr <sup>c</sup> |       | MSE <sup>d</sup> |       | Corr <sup>c</sup> |       | MSE <sup>d</sup> |       |
|                     |                                                | ANN               | MLR   | ANN              | MLR   | ANN               | MLR   | ANN              | MLR   | ANN               | MLR   | ANN              | MLR   |
| 1 to 11             | 2                                              | 0.835             | 0.748 | 1.386            | 2.023 | 0.750             | 0.418 | 0.011            | 0.020 | 0.750             | 0.527 | 0.012            | 0.019 |
|                     | 3                                              | 0.834             | 0.739 | 1.387            | 1.967 | 0.787             | 0.396 | 0.010            | 0.021 | 0.777             | 0.488 | 0.010            | 0.020 |
|                     | 4                                              | 0.852             | 0.741 | 1.200            | 1.931 | 0.804             | 0.428 | 0.008            | 0.018 | 0.743             | 0.497 | 0.012            | 0.019 |
|                     | 5                                              | 0.864             | 0.742 | 1.157            | 1.884 | 0.798             | 0.406 | 0.008            | 0.019 | 0.743             | 0.483 | 0.011            | 0.019 |
|                     | 6                                              | 0.815             | 0.742 | 1.487            | 1.880 | 0.763             | 0.379 | 0.010            | 0.020 | 0.735             | 0.521 | 0.013            | 0.019 |
| 1 to 11 - 2         | 2                                              | 0.817             | 0.747 | 1.456            | 1.941 | 0.751             | 0.386 | 0.009            | 0.019 | 0.757             | 0.508 | 0.010            | 0.018 |
|                     | 3                                              | 0.826             | 0.732 | 1.492            | 2.102 | 0.759             | 0.396 | 0.010            | 0.019 | 0.756             | 0.485 | 0.012            | 0.021 |
|                     | 4                                              | 0.871             | 0.758 | 1.035            | 1.753 | 0.792             | 0.378 | 0.009            | 0.020 | 0.735             | 0.513 | 0.012            | 0.020 |
|                     | 5                                              | 0.838             | 0.734 | 1.291            | 1.931 | 0.748             | 0.362 | 0.010            | 0.020 | 0.739             | 0.501 | 0.012            | 0.019 |
|                     | 6                                              | 0.815             | 0.735 | 1.611            | 2.062 | 0.780             | 0.427 | 0.009            | 0.018 | 0.715             | 0.486 | 0.013            | 0.021 |

Continue...

|                   |   | Corr <sup>c</sup> |       | MSE <sup>d</sup> |       | Corr <sup>c</sup> |       | MSE <sup>d</sup> |       | Corr <sup>c</sup> |       | MSE <sup>d</sup> |       |
|-------------------|---|-------------------|-------|------------------|-------|-------------------|-------|------------------|-------|-------------------|-------|------------------|-------|
|                   |   | ANN               | MLR   | ANN              | MLR   | ANN               | MLR   | ANN              | MLR   | ANN               | MLR   | ANN              | MLR   |
| 1 to 11 - 6       | 2 | 0.8031            | 0.740 | 1.598            | 2.026 | 0.785             | 0.445 | 0.009            | 0.019 | 0.756             | 0.501 | 0.010            | 0.018 |
|                   | 3 | 0.8551            | 0.746 | 1.127            | 1.840 | 0.770             | 0.366 | 0.010            | 0.021 | 0.775             | 0.546 | 0.011            | 0.019 |
|                   | 4 | 0.84726           | 0.758 | 1.371            | 1.953 | 0.783             | 0.387 | 0.008            | 0.018 | 0.747             | 0.503 | 0.010            | 0.017 |
|                   | 5 | 0.86496           | 0.727 | 1.118            | 2.073 | 0.791             | 0.417 | 0.007            | 0.016 | 0.737             | 0.510 | 0.011            | 0.017 |
|                   | 6 | 0.8443            | 0.724 | 1.195            | 1.919 | 0.801             | 0.404 | 0.009            | 0.019 | 0.758             | 0.500 | 0.011            | 0.019 |
| 1 to 11 - 7       | 2 | 0.822             | 0.745 | 1.313            | 1.867 | 0.771             | 0.346 | 0.010            | 0.021 | 0.773             | 0.461 | 0.010            | 0.020 |
|                   | 3 | 0.813             | 0.730 | 1.392            | 1.970 | 0.835             | 0.396 | 0.007            | 0.019 | 0.741             | 0.517 | 0.011            | 0.017 |
|                   | 4 | 0.863             | 0.746 | 1.145            | 1.941 | 0.780             | 0.379 | 0.008            | 0.019 | 0.745             | 0.499 | 0.010            | 0.017 |
|                   | 5 | 0.863             | 0.734 | 1.077            | 1.936 | 0.827             | 0.378 | 0.007            | 0.020 | 0.747             | 0.469 | 0.011            | 0.020 |
|                   | 6 | 0.838             | 0.765 | 1.499            | 1.955 | 0.718             | 0.386 | 0.011            | 0.018 | 0.742             | 0.499 | 0.010            | 0.017 |
| 1 to 11 - 2 and 6 | 2 | 0.816             | 0.750 | 1.488            | 1.979 | 0.724             | 0.379 | 0.010            | 0.018 | 0.788             | 0.523 | 0.010            | 0.019 |
|                   | 3 | 0.815             | 0.727 | 1.508            | 1.990 | 0.761             | 0.351 | 0.009            | 0.019 | 0.764             | 0.492 | 0.010            | 0.018 |
|                   | 4 | 0.825             | 0.736 | 1.483            | 2.081 | 0.796             | 0.388 | 0.009            | 0.020 | 0.726             | 0.499 | 0.012            | 0.019 |
|                   | 5 | 0.841             | 0.751 | 1.263            | 1.853 | 0.729             | 0.371 | 0.011            | 0.019 | 0.738             | 0.494 | 0.012            | 0.019 |
|                   | 6 | 0.817             | 0.733 | 1.457            | 1.915 | 0.778             | 0.372 | 0.009            | 0.019 | 0.728             | 0.517 | 0.012            | 0.018 |

**Table 2.** Results of tested different models' artificial neural network (ANN) and multiple linear regression (MLR) to predict forage production (Forage mass, Leaf and Stem percentages) with varying model inputs and ANN parameters. <sup>a</sup> Inputs are defined in Table 1, <sup>b</sup> N<sup>o</sup> hidden layer – structure of ANN, <sup>c</sup> Corr – Pearson correlation value between predicted values and observed values, <sup>d</sup> MSE – mean square error of prediction.

The analysis results (Table 3) showed that there was no difference between the different inputs that were evaluated ( $p=0.656$ ).

| Variation causes                | DF  | SS    | MS    | F     | p-Value               |
|---------------------------------|-----|-------|-------|-------|-----------------------|
| Inputs                          | 4   | 0.004 | 0.001 | 0.611 | 0.656 <sup>NS</sup>   |
| N° hidden layer                 | 4   | 0.015 | 0.004 | 2.271 | 0.063 <sup>NS</sup>   |
| Model                           | 1   | 0.560 | 0.560 | 340.2 | <0.0001 <sup>**</sup> |
| <i>Interactions<sup>a</sup></i> |     |       |       |       |                       |
| A x B                           | 16  | 0.017 | 0.001 | 0.648 | 0.842 <sup>NS</sup>   |
| A x C                           | 4   | 0.003 | 0.001 | 0.436 | 0.782 <sup>NS</sup>   |
| B x C                           | 4   | 0.014 | 0.004 | 2.119 | 0.080 <sup>NS</sup>   |
| A x B x C                       | 16  | 0.009 | 0.001 | 0.331 | 0.993 <sup>NS</sup>   |
| Residuals                       | 200 | 0.329 | 0.002 | -     | -                     |
| Total                           | 249 | 0.950 | -     | -     | -                     |

**Table 3.** Analysis of variance for main effects and interaction resulted of Pearson correlation (Corr) into different models (artificial neural network [ANN] and multiple linear regression [MLR]) used to predict forage production (Forage mass, Leaf and Stem percentages) with varying model inputs and ANN parameters. DF – degree freedom, SS – sum square, MS – mean square, <sup>a</sup> A – Inputs, B – N° hidden layer and C – Model, <sup>\*\*</sup> - significant at a 1% probability level, <sup>NS</sup> - non-significant at a 5% probability level.

The same result, i.e., the absence of differences, was observed for the ANN structure (N° hidden layers,  $p=0.063$ ), but some trends were observed in this case. The values (Table 2) indicated that better prediction results were obtained using an ANN structure with three or four hidden layers, causing a quadratic effect, which is represented by the equation  $y = 0.7356 + 0.0282x - 0.0033x^2$  (where  $y$  is the Corr value and  $x$  is the N° hidden layers). When different models are compared in Table 3 (ANN or MLR), differences were observed ( $p<0.0001$ ), showing that ANN was better than MLR with respect to the prediction of forage production (fm, %, and %s). Following other analyses, interactions were developed between all causes of variations (inputs [A], N° hidden layer [B], and model [C]; Table 3). There is no significance for these interactions ( $p>0.05$ ).

Highlighted can be done to N° hidden layer x Model that result in tendency ( $p=0.080$ ), probably caused by Model used, mainly ANN.

When the results obtained for animal production predictions are observed to be similar to that for forage production, the use of ANNs resulted in higher Corr values compared with MLR for all inputs evaluated (Table 4). For these inputs, differences ( $p<0.0001$ ) were observed (Table 5).

| Inputs <sup>a</sup>    | N° hidden layer <sup>b</sup> | Corr <sup>c</sup> |       | MSE <sup>d</sup> |       |
|------------------------|------------------------------|-------------------|-------|------------------|-------|
|                        |                              | ANN               | MLR   | ANN              | MLR   |
| 1 to 15 - 6            | 2                            | 0.722             | 0.678 | 0.088            | 0.099 |
|                        | 3                            | 0.728             | 0.666 | 0.079            | 0.092 |
|                        | 4                            | 0.707             | 0.663 | 0.090            | 0.097 |
|                        | 5                            | 0.706             | 0.667 | 0.082            | 0.089 |
|                        | 6                            | 0.713             | 0.669 | 0.087            | 0.095 |
| 1 to 15 - 2 to 4 and 6 | 2                            | 0.724             | 0.650 | 0.091            | 0.109 |
|                        | 3                            | 0.704             | 0.640 | 0.085            | 0.096 |
|                        | 4                            | 0.688             | 0.620 | 0.092            | 0.106 |
|                        | 5                            | 0.694             | 0.634 | 0.091            | 0.100 |
|                        | 6                            | 0.732             | 0.659 | 0.078            | 0.095 |
| 1 to 15 – 1 to 6       | 2                            | 0.661             | 0.480 | 0.098            | 0.130 |
|                        | 3                            | 0.677             | 0.496 | 0.097            | 0.127 |
|                        | 4                            | 0.672             | 0.481 | 0.094            | 0.128 |
|                        | 5                            | 0.682             | 0.542 | 0.096            | 0.126 |
|                        | 6                            | 0.668             | 0.504 | 0.092            | 0.124 |

**Table 4.** Results of tested different models' artificial neural network (ANN) and multiple linear regression (MLR) to predict animal production (Average Daily Gain) with varying model inputs and ANN parameters. <sup>a</sup> Inputs are defined in Table 1, <sup>b</sup> N° hidden layer – structure of ANN, <sup>c</sup> Corr – Pearson correlation value between predicted values and observed values, <sup>d</sup> MSE – mean square error of prediction.

The higher prediction values (0.72 and 0.67 for ANN and MLR, respectively) were obtained using first the input (1 to 15 – 6), which corresponds to all variables, with the exception of only the humidity (Table 1). However, the worst prediction values (0.67

and 0.50 for ANN and MLR, respectively) were obtained using the last input (1 to 15 – 1 to 6), which excludes all climate variables (Table 1). The mean MSE was calculated for all combinations of the input and N° hidden layers, and the values were 89 g for ANN versus 107 g for MLR. The N° hidden layers did not vary for the structures that were evaluated ( $p=0.431$ ). As with the last dataset, the model that was used was the reason for the difference ( $p<0.0001$ ). The ANN predictions resulted in better Corr values compared to those of MLR, i.e., 0.70 versus 0.60. When there were interactions between inputs [A], N° hidden layer [B] and Model [C] (Table 5), the effect was observed only for inputs x Model ( $p<0.0001$ ), where there was a quadratic effect for MLR, and a linear effect for ANN.

| Variation causes                | DF  | SS    | MS    | F     | p-Value             |
|---------------------------------|-----|-------|-------|-------|---------------------|
| Inputs                          | 2   | 0.320 | 0.160 | 96.84 | <0.0001**           |
| N° hidden layer                 | 4   | 0.006 | 0.002 | 0.962 | 0.431 <sup>NS</sup> |
| Model                           | 1   | 0.342 | 0.342 | 207.1 | <0.0001**           |
| <i>Interactions<sup>a</sup></i> |     |       |       |       |                     |
| A x B                           | 8   | 0.017 | 0.002 | 1.254 | 0.274 <sup>NS</sup> |
| A x C                           | 2   | 0.111 | 0.056 | 33.65 | <0.0001**           |
| B x C                           | 4   | 0.003 | 0.001 | 0.382 | 0.821 <sup>NS</sup> |
| A x B x C                       | 8   | 0.003 | 0.000 | 0.186 | 0.992 <sup>NS</sup> |
| Residuals                       | 120 | 0.198 | 0.002 | -     | -                   |
| Total                           | 149 | 1.000 | -     | -     | -                   |

**Table 5.** Analysis of variance for main effects and interaction resulted of Pearson correlation (Corr) into different models (artificial neural network [ANN] and multiple linear regression [MLR]) used to predict animal production (Average Daily Gain) with varying model inputs and ANN parameters. DF – degree freedom, SS – sum square, MS – mean square, <sup>a</sup> A – Inputs, B – N° hidden layer and C – Model, \*\* - significant at a 1% probability level, <sup>NS</sup> - non-significant at a 5% probability level.

## DISCUSSION

Our results were in agreement with the previous knowledge that ANNs are chosen based on their ability to find nonlinear realistic relationships between causes and indices which can explain the behaviors of complex systems, such as the biological systems

evaluated in this research [12]. Considering the study by van de Ven et al. [5], the models that were evaluated in this research (forage and animal production) could be considered limited production because it employed information in the inputs (Table 1), such as the genetic characteristics (crops, breed), climate (temperature, photoperiod, rainfall, rainy days, humidity), as well as water and food quantity (nitrogen fertilizer level, supplementation level, sward height, forage mass, leaf and stem percentages).

Both Figures 1 and 2 clearly show that there were no groups in each dataset (forage and animal production). Clustering could be considered as a tool that is used to segment large heterogeneous datasets into smaller and homogeneous subsets, which could be easily handled to be modeled and analyzed [20]. The PCA developed for both datasets did not create these previously mentioned subsets, and consequently, it can be understood that all factors considered in each analysis are responsible for similar characteristics among all of the data analyzed.

Considering the results obtained by analyzing the forage production dataset (Table 3), it is possible to determine that ANN had a greater capacity to predict results (fm, %l, and %s) than MLR. Therefore, when only the ANN results were studied, there were no differences between all of the inputs that were evaluated (Table 2), enabling us to use the smaller number of variables in the inputs. This smaller quantity requires less computational cost, and consequently a smaller memory cost to develop the ANN analyses. In addition to this condition, the results in Table 3 show that fewer (2 hidden layers – Table 2) N° hidden layers could be used without affecting the prediction results. In this way, the variables that were used in the inputs were the rainfall, temperature (max and min), rainy days, stocking rate, nitrogen fertilizer level, supplementation level, forage crop, and sward height (Table 2).

Thus, considering factors that are important to grass plant physiology, our inputs that were used in the ANN architecture are in agreement with results from other study [21]. The following factors were reported to be important: light, temperature, photoperiod, humidity, wind, rainfall, soil fertility, soil physical compound, topography, forage genetics potential (production and nutritive value), environmental adaptation, seed competition and control, perennial, animal acceptance during grazing, grazing method and system, stocking rate, and fertilizer strategies. Therefore, to compare this classic report with inputs used in the ANN analyses, it can be mentioned that the inputs are associated with these factors.

To understand each input and its importance to the prediction of results of fm, %, and %s, were presented the responses for each one for forage production. Rainfall and rainy days are directly associated with water availability to plants. This availability is important because it results in conditions that are optimum for plant metabolism, but both low and excess water availability can cause problems in plant mineral nutrition [22]. The importance of both inputs (rainfall and rainy days) was demonstrated in Romanzini et al. [23], which evaluated important factors in the relationship with forage production using multivariate analysis. They reported that rainy days and humidity were positively correlated with the total forage production. With respect to the other climate inputs used, the maximum and minimum temperatures are important because the C4 photosynthetic pathway had a great growth range. The C4 species has higher photosynthesis temperatures [24]. However, according to the same authors, these plants have a reduced ability to acclimatize to the optimum temperature for photosynthesis associated with the growth temperature. Thus, these inputs (related to temperature, maxima, and minima) need to be used in ANN analyses in order for variations in temperatures to be understood for biological process called forage production.

If other inputs are observed (stocking rate, nitrogen fertilizer level, and supplementation level), can be understood the importance of addressing the development of beef cattle production using forage as the main nutrient source. With respect to the stocking rate, its use in ANN structures of forage production can be explained by its relationship with grazing. This grazing corresponds to an act of defoliation, which is considered a major management imposition on the forages, and its impact is related to both the severity and timing of defoliation [25]. The same authors reported that this defoliation should be handled to provide optimal conditions both persistence as to production of the pasture, our aim in this research. The other input, i.e., the nitrogen fertilizer level, could be described as a tool that is adopted primarily to increase the forage quality and quantity [26]. The fertilization using nitrogen is a common management technique that results in increased forage yields [27]. Recommendation with nitrogen providing at least 50% of agronomic requirement can cause an improved in soil quality [28]. This improvement could facilitate conditions that are necessary for forage development. Finally, the last management input, i.e., animal supplementation level, directly affects the forage intake by animals, and consequently, the forage production. Following the classical model of three interaction effects were found to exist between forage and supplement intakes, namely additive, combined, and substitutive [29]. Each one results in a different forage intake level, which could cause the forage production due to defoliation during grazing to be equal or lesser than what is observed without supplementation. This justifies the use of the supplementation level in the input during ANN analysis.

The last inputs that were used in the ANN structure of forage production were the forage crop and sward height. Both inputs are related to the sward structure, and it is important to determine the forage productivity. Both of the forage crops (Marandu and

Xaraes) that were evaluated in this study were cultivars of *Urochloa brizantha*, but even with this common origin, they showed some varied characteristics, which can alter the forage production. Marandu grass has good potential in shadows, with high roots and seed production [30]. The same authors reported that Xaraes grass has high productivity, mainly because of leaves that have high support capacity. Therefore, each forage crop has unique characteristics that are important as inputs in ANN structures. With respect to the sward height, it was reported that the sward structure mentioned above is frequently determined by global attributes, which are referred to as the sward height and herbage mass [31]. The first input used in our ANN to predict the forage production, and the second one is in response to our ANN and is called the forage mass (fm). Another important point about the sward height for forage production predicted in our research is that it is correlated to the defoliation process, which is developed by grazing, and therefore, it determines the sward residual architecture, which influences plant regrowth [32]. It is thus very important to predict the forage production using ANN analysis.

When was evaluated the other dataset, i.e., animal production, as observed with another dataset (forage production), compared with MLR, ANN was better in terms of predicting the result (ADG, Table 5). However, in contrast with what occurred for forage production, the inputs used in this dataset were different in terms of how they were evaluated (Table 5). As a result, both the first (1 to 15 – 6) and second ones (1 to 15 – 2 to 4 and 6) were better than the third (1 to 15 -1 to 6) ( $p < 0.0001$ ). Considering the fewer computations required, the second input could be used (Table 4), which considers these variables: rainfall, rainy days, stocking rate, nitrogen fertilizer level, supplementation level, forage crop, sward height, animal breed, forage mass, leaf and stem percentages. If these observed inputs can be understood the better Corr value obtained, close to 0.70, that could be considered median. None of the inputs that were used were related to the feed's

nutritional value or dry matter intake, which are both directly related to the animal performance. These inputs were not used because they are not easily measured on land.

To understand the effect of each input on the ANN structure with respect to the prediction of animal production, as measured in ADG, these inputs (Table 1) were divided into groups, namely climate (rainfall, rainy days) and management (all others). The maximum growth rate is dependent on the species, breed, sex, and climate [5]. Our inputs had some of these characteristics in the ANN structure. With respect to climate, it was reported that environment factors, include rainfall, can alter the animal behavior, and consequently change the dry matter intake, which is the main variable associated with ADG [33]. These two inputs, which are grouped in the climate category, significantly affect the forage production (as mentioned previously), and consequently, could cause an increase in animal performance that is due mainly to the forage quantity and quality available to animal intake.

Considering all of the other inputs that are used in ANN structures to predict the relationship between the animal production and management, can be explained the general considerations that are associated with this input in beef cattle production on grasslands. The effect of the stocking rate on the ADG can be understood using the classic theory [34]. The author reported that there is a fitting stocking rate that results in an adequate gain per animal and gain per area. Thus, it is important to understand that neither of the gains (animal and area) was improved because to obtain the best gain per animal, the stocking rate would result in undergrazing. On the other hand, the best gain per area resulted in a high stocking rate, causing overgrazing in the area. Therefore, the use of the stocking rate is fundamental to predicting the animal production results because it varies with grazing pressure. When another variable, i.e., the supplementation level, is observed, it can be reported that this is important to predict animal production results

because it is an important tool that is used to increase the stocking rate without causing overgrazing into pasture systems. Some studies [2, 35] reported that supplementation is an important management tool of beef cattle production, which causes an increase in ADG. Thus, owing to this important correlation with ADG, its use in inputs for the prediction of animal production can be understood.

The inputs, namely nitrogen fertilizer level, forage crop, sward height, forage mass, and leaf and stem percentages, could be included because they are all associated with forage conditions (quality and quantity). If considered that animal performance, which is measured by ADG, is directly correlated with volunteer feed intake and nutritional value [36], all of the changes in forage conditions can vary the animal ADG. With respect to the nitrogen fertilizer level, nitrogen is a key nutrient that contributes to the pasture quality and production [37]. These characteristics are directly associated with animal performance. In addition, nitrogen can be associated with other inputs that are important to obtain animal performance results. This nutrient causes changes in the forage mass as well as leaf and stem percentages, and when associated with grazing, can alter sward height. The decrease in the quantity of nitrogen available to forage can decrease the emission speed and lifespan of leaves in addition to decreasing the number of leaves, and consequently the light interception for photosynthesis [38]. On the other hand, nitrogen fertilizer can increase forage quality, while increasing the leaf mass, emergence of new shoots, and leaf longevity [39]. According to these authors, these results for the forage improve animals' voluntary dry matter intake, consequently increasing the ADG, which is the variable predicted in the animal production ANN.

Finally, the input called animal breed is very important in ANNs that aim to predict ADG because each breed has specifications that result in different growth curves. Evaluating the same two breeds used in a research (Nellore and  $\frac{1}{2}$  Nellore  $\times$   $\frac{1}{2}$  Aberdeen

Angus) in pasture systems with supplementation, there were no differences in carcass yield and characteristics. However, it was observed differences in the ADG between both breeds [40]. The differences occurred basically based on the breed origin: Nellore from *Bos taurus indicus*, which produced animals with resistance to the environment and ectoparasites, and Aberdeen Angus from *Bos taurus taurus*, which produced animals that were less adapted to warm climates but exhibited good finishing precocity. Therefore, it was important to utilize this input (animal breed) in ANN structures to predict animal production.

## CONCLUSION

The use of artificial neural networks, along with specific structures for each evaluation, is a potential tool in the prediction of future results for forage mass, leaf and stem percentages and animals average daily gain using easily measurable inputs to support owners' decisions for beef cattle production in grazing systems, allowing us to define the best management system to increase system productivity.

## AVAILABILITY OF DATA AND MATERIALS

Requests to access additional data for exclusive research purpose may be sent to the following contact: Eliéder Prates Romanzini, [elieder.romanzini@gmail.com](mailto:elieder.romanzini@gmail.com). Via de Acesso Prof. Paulo Donatto Castellane s/n, 14884-900, Departamento de Zootecnia, Unesp, Jaboticabal, SP, Brazil

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## AUTHORS' CONTRIBUTIONS

L M. D.; R. G. L.; A. H.; E. E. D.; A. C. F. and T. L. R. A. conceived and designed the experiments; E. P. R., P. A. B. and R. A. R. interpreted the results and contributed to wrote the manuscript; E. P. R. and P. A. B. performed the analysis and draft the manuscript and R. A. R. and E. B. M. supervised and coordinated the analysis. All authors read and approved the final version of the manuscript.

## ADDITIONAL INFORMATION

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## CHAPTER 3

O artigo a seguir está redigido conforme normas de publicação do Periódico: Agricultural Systems.

**Economic evaluation of the beef cattle production industry with intensification in Brazil's tropical pastures**

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**ABSTRACT** – The Brazilian beef cattle production is an important source that keep positive gross domestic product. The main cause of these values is the low production costs due pastures utilization of the production system in all phases. However, insert technologies like pasture management and supplementation can improve productivity and increase incomes. The hypothesis this study is that different scenarios (year, supplementation level) not change the economic results of beef cattle production during rearing and finishing phase in Brazilian's tropical pastures. Four scenarios were evaluated in combination with fourteen supplements, it was originating from some research developed inside Forage Crops and Grasslands section of São Paulo State University among year 2011 and 2014. The economic evaluation was analyzed by cost-effective operating, cost-total operating, gross revenue, operating profit and financial net income. Were calculated profitability, internal rate of return (IRR), benefit:cost ratio (B:C), simple payback period (SPP) and break-even point by period and daily too. The prices were obtained inside local market for each year and the values were converted by the exchanged rate of each year too. During rearing phase, the best result was observed for scenario 2 (2012), supplement 3.2 (mineral mix) with values of 11 cycles, 26.3%, 9.30%, and 0.39 for SPP, profitability, IRR, and B:C ratio, respectively. Already to finishing phase, the best scenario was the 3 (2013), supplement 10 (multiple supplement with supplementation level equal 1.0% body weight [BW]), which obtained 4 cycles, 68.7%, 27.00%, and 2.34 for the same variables above mentioned. Results were consistent being that higher IRR and profitability occurred when used low supplementation level. Hence, the economic responses of beef cattle production developed in tropical pastures from Brazil changed among different scenarios and supplements evaluated in this study.

**Keywords:** cost total operating; supplementation; wet season; dry season

## **1.Introduction**

The values of beef cattle production are higher year after year. According to United States Department of Agriculture (USDA, 2017), the stock of beef cattle from Brazil is close to 222 million of head and the production is 9.5 million ton, measured in carcass weight. These values enable to Brazil be among bigger producers and exportation countries of the world. However, the Brazilian productive indexes are not better than other power producers as the United States and Australia (Alves, 2011). Basically, beef cattle production in Brazil is developed using pastures as main food source, so the technologies used normally are very poor.

Perhaps the low use of technologies causes higher profits due to the low production costs. Nevertheless, if considered every all circumstance, these systems will not persist inside new livestock which considers animal performance, climate changes always looking for economics benchmarking. Thus, an important change on beef cattle production systems is the high intensification which can through using technologies as pasture management and supplementation improve results and increase incomes. If considered the importance of the economic results to show the best ways, are few types of research (Barbero et al., 2017; Kamali et al., 2016 and Figueiredo et al., 2007) that evaluate these economic results of the beef cattle production using or no high production intensity. So, our hypothesis considered that supplementation used at different conditions, years, not change the economic responses during rearing and finishing phases of beef cattle production developed in Brazilian's tropical pastures.

## 2. Material and Methods

### 2.1. Description of the dataset

The experiments were developed in the Forage Crops and Grasslands section of São Paulo State University, “Júlio de Mesquita Filho” (Unesp) (Jaboticabal, São Paulo, Brazil). The typical climate of the region is the subtropical humid type, with dry winters and wet summers. Pastures were seeded with *Urochloa brizantha* (Hochst.) Stapf. ‘Marandu’ (Palisade grass) handled using continuous grazing system, with variable stocking rate, sward height at 25 cm according to some researchers (Casagrande et al., 2011; Barbero et al., 2015 and Barbero et al., 2017).

Data were evaluated since the production year 2010/2011 until 2013/2014, the first year is because the adjusts on stocking rate and sward height and fertilizer practice that occurred during wet season, close December. So, we had four scenarios, 1: 2010/2011; 2: 2011/2012; 3: 2012/2013 and 4: 2013/2014 each one with different nutritional strategies (Table 1). Each scenario developed during different years had different supplements, with individual chemical composition (Table 2), due to ingredients used (energetic [corn meal, citrus pulp, Lactoplus<sup>®</sup>], protein [cotton seed meal, cotton seed, soybean meal, soybean grain, urea] and nucleus) and supplied levels. Other significant difference is the weather that cause changes on production and nutritive value of forage, considered the main food source. During the production years from scenarios 1, 2, 3 and 4 the mean of temperature and rainfall were respectively, 23.4°C and 264.1 mm; 22.9°C and 105.4 mm; 23.5°C and 88.1 mm; and 22.8°C and 78.5 mm. Inside each year were considered two distinct phases: rearing phase during wet season when was used high stocking rate and fewer supplementation levels, and finishing phase, developed during the dry season, when the animals were finished and after to allow slaughter weight (up to 460 kg) was sold.

Animal performance data and productive indexes used to develop every economic analysis were taken out of Theses (Oliveira, 2014; Valente, 2015; Barbero, 2016 and Koscheck, 2016) and were adjusted for characteristics above described (sward height: 25 cm and paddock area: 1.0 ha). So, were used initial and final body weight (kg), stocking rate (animal unit [AU].ha<sup>-1</sup>), supplementation level (% body weight [BW]), length measured at days, for each phase inside every scenario (Table 3).

## *2.2. Economic evaluation*

The economic evaluation was developed by phase (rearing and finishing). Each scenario had a different nutritional strategy, with different supplement, supplementation levels during each phase. We evaluated the economic results inside each phase on different scenarios. These evaluations were considering: cost-effective operating (CEO), cost-total operating (CTO) (Matsunaga et al., 1976), gross revenue (GR), operating profit (OP) and financial net income (FNI), every measured in US\$. Another analysis developed to compound CTO was linear depreciation (LD). These calculations considered new value (NV), scrap value (SV), lifetime (LT) of the building, equipment and every all involved with the beef cattle production and use days (UD) of building and equipment. So, the LD from each item was calculated by  $[(NV - SV / LT) / 365] * UD$  (Lopes et al., 2011). Other analyses were made to evaluate economically each phase, the profitability was calculated by  $[OP / GR]$ . The simple payback period (SPP) was calculated considering average capital stocktaking pondered by area in use (ACS), the capital cost divided by  $[GR - CEO]$ , the savings per year (She et al., 2018). The SPP is the time, measured in cycles, to pay all investments of the system. Another one economic variable used was internal rate of return (IRR), calculated by  $100 / SPP$  (Aguiar and Resende, 2013). We calculated yet the benefit:cost ratio (B:C) by  $[(GR - CEO) / CEO]$  and a break-evenpoint (BEP) of the period and daily, both measured in kilogram of body weight (kg BW), first

calculated by  $[CTO / (\text{revenue pay per kg} - \text{average CEO})]$  and the second calculate by  $[\text{BEP period/length days}]$ .

Input prices were average prices during the period 2010–2014 and were obtained from Anuário Brasileiro da Pecuária (ANUALPEC, 2010), Centro de Estudos Avançados em Economia Aplicada (CEPEA, 2017) and quotation in the same region of animal production (northeast São Paulo State) during the period above mentioned. The values were calculated in US\$ according exchange rate for each year (2011 – R\$1.67; 2012 – R\$1.95; 2013 – R\$2.16; 2014 – R\$2.35).

#### *2.2.1. Rearing phase*

The CEO was calculated considering purchase of steers Nellore, supplements and fertilizer, costs with supplementation and fertilization practice and management costs (medicine and animal marker). The CTO was calculated by  $[\text{CEO} + \text{LD}]$ .

The GR was calculated by sold of animals to keep accurate stocking rate during the next phase (dry season) when this stocking rate is less than rearing phase. The animals were sold considering the BW to define the price by head or kg, according to historic quotation (CEPEA, 2017).

#### *2.2.2. Finishing phase*

The CEO was calculated considering purchase of supplements, costs with supplementation practice and management costs (medicine and animal marker). The CTO was calculated by the same equation that for rearing phase.

The GR was calculated by sold of animals to slaughterhouse. The animals were sold considering the BW and carcass yield of 50% to define the price by kg, according to historic quotation (CEPEA, 2017).

### 2.3. Multivariable analysis

Using some economic results and indexes ((CEO, CTO, GR, OP, FNI, Profit., IRR, B:C), %LD into CTO), calculated for each scenario and supplement, and Exchange Rate (US\$ to R\$) and Steer price (US\$.head<sup>-1</sup>) related to each year evaluated (2011 to 2014) was developed a CLUSTER analysis to define the clusters of association between scenario and supplement. All variables previously mentioned were standardized and on evaluation were used to measure distance the Euclidean distances and Ward's Method as Amalgamation (linkage) rule (Rosa et al., 2017 and Mingoti, 2005). Software used was STATISTICA v.12 (Stat Soft, Inc., 2014).

### 3.Results

The economic results (Figure 1) showed all scenarios for distinct phases (rearing and finishing). When observed the Figure 1 we can see that both costs, CEO and CTO, are higher during rearing phase for all scenarios. The less CEO during rearing phase occurred at scenario 2 and 3 for supplements 3.2 and 9, respectively. These costs, for supplements previously mentioned, were US\$3,023.35 and US\$3,098.79. Following these evaluations, the CTO was lesser for the same supplements (US\$3,087.55 and US\$3,140.40, respectively for supplement 3.2 and 9). On other hand, yet inside rearing phase, the higher costs (CEO and CTO) were observed at scenario 2 and 4 for supplements 8 and 13 with average values close to US\$4,665.85 and US\$4,722.36, respectively for both costs.

When observed the GR inside rearing phase, the high values were to scenarios 2 (US\$4,195.10) and the less were to scenario 4, supplement 13 (US\$2,577.71) followed by scenario 3, supplement 9 (US\$2,724.67). If associated these results (GR, CEO and CTO), we can observe the values of OP and FNI. So, the best result was to scenario 2, supplement 3.2 (US\$1,107.25 and US\$1,171.75, respectively to OP and FNI) and the

worst was to scenario 4, supplement 13 (-US\$2,562.06 and -US\$2,525.68, respectively to OP and FNI).

Inside Figure 1, we can observe yet another phase (finishing) when the costs, CEO and CTO, were lesser than during rearing phase. At finishing phase, the OP and FNI were higher than the same variable inside each scenario during rearing phase. During finishing phase, the GR were higher than costs, so, the results were better.

Every scenario during finishing phase use some supplement in elevated levels than during rearing phase itself. The excessive costs during finishing phase were observed for scenarios 1 and 4 with use of supplements 6 and 14, respectively. When the CEO and CTO were US\$1,061.80 and US\$1,108.31 (scenario 1, supplement 6) and US\$1,065.04 and US\$1,106.35 (scenario 4, supplement 14), respectively for costs. In other hand, the less costs were to scenarios 1 and 3 with supplements 4 and 10, respectively. The scenario 1, supplement 4 resulted in CEO and CTO values US\$778.53 and US\$825.04, respectively. Already, scenario 3, supplement 10 resulted US\$732.18 and US\$762.31, respectively for the same costs.

If considered the GR the higher value was obtained for scenario 3, supplement 10, when the revenue was US\$2,442.70. The scenario 1, for all supplements (4, 5 and 6) resulted in GR values closed, with mean equal US\$1,938.84. The less GR value was to scenario 4, supplement 14, with US\$1,697.00. So, the OP and FNI were positively correlated to GR, when the higher GR values resulted in increase of OP and FNI. In this way, the better result for OP and FNI was to scenario 3, supplement 10 (US\$1,680.39 and US\$1,710.52, respectively) followed by scenario 1, supplements 4 (US\$1,057.17 and US\$1,103.68, respectively for OP and FNI), 5 (US\$987.11 and US\$1,033.62, respectively for OP and FNI) and 6 (US\$876.48 and US\$922.99, respectively for OP and FNI). The less OP and FNI was occurred to scenario 4, supplement 14, respectively US\$590.65 and US\$631.96.

After to know economic results for each phase (rearing and finishing), inside each scenario. We developed another analysis and the results were showed in Table 4. These results showed that the best profitability for rearing phase occurred to scenario 2, supplement 3.2 (26.3%) and for finishing phase was to scenario 3, supplement 10 (68.7%), which was the best profitability among every scenarios and supplements. We had some negative profitability values during rearing phase for every scenario that used supplements (1, 2, 8, 9, 12 and 13) (Table 4).

The SPP, calculated in cycles, had some not available values (Table 4) occurred when the profitability were negative values, at rearing phase into all scenarios. Another SPP values are not negative values; however, we can see some worst results like showed to scenario 2, supplement 7 (94 cycles), scenario 4, supplement 11 (71 cycles). The best SPP during rearing phase was observed for scenario 2, supplement 3.2 (11 cycles). If observed the finishing phase the best result was for scenario 3, supplement 10 (4 cycles). On other hand, the worst result for finishing phase occurred to scenario 4, supplement 14 (15 cycles).

These data corroborated with other results previously showed and with another like IRR and B:C ratio (Table 4). The best IRR calculated for rearing and finishing phase were observed for scenario 2, supplement 3.2 (9.30%) and scenario 3, supplement 10 (27.00%), respectively. In this way, the best B:C ratio between different phase and all scenarios were repeated for these scenarios 2 and 3, supplements 3.2 (0.39) and 10 (2.34), respectively.

We calculated BEP for period and daily (Table 4), always for kg BW.ha<sup>-1</sup>, too. If considered that less values BEP were better, because even with the less productivity there will be able to pay CTO. So for these variables during rearing phase the expressive results occurred for scenario 1, supplement 3.1 for BEPp, 302.99 kg BW.ha<sup>-1</sup>, and for BEPd, 2.71

kg BW.ha<sup>-1</sup> , If observed just BEPp the scenario 4, supplement 13 was lesser than previously mentioned ( kg BW.ha<sup>-1</sup>), however when compared BEPd, the value is higher (3.21 kg BW.ha<sup>-1</sup>) than scenario 1, supplement 3.1. Already to finishing phase, the great results could be observed for scenario 1, supplement 4 with BEPp, 175.10 kg BW.ha<sup>-1</sup>, and BEPd, 1.56 kg BW.ha<sup>-1</sup>, which was close to scenario 4, supplement 14 (1.54 kg BW.ha<sup>-1</sup>).

The multivariable analyses were developed to improve the observation of each scenario and supplement effect into economic results. So, if observed Figure 2 we can highlight the clustering between rearing and finishing phase. Considering that each scenario was developed during different years, so we could have not a great clustering. However, was possible to observe the cluster between rearing scenarios and finishing scenarios with linkage distance equal 10 (Figure 2). If observed with more attention the Figure 2, we can see that each scenario was clustered with different linkage distances into each phase [rearing phase (scenario 1 – linkage distance 2 and scenario 2 – linkage distance 3) and finishing phase (scenario 1 – linkage distance 1 and scenario 4 – linkage distance 4)]. Just the scenario 4 into rearing phase that had a different clustering, due supplement 13.

#### **4.Discussion**

A crucial point is that the economic evaluation is placed and temporal-dependent due the prices been obtained to a specific Brazilian region, São Paulo State and that each one year had external effects, like exchange rate. The occurred during rearing phase, higher costs can be understood due mainly the purchase Nellore steers (12 months old). This cost represented 61.33 until 85.47% of CTO among different scenarios and supplements of this study. If considered supplementation costs during rearing phase, the mineral mix (scenario 1 and 2, supplements 3.1 and 3.2, respectively) resulted in 2.59 and 2.93% CTO.

Both values are low when compared to other multiple supplements used inside each scenario 17.80 and 28.61% CTO average between supplements 1 and 2 (scenario 1) and supplements 7 and 8 (scenario 2), respectively. For other scenarios the multiple supplement represented 15.59% of CTO (scenario 3, supplement 9) and 16.90% CTO (average among supplements 11, 12 and 13 of scenario 4). This clustering among different scenarios and the supplements used into each one can be observed by cluster analysis showed on Figure 2.

The CTO composition available enable to understand that supplementation result the bigger different cost among scenarios evaluated. Consequently, higher level of supplementation is responsible for higher CTO and can cause negative profitability inside beef cattle production system. Thus, these values confirmed that feeding strategy is a critical point inside farm management affecting the beef cattle performance besides can to cause negatively profitability of systems (Hristov et al., 2013). Another important cost during rearing phase is the pasture management practices adopted in high intensification systems. For example, in these studies, the fertilizer application to increase the stocking rate values above to 5.00 AU.ha<sup>-1</sup> (Table 3) resulted in high cost. The fertilization practice was responsible to around 10% of CTO average among scenarios. Kamali et al. (2016) reported that the system's intensification improves the costs due higher requirements for labor, machinery and especially fertilizer.

About the OP and FNI during rearing phase (Figure 1) the values are very variable among distinct scenarios and inside each scenario for supplements used. This variation had the same standard between scenarios 1 and 2, when the supplements 3.1 and 3.2 (mineral mix [Table 1]) resulted in higher OP and FNI due mainly the lesser costs. The higher OP and NI can be understood due to the quality of forage that animals grazed during rearing

phase, the wet season, what enables that animal requirements were achieved, and the animals' performance was great (Reis et al., 2016).

Therefore, during rearing phase scenarios that use supplements 3.1 and 3.2 (mineral mix [Table 1]) or 7 and 11 (low supplementation level [Table 1]) had positive profitability. However, if observed every economic result, like reported by Kamali et al. (2016) the changes in cattle performance caused by dietary supplementation did not increase OP. So, the best situation occurred at scenario 2, supplement 3.2 (Table 4), when the SPP (11 cycles) is lesser than other scenarios and supplements during this phase. In this way the other variables evaluated, IRR (9.30%), B:C ratio (0.39), confirmed this affirmation. The BEPd showed that is necessary  $0.703 \text{ kg BW} \cdot \text{animal}^{-1} \cdot \text{day}^{-1}$  into area to pay all costs. This value is possible inside a beef cattle production system if considered animal production measured in average gain daily (ADG) equal  $1.15 \text{ kg} \cdot \text{animal}^{-1} \cdot \text{day}^{-1}$  (Barbero et al., 2015 mentioned by Reis et al., 2016).

Our results demonstrated that mineral mix (scenario 2, supplement 3.2) should be used during rearing phase (wet season) of Nellore steers if considered the economic performance of beef cattle farms. This affirmation can be reinforced by the price pay to these animals at 2012, when the value payed by animal (GR unity value) was the lesser (US\$599.30) compared to 2011 (US\$732.99) the year of another great scenario (scenario 1, supplement 3.1). However, according to Borges et al. (2014), there are a lack skills and knowledge for pastures management what cause low rate of adoption of high intensive productivity into beef cattle production. Due these points the adoption of this scenario by farmers may be to higher economic risks.

When observed the results from finishing phase (Figure 1), every all scenarios had more than 90% of CTO compounded by supplement costs. This value is because during this phase, dry season, the main food source is the supplement. The intake of supplement by

animals is above 1.0%BW (Table 1). Although this high consumption, the finishing phase was more economic efficient than rearing phase due less COE. The main cause of these result was absence purchase animals and fertilizer beside the reduction in stocking rate (Table 3), what cause fewer costs by area. This reduction in the stocking rate is an efficient pasture management tool to keep perennial grass during dry season. During dry season grass growth is limited by low temperature and humidity (Valle et al., 2000) and so, to keep high stocking rate can degrade the pastures.

The higher GR was the same scenario and supplement that had higher OP and FNI. The scenario 3, supplement 10 was the best (GR, OP and FNI, US\$2,442.70, US\$1,680.39 and US\$1,710.52, respectively) among all scenarios into finishing phase. Among other points the main causes of this values into scenario 3, supplement 10, can be the bigger stocking rate ( $3.18 \text{ AU.ha}^{-1}$ ) and FBW (514.0 kg) if compared with another all scenarios (averages  $2.58 \text{ AU.ha}^{-1}$  and 477.3 kg [Table 3]). Additional to higher values of stocking rate and FBW, the scenario 3, was developed in 2013, a year with great rainy distribution (Table 2) during the wet season, what resulted increase on forage' quantity and quality. Another key point about the superiority analyzed into scenario 3, supplement 10 is the price of corn grain (the main compound of supplement [Table1]), 11.0 and 9.46% cheaper than scenarios 1 and 2, respectively. Although the scenario 3, supplement 10 be the best, all scenarios resulted in positive OP and FNI (Figure 1).

The results of economic analysis (Table 4) confirmed the previously observed into Figure 1. Among finishing phase evaluated inside scenarios 1, 3 and 4 the best profitability, 68.7% occurred to scenario 3, supplement 10. However, should be highlighted that all scenarios had positive profitability. Consequently, these scenarios could be recommended to use inside beef cattle production system. Likewise, that profitability another economics variable (SPP, IRR, B:C ratio [Table 4]) determined that the scenario 3, supplement 10

was the better. If considered that more than 90% of CTO during finishing phase is relative to supplement costs and to among all scenarios the lesser level supplementation (1.0% BW [Table1]) were to scenario 3, supplement 10 and scenario 1, supplement 4 is possible to understand the positive economic results. In the same way, Silva et al. (2010) reported that higher IRR and profitability occurred when used low supplementation level.

According to Almeida et al. (2014) how much higher the IRR value of a project, higher will be the attractiveness for its use. Thus, if considered the results of economic analysis (profitability, SPP, IRR and B:C ratio) at both phase (rearing and finishing) the best combination, without consider the weather variation, of this study was scenario 2, supplement 3.2 for rearing phase, and scenario 3, supplement 10 for finishing phase.

## **5.Conclusion**

The economic responses of beef cattle production developed in tropical pastures from Brazil changed such in rearing as finishing phase due different strategies used in each scenario evaluated. Therefore, understand the pastures management and animal performance results is a crucial point for increasing the profits of the system due excessive costs that supplementation insert promote into husbandry company during all phases. In this way, the right pasture management during wet season allow uses only mineral mix as supplement to obtain best economic results join to animal performance. During dry season the supplementation is higher, and the best economic results were originated from scenario with less supplementation level, but with animals starting season heavier.

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**Table 1.** Nutritional strategies, the percentage of body weight (%BW) supplied daily, during different phase (rearing and finishing phases) of the scenarios evaluated, since 2010 until 2014 in tropical pastures

| Scenario | Phase     | Supplement <sup>1</sup> | Supplementation level (% BW) |     |     |     |     |     |     |                   |
|----------|-----------|-------------------------|------------------------------|-----|-----|-----|-----|-----|-----|-------------------|
|          |           |                         | 0.1                          | 0.3 | 0.5 | 0.6 | 1.0 | 1.5 | 2.0 | <i>Ad libitum</i> |
| 1        | Rearing   | Supp. 1                 |                              | X   |     |     |     |     |     |                   |
|          |           | Supp. 2                 |                              | X   |     |     |     |     |     |                   |
|          |           | Supp. 3.1               |                              |     |     |     |     |     |     | X                 |
|          | Finishing | Supp. 4                 |                              |     |     |     | X   |     |     |                   |
|          |           | Supp. 5                 |                              |     |     |     |     | X   |     |                   |
|          |           | Supp. 6                 |                              |     |     |     |     |     | X   |                   |
| 2        | Rearing   | Supp. 7                 |                              |     | X   |     |     |     |     |                   |
|          |           | Supp. 8                 |                              |     | X   |     |     |     |     |                   |
|          |           | Supp. 3.2               |                              |     |     |     |     |     |     | X                 |
|          | Finishing |                         |                              |     |     |     |     |     |     |                   |
| 3        | Rearing   | Supp. 9                 |                              | X   |     |     |     |     |     |                   |
|          | Finishing | Supp. 10                |                              |     |     |     | X   |     |     |                   |
| 4        | Rearing   | Supp. 11                | X                            |     |     |     |     |     |     |                   |
|          |           | Supp. 12                |                              | X   |     |     |     |     |     |                   |
|          |           | Supp. 13                |                              |     |     | X   |     |     |     |                   |
|          | Finishing | Supp. 14                |                              |     |     |     |     |     | X   |                   |

<sup>1</sup> Composition of supplement: Supp. 1 – 77.35% Corn meal + 7.67% Cotton seed meal + 2.83% Urea + 12.15% Nucleus; Supp. 2 – 77.28% Citrus pulp + 10.8% Cotton seed meal + 2.95% Urea + 8.97% Nucleus; Supp. 3.1 and Supp. 3.2 – Mineral Mix; Supp. 4 – 36.12% Corn meal + 34.4% Citrus pulp + 17.97% Cotton seed meal + 2.98% Urea + 8.53% Nucleus; Supp. 5 – 40.12% Corn meal + 39.71% Citrus pulp + 11.85% Cotton seed meal + 1.75% Urea + 6.57% Nucleus; Supp. 6 – 42.75% Corn meal + 42.84% Citrus pulp + 7.93% Cotton seed meal + 1.56% Urea + 4.92% Nucleus; Supp. 7 – 46% Corn meal + 50% Soybean grain + 4% Nucleus; Supp. 8 – 45% Corn meal + 40% Soybean meal + 11% Lactoplus<sup>®</sup> + 4% Nucleus; Supp. 9 – 23% Corn meal + 38% Citrus pulp + 31% Cotton seed + 8% Nucleus; Supp. 10 – 67.1% Corn meal + 19.2% Soybean meal + 3% Urea + 10.7% Nucleus; Supp. 11 – 19% Citrus pulp + 52% Cotton seed meal + 29% Nucleus; Supp. 12 – 23% Corn meal + 38% Citrus pulp + 31% Cotton seed meal + 8% Nucleus; Supp. 13 – 23.5% Corn meal + 47% Citrus pulp + 23% Cotton seed meal + 6.5% Nucleus; Supp. 14 – 91.4% Corn meal + 7.6 % Soybean meal + 0.8% Urea + 0.2% Nucleus.

**Table 2.** Chemical composition of each supplement used during different phase (rearing and finishing phases) from scenarios evaluated, since 2010 until 2014 in tropical pastures

| Scenario | Phase     | Supplement             | Chemical composition (% DM) <sup>1</sup> |       |       |       |       |      |       |       |
|----------|-----------|------------------------|------------------------------------------|-------|-------|-------|-------|------|-------|-------|
|          |           |                        | DM                                       | OM    | CP    | NDF   | NDFap | iNDF | ADF   | TDN   |
| 1        | Rearing   | Supp. 1                | 91.43                                    | 85.52 | 19.23 | 15.45 | 13.09 | 3.58 | 6.26  | 72.58 |
|          |           | Supp. 2                | 90.34                                    | 82.86 | 19.10 | 34.87 | 30.91 | 5.82 | 19.74 | 60.16 |
|          |           | Supp. 3.1 <sup>2</sup> | -                                        | -     | -     | -     | -     | -    | -     | -     |
|          | Finishing | Supp. 4                | 91.00                                    | 87.08 | 23.22 | 20.65 | -     | -    | 10.06 | -     |
|          |           | Supp. 5                | 91.00                                    | 85.94 | 17.00 | 21.33 | -     | -    | 13.52 | -     |
|          |           | Supp. 6                | 90.00                                    | 91.48 | 15.44 | 25.84 | -     | -    | 12.01 | -     |
| 2        | Rearing   | Supp. 7                | 89.10                                    | 94.20 | 23.00 | -     | -     | -    | -     | 81.70 |
|          |           | Supp. 8                | 88.30                                    | 94.20 | 22.00 | -     | -     | -    | -     | 80.20 |
|          |           | Supp. 3.2 <sup>3</sup> | -                                        | -     | -     | -     | -     | -    | -     | -     |
|          | Finishing |                        |                                          |       |       |       |       |      |       |       |
| 3        | Rearing   | Supp. 9                | 90.30                                    | -     | 16.10 | 14.40 | -     | -    | 8.39  | -     |
|          | Finishing | Supp. 10               | -                                        | 78.00 | 22.00 | 15.40 | -     | -    | 6.18  | -     |
| 4        | Rearing   | Supp. 11               | 91.00                                    | 77.46 | 22.00 | 15.00 | -     | 6.00 | 9.10  | -     |
|          |           | Supp. 12               | 92.00                                    | 85.36 | 16.00 | 14.50 | -     | 5.80 | 8.40  | -     |
|          |           | Supp. 13               | 89.00                                    | 96.13 | 14.00 | 14.80 | -     | 5.90 | 9.20  | -     |
|          | Finishing | Supp. 14               | -                                        | 87.50 | 14.00 | 14.20 | -     | -    | 16.31 | -     |

<sup>1</sup> DM: dry matter; OM: organic matter; CP: crude protein; NDF: neutral detergent fiber; NDFap: neutral detergent fiber corrected for ash and protein; iNDF: indigestive neutral detergent fiber; ADF: acid detergent fiber; TDN: total digestible nutrients. <sup>2</sup> 150 g.kg<sup>-1</sup> Calcium; 80 g.kg<sup>-1</sup> Phosphorus; 10 g.kg<sup>-1</sup> Magnesium; 40 g.kg<sup>-1</sup> Sulfur; 130 g.kg<sup>-1</sup> Sodium. <sup>3</sup> Ca Min./Max. 139/155 g.kg<sup>-1</sup>; P. 80 g.kg<sup>-1</sup>; Mg. 10 g.kg<sup>-1</sup>; E. 40 g.kg<sup>-1</sup>; Na. 130 g.kg<sup>-1</sup>; Co. 1,350 mg.kg<sup>-1</sup>; Mn. 1,040 mg.kg<sup>-1</sup>; Zn. 5,000 mg.kg<sup>-1</sup>; I. 100 mg.kg<sup>-1</sup>; Co. 80 mg.kg<sup>-1</sup>; Se. 26 mg.kg<sup>-1</sup>; F. 1,333 mg.kg<sup>-1</sup>.

**Table 3.** Animal performance data and productive indexes of each scenario and phase (rearing and finishing) for beef cattle production developed in tropical pastures from Brazil

| Scenario | Phase     | Supp.* | Variable         |                  |                            |                     |
|----------|-----------|--------|------------------|------------------|----------------------------|---------------------|
|          |           |        | IBW <sup>1</sup> | FBW <sup>2</sup> | Stocking Rate <sup>3</sup> | Length <sup>4</sup> |
| 1        | Rearing   | 1      | 251.0            | 361.0            |                            |                     |
|          |           | 2      | 260.5            | 365.8            | 5.03                       | 112                 |
|          |           | 3.1    | 262.6            | 334.4            |                            |                     |
|          | Finishing | 4      | 381.8            | 464.2            | 2.53                       |                     |
|          |           | 5      | 369.1            | 480.8            | 2.61                       | 112                 |
|          |           | 6      | 373.4            | 489.5            | 2.65                       |                     |
| 2        | Rearing   | 7      |                  |                  |                            |                     |
|          |           | 8      | 243.0            | 340.0            | 4.54                       | 141                 |
|          |           | 3.2    |                  |                  |                            |                     |
|          | Finishing | -      | -                | -                | -                          | -                   |
| 3        | Rearing   | 9      | 335.0            | 430.0            | 5.09                       | 84                  |
|          | Finishing | 10     | 441.0            | 514.0            | 3.18                       | 85                  |
| 4        | Rearing   | 11     | 232.7            | 339.8            | 5.31                       | 127                 |
|          |           | 12     | 232.8            | 349.9            | 5.37                       | 212                 |
|          |           | 13     | 352.3            | 397.5            | 5.70                       | 85                  |
|          | Finishing | 14     | 371.2            | 474.5            | 2.52                       | 140                 |

\*Supp. 1 – 77.35% Corn meal + 7.67% Cotton seed meal + 2.83% Urea + 12.15% Nucleus; Supp. 2 – 77.28% Citrus pulp + 10.8% Cotton seed meal + 2.95% Urea + 8.97% Nucleus; Supp. 3.1 and Supp. 3.2 – Mineral Mix; Supp. 4 – 36.12% Corn meal + 34.4% Citrus pulp + 17.97% Cotton seed meal + 2.98% Urea + 8.53% Nucleus; Supp. 5 – 40.12% Corn meal + 39.71% Citrus pulp + 11.85% Cotton seed meal + 1.75% Urea + 6.57% Nucleus; Supp. 6 – 42.75% Corn meal + 42.84% Citrus pulp + 7.93% Cotton seed meal + 1.56% Urea + 4.92% Nucleus; Supp. 7 – 46% Corn meal + 50% Soybean grain + 4% Nucleus; Supp. 8 – 45% Corn meal + 40% Soybean meal + 11% Lactoplus<sup>®</sup> + 4% Nucleus; Supp. 9 – 23% Corn meal + 38% Citrus pulp + 31% Cotton seed + 8% Nucleus; Supp. 10 – 67.1% Corn meal + 19.2% Soybean meal + 3% Urea + 10.7% Nucleus; Supp. 11 – 19% Citrus pulp + 52% Cotton seed meal + 29% Nucleus; Supp. 12 – 23% Corn meal + 38% Citrus pulp + 31% Cotton seed meal + 8% Nucleus; Supp. 13 – 23.5% Corn meal + 47% Citrus pulp + 23% Cotton seed meal + 6.5% Nucleus; Supp. 14 – 91.4% Corn meal + 7.6% Soybean meal + 0.8% Urea + 0.2% Nucleus. <sup>1</sup>IBW – initial body weight (kg); <sup>2</sup>FBW – final body weight (kg); <sup>3</sup>Stocking rate (AU.ha<sup>-1</sup>); <sup>4</sup>Length experiment (days).

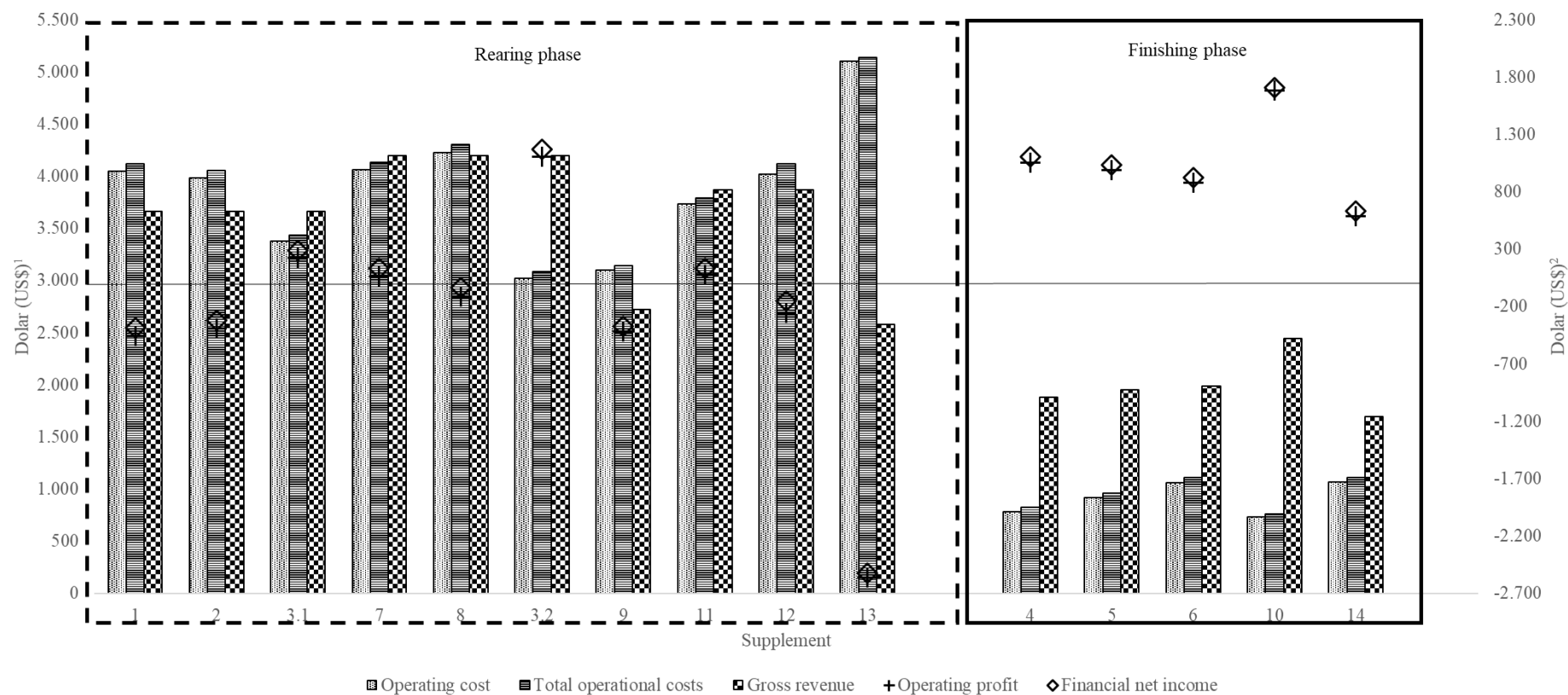


**Figure 1.** Economic results from scenarios (different supplements) during two phases (rearing and finishing) of beef cattle production developed in tropical pastures from Brazil, measured in Dollar per hectare per cycle (US\$.ha<sup>-1</sup>.cycle<sup>-1</sup>). <sup>1</sup> First axis: Cost-effective operating; Cost-total operating and Gross revenue; <sup>2</sup> Second axis: Operating profit and Financial net income.

**Table 4.** Economic analysis of each scenario and phase (rearing and finishing) for beef cattle production developed in tropical pastures from Brazil

| Scenario | Phase     | Supp.* | Economic variable    |                  |                  |                  |                   |                   |
|----------|-----------|--------|----------------------|------------------|------------------|------------------|-------------------|-------------------|
|          |           |        | Profit. <sup>1</sup> | SPP <sup>2</sup> | IRR <sup>3</sup> | B:C <sup>4</sup> | BEPp <sup>5</sup> | BEPd <sup>6</sup> |
| 1        | Rearing   | 1      | -12.5                | NA <sup>7</sup>  | -3.29            | -0.10            | 890.78            | 7.95              |
|          |           | 2      | -10.7                | NA               | -2.73            | -0.08            | 852.54            | 7.61              |
|          |           | 3.1    | 6.1                  | 41               | 2.47             | 0.09             | 302.99            | 2.71              |
|          | Finishing | 4      | 56.1                 | 10               | 10.31            | 1.42             | 175.10            | 1.56              |
|          |           | 5      | 50.5                 | 10               | 9.61             | 1.13             | 237.38            | 2.12              |
|          |           | 6      | 44.1                 | 12               | 8.55             | 0.87             | 242.84            | 2.17              |
| 2        | Rearing   | 7      | 1.4                  | 94               | 1.07             | 0.03             | 692.13            | 4.91              |
|          |           | 8      | -2.7                 | NA               | -0.26            | -0.01            | 691.60            | 4.90              |
|          |           | 3.2    | 26.3                 | 11               | 9.30             | 0.39             | 694.04            | 4.92              |
|          | Finishing | -      |                      |                  |                  |                  |                   |                   |
| 3        | Rearing   | 9      | -15.3                | NA               | -5.50            | -0.12            | 674.14            | 8.03              |
|          | Finishing | 10     | 68.7                 | 4                | 27.00            | 2.34             | 228.38            | 2.69              |
| 4        | Rearing   | 11     | 1.9                  | 71               | 1.40             | 0.04             | 871.29            | 6.86              |
|          |           | 12     | -6.6                 | NA               | -0.92            | -0.04            | 961.16            | 4.53              |
|          |           | 13     | -99.4                | NA               | -37.14           | -0.49            | 273.19            | 3.21              |
|          | Finishing | 14     | 34.7                 | 15               | 6.56             | 0.59             | 214.99            | 1.54              |

\* Supp. 1 – 77.35% Corn meal + 7.67% Cotton seed meal + 2.83% Urea + 12.15% Nucleus; Supp. 2 – 77.28% Citrus pulp + 10.8% Cotton seed meal + 2.95% Urea + 8.97% Nucleus; Supp. 3.1 and Supp. 3.2 – Mineral Mix; Supp. 4 – 36.12% Corn meal + 34.4% Citrus pulp + 17.97% Cotton seed meal + 2.98% Urea + 8.53% Nucleus; Supp. 5 – 40.12% Corn meal + 39.71% Citrus pulp + 11.85% Cotton seed meal + 1.75% Urea + 6.57% Nucleus; Supp. 6 – 42.75% Corn meal + 42.84% Citrus pulp + 7.93% Cotton seed meal + 1.56% Urea + 4.92% Nucleus; Supp. 7 – 46% Corn meal + 50% Soybean grain + 4% Nucleus; Supp. 8 – 45% Corn meal + 40% Soybean meal + 11% Lactoplus<sup>®</sup> + 4% Nucleus; Supp. 9 – 23% Corn meal + 38% Citrus pulp + 31% Cotton seed + 8% Nucleus; Supp. 10 – 67.1% Corn meal + 19.2% Soybean meal + 3% Urea + 10.7% Nucleus; Supp. 11 – 19% Citrus pulp + 52% Cotton seed meal + 29% Nucleus; Supp. 12 – 23% Corn meal + 38% Citrus pulp + 31% Cotton seed meal + 8% Nucleus; Supp. 13 – 23.5% Corn meal + 47% Citrus pulp + 23% Cotton seed meal + 6.5% Nucleus; Supp. 14 – 91.4% Corn meal + 7.6% Soybean meal + 0.8% Urea + 0.2% Nucleus. <sup>1</sup>Profitability (%); <sup>2</sup>Simple payback period (cycles); <sup>3</sup>Internal rate of return (%); <sup>4</sup>Benefit:Cost ratio; <sup>5</sup>Break-even point of period (kg BW); <sup>6</sup>Break-even point daily (kg BW). <sup>7</sup>Not available.

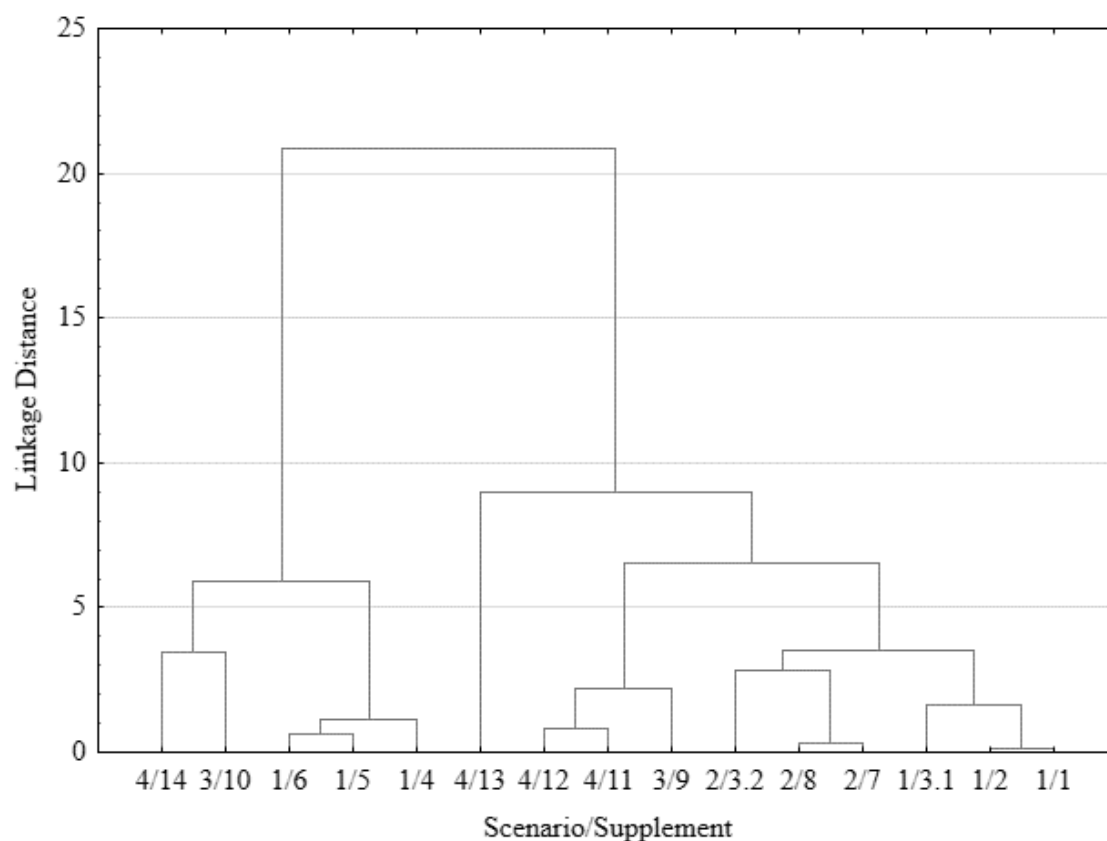


**Figure 2.** Dendrogram of different scenarios and supplements evaluated considering economic indexes (Cost-Effective Operating, Cost-Total Operating [CTO], Gross Revenue, Operating Profit, Financial Net Income, Profitability, Internal Rate of Return, Benefit:Cost ratio), %Liner Depreciation into CTO, Exchange Rate (US\$ to R\$) and Steer price (US\$.head<sup>-1</sup>)

**CHAPTER 4**

O artigo a seguir está redigido  
conforme normas de publicação do  
Periódico: Land Use Policy.

## **Use of nitrogen fertilizer to enhance beef cattle production in tropical Brazilian pastures**

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### **Declaration of interest**

None

**ABSTRACT** – Tropical pastures are the main food source in Brazil for beef cattle production. However, the current pasture management system does not allow reach the best results possible within livestock. Among different techniques that can be used to improve pasture management, nitrogen (N) fertilization can be considered the easiest and most practical. Therefore, our hypothesis is that economic results and indexes do not change on increasing N fertilizer levels in beef cattle production. The present study was conducted over three years (2014/2015, 2015/2016, and 2016/2017) and four treatments using urea fertilizer (0, 90, 180 and 270 kg N ha<sup>-1</sup> year<sup>-1</sup>) were evaluated. Both the economic results (cost-effective operating, cost-total operating, gross revenue, operating profit, net income, and cost-total operating mean) and economic indexes (profitability, payback, internal rate of return, benefit-to-cost ratio, break-even point daily and of period), and net present value were evaluated. Regarding the economic results, a pattern could be observed, which is relating to increasing of N fertilizer levels, cause an increase in some variables: cost-effective operating and cost-total operating from those measuring costs, and gross revenue, operating profit, and net income from those measuring revenues. Concerning the economic indexes, treatment with 180 kg N ha<sup>-1</sup> resulted in increases in profitability, payback, internal rate of return, and net present value (6% and 12%) of 17.76%, 2.79 years, 35.79%, US\$5,926.03 and US\$1,854.35 respectively. For this study, the principal component analysis developed determined that the main costs associated to profitability were supplementation and animal purchases costs. Hence about N fertilization the best treatment to be recommended for Brazilian beef cattle production developed using tropical grasses is 180 kg N ha<sup>-1</sup> per year.

**Keywords:** cost-total operating; pasture management; principal component analysis.

## 1. Introduction

Brazilian beef cattle production is among the largest industries in the world. The numbers show the importance of this system: Brazil has around 222 million cattle, which results in 9.7 million tons of carcasses (Associação Brasileira das Indústrias Exportadoras de Carne - ABIEC, 2018). These high figures are significantly responsible for Brazil's positive gross domestic product (GDP). The main Brazilian export product is *in natura* or fresh meat. During 2017, according to ABIEC (2018), Brazil exported close to 1.21 million tons of fresh meat. Total Brazilian exports, if summed with other products, are close to 1,540 tons of carcass equivalents, which is valued at approximately US\$6.28 billion.

The main production system of Brazilian beef cattle is considered to be based on the use of pastures, but without any technology. According to Agastin et al. (2013) this system, which mainly uses pastures, tends to have a higher profitability than feedlots. Therefore, it is justifiable to say that Brazilian production still has large room for improvement using different technological packages. Among all strategies to improve pasture management, using appropriate stocking rates during different seasons is a primary and basic technology, which has had the greatest impact on profitability (Mulliniks et al., 2015). Nitrogen (N) fertilization is one of many techniques which could be used to increase the stocking rates. However, the efficiency of N fertilization in grazed pasture systems is affected by different factors, including environmental and management practices (Vogeler, Lucci, and Shepherd, 2016). Therefore, simply increasing N fertilizer levels will not result in a higher forage production, and possibly will not increase the stocking rates.

Increasingly, beef producers have introduced recent technologies to the system to maintain a positive GDP and to improve farm profitability. However, as defined in

economics studies, an increase in N fertilizer levels has been explained by using the theory of a production function, which defines the relationship between inputs (N fertilizer) and the maximum amount of produce that can be produced within a given period of time with a given level of technology (Keat, Young, and Erfle, 2014). Therefore, considering the economical classical concept of a production function, our hypothesis is that economic results and indexes do not change after increasing nitrogen fertilizer levels in the beef cattle production system that uses tropical forage as the main food source. So, this research aimed evaluated economic results from beef cattle production using tropical pastures as the main food source, beside try to understand by principal component analysis, a multivariable analysis, how each cost and economic results is associated specifically for this research.

## **2. Material and Methods**

### *2.1. Experiment and management*

Our experiment was developed by the Forage Crops and Grasslands section, Animal Science department of São Paulo State University, “Júlio de Mesquita Filho” (Unesp) (Jaboticabal, São Paulo, Brazil). The climate of the region in northeast São Paulo state is subtropical humid, with dry winters and wet summers. Pastures were seeded with *Urochloa brizantha* (Hochst.) Stapf. “Marandu” (Palisade grass) in 2001, and afterwards managed using a continuous grazing system with a variable stocking rate. Sward height was maintained at 25 cm, considering a 95% light interception efficiency. The present study was conducted over three years (2014/2015, 2015/2016, and 2016/2017), and four treatments using urea fertilizer (0, 90, 180 and 270 kg N ha<sup>-1</sup>) were evaluated, after applying them in three fertilization stages during the wet season for three replications, in a total of 12 paddocks. During these fertilization processes were made a correction

fertilizer using phosphorus and potassium. To evaluate animal performance, we used Nellore young bulls (*Bos taurus indicus*) with different initial body weights (BW: 309.5 kg, 251.5 kg, and 244.0 kg in the first, second, and third experimental years). The bulls were identified, weighed, and randomly distributed to groups of six bulls per paddock. The remaining animals were used to maintain a pre-determined grazing height using the put-and-take methodology (Mott and Lucas, 1952).

Due to pasture management during the first and second years (2014/2015 and 2015/2016), two phases (growing and finishing) were evaluated for each treatment, always adjusting the stocking rate to preserve great conditions for forage allowance. In the last experimental year (2016/2017), due to weather conditions, to maintain the pasture perennially, only the growing phase was implemented. The growing phase—when animals are rearing, up to nearly 360 kg BW—was conducted during the wet season, when the stocking rate can be higher depending on grazing management. The finishing phase—when animals are finishing, up to nearly 500 kg BW—was implemented during the dry season, when the stocking rate is generally smaller, to preserve best conditions for forage regrowth.

## 2.2. Description of the dataset

Data were analyzed following year combinations since 2014/2015 until 2016/2017. The first year was chosen because of the adjustments to the stocking rate and sward height and the fertilizer practice that occur during the wet season, close to December. Hence, we had three experimental years: 1 (2014/2015), 2 (2015/2016), and 3 (2016/2017). During these periods (growing phase), we had the same supplements, that was, mineral mixture, for all treatments. Weather differences occurred among experimental years, what can to have caused changes to production and to the nutritive value of forage, considered to be the main food source.

Animal performance data and productive indexes used to perform the economic analyses were recorded for each experimental year and adjusted for paddock area—1.0 ha—to facilitate the comparison. Thus, as variables, we used the initial and final body weight (kg), stocking rate (animal unit [AU].ha<sup>-1</sup>), and supplementation costs (mineral mixture used during the growing phase and supplements [1.5% BW] used during the finishing phase, which were formulated using different ingredients, such as dried distillers grain, cotton seed meal, corn meal, urea, and a mineral mixture). Nitrogen fertilizer level (0, 90, 180 and 270 kg N ha<sup>-1</sup> year<sup>-1</sup>) was our main research variable to be analyzed.

### *2.3. Economic evaluation*

We evaluated the economic results in each phase (growing and finishing) for all the experimental years. These evaluations considered cost-effective operating (CEO), cost-total operating (CTO) (Matsunaga et al., 1976), gross revenue (GR), operating profit (OP), and financial net income (FNI), all measured in US\$. Another important analysis performed to compound CTO was linear depreciation (LD), which considered new value (NV), scrap value (SV), lifetime of the building, equipment and everyone involved in beef cattle production (LT) and use days of the building and equipment (UD). The LD of each item was calculated as  $[(NV-SV/LT)/365]*UD$  (Lopes et al., 2011).

Other analyses were conducted to evaluate each phase economically. Some economic indexes were calculated; the first was profitability, calculated as  $[OP/GR]$ . The second one, payback, measured in years, was calculated using average capital stocktaking by area in use divided by  $[GR - CEO]$ ; payback is the time taken to repay all investments made in the system. The average capital stocktaking by area in use, correspond to real use of building, equipment and everyone (items) involved in beef cattle production for each treatment, thus due the experimental conditions all these items had its costs pondered to compound the initial investment, which followed the use proportion for each treatment

evaluated. Another economic variable used was internal rate of return (IRR), calculated as  $100/\text{payback}$  (Aguar and Resende, 2013). We also calculated the benefit-to-cost ratio (B:C) as  $[(GR - CEO) / CEO]$ . Further, we computed break-even points (BEP) of the entire period and a daily one, both measured in kg BW. The BEP of the entire period was calculated as  $[CTO / (\text{revenue pay per kg} - \text{average CEO})]$  and the daily BEP as  $[\text{BEP period} / \text{length days}]$ . The net present value (NPV) was calculated considering ten years and three different taxes (6, 12 and 18%) per the equation described in Aguar and Resende (2013)  $[\text{NPV} = \sum \text{Results} - (\text{Investment} / (1 - \text{taxes})^{10})]$ .

The CEO of each experimental year was calculated based on purchase of Nellore bulls, fertilizer, fertilization practice costs, purchase of supplements, supplementation practice, and management costs (medicine and animal markers). The CTO was calculated as  $CEO + LD$ . The GR of each experimental year was calculated by selling animals to maintain an accurate stocking rate during the next phase (dry season – finishing phase), when the stocking rate was less than that of the growing phase. The animals were sold using the BW to determine the price by head or kilogram, according to historical price quotations (Centro de Estudos Avançados em Economia Aplicada - CEPEA, 2018); additionally, animals were sold to slaughterhouses. This was done using the BW and carcass yield of 50% to define the price by kilogram based on historical price quotations (CEPEA, 2018).

The input prices were the average prices during 2014–2017 and were obtained from Anuário Brasileiro da Pecuária - ANUALPEC (2017) and CEPEA (2018), and the price quotations were from the same region of animal production (northeast São Paulo State) during the aforementioned period. The values were calculated in US\$ according to the exchange rate for each year (2014: R\$2.35; 2015: R\$3.34; 2016: R\$3.48; 2017: R\$3.17).

#### *2.4. Multivariable analysis*

Principal component analysis (PCA) was conducted using economic results (CEO, CTO, GR, OP, and FNI), economic indexes (profitability, payback, IRR, and NPV of 6%, 12% and 18% respectively), and main costs (animal, fertilization, and supplementation). The data were standardized before the analysis. Subsequently, factor analysis was performed with the extraction factors effect using principal components calculated from the correlation matrix of the variables (Seal, 1964; Jeffers, 1978).

The first factor extracted from the previously mentioned matrix was the linear combination of the original variables, which gave the highest total variability of the data used. The other factor was the second linear function of the original variables, which explained the total variability from the residual variables. The factors obtained in the analysis, which will be used in PCA, are independent, do not include unity, and are standardized variables (normal distribution with mean = 0 and variance = 1). The coefficient obtained from the linear functions for each variable was used to understand significance based on its sign (positive or negative) and value. Only values above 0.70 were considered significant, and, consequently, responsible for the effects in the analysis. Multivariable analyses were performed using Software STATISTICA v.12 (Stat Soft, Inc., 2016).

### **3. Results**

The weather data shows that 2015 had more rainfall (1,711.9 mm) than the other observed years (mean 1,047.2 mm). If the productive year 2015/2016 is considered, during the fertilizer period conducted between December 2015 and February 2016, the weather conditions (temperature [range 31.9 to 20.6°C], rainfall [range 449.4 to 201.0

mm] and rainy days [range 18 to 14 days]) were appropriate for forage growth, allowing a good answer at N fertilizer for forage.

The increase in N fertilizer levels caused a systematic increase in all the economic results for the observed years as well as the total (Table 1). Should be highlighted that during the productive year 2016/2017, the finishing phase was not conducted. Therefore, results were only obtained for the growing phase for every treatment evaluated. CEO increased by 29.60%, 18.57%, and 15.75% for treatments between 0 and 90 kg N ha<sup>-1</sup>, 90 and 180 kg N ha<sup>-1</sup>, and 180 and 270 kg N ha<sup>-1</sup> respectively. For treatments from 0 kg N ha<sup>-1</sup> to 180 and 270 kg N ha<sup>-1</sup>, CEO increased by 53.67% and 77.87% respectively. Following the same pattern, CTO values increased similarly: 29.11%, 18.34%, and 15.53% for treatments 0 and 90 kg N ha<sup>-1</sup>, 90 and 180 kg N ha<sup>-1</sup>, and 180 and 270 kg N ha<sup>-1</sup> respectively. Compared to treatment with 0 kg N ha<sup>-1</sup>, the CTO results increased by 52.79% and 78.55%, respectively, for treatments of 180 and 270 kg N ha<sup>-1</sup>.

Gross revenue increased following the increase in N fertilizer levels (Table 1): for treatments of 0, 90, 180, and 270 kg N ha<sup>-1</sup>, it was US\$7,578.52, US\$9,778.32, US\$11,827.34, and US\$13,371.98 respectively. Except the treatment with no N fertilizer (0 kg N ha<sup>-1</sup>), GR was better during the productive year 2015/2016 (US\$1,929.12). With the other treatments, GR was better in productive year 2014/2015: US\$3,503.19, US\$4,985.03, and US\$5,554.95 for treatments of 90, 180, and 270 kg N ha<sup>-1</sup> respectively. Note that in the last productive year, 2016/2017, there was no finishing phase with animals.

Following GR results, operating profit (OP) had higher values during productive year 2014/2015 (Table 1) compared to the other productive years. The total OPs were US\$1,209.59, US\$1,555.47, US\$2,096.18 and US\$2,130.03 for treatments of 0, 90, 180,

and 270 kg N ha<sup>-1</sup>. Like OP, the FNI values had the same pattern for the different treatments: US\$1,550.90, US\$1,966.67, US\$2,564.87, and US\$2,650.77, respectively, for nitrogen fertilizer levels of 0, 90, 180 and 270 kg N ha<sup>-1</sup>.

As regards the cost-total operating mean (CTOm) measured in US\$.kg BW<sup>-1</sup>, the values clearly showed that an increase in technology package (caused by the increase in N fertilizer levels) results in a higher CTOm (Table 1). Between treatments 0 and 90 kg N ha<sup>-1</sup> the result was similar, mainly due head number purchase during growing phase. The increase of CTOm was 0.78% and 2.34%, respectively, for treatments between 0 and 180 kg N ha<sup>-1</sup>, and 0 and 270 kg N ha<sup>-1</sup>. Comparing between 180 and 270 kg N ha<sup>-1</sup>, the increase was 1.55%.

Some economic indexes are presented in Table 2. The profitability was better with a treatment of 180 kg N ha<sup>-1</sup> (increase of 17.76%) compared to that with the other treatments (increases of 15.92% and 15.96% for 0 and 90 and for 270 kg N ha<sup>-1</sup> respectively). Another economic index analyzed was payback. The results showed small differences between the treatments of 180 and 270 kg N ha<sup>-1</sup> (2.79 and 2.30 years respectively) and between the treatments of 0 and 90 kg N ha<sup>-1</sup> (4.30 and 4.25 years respectively). Thus, better payback was obtained with 270 kg N ha<sup>-1</sup>, which was 1.87 times smaller than the worst value obtained with 0 kg N ha<sup>-1</sup>. Similarly, IRR was better with the treatment of 270 kg N ha<sup>-1</sup> (43.38%), followed by those of 180, 90, and 0 kg N ha<sup>-1</sup> (35.79%, 23.55% and 23.26% respectively).

The B:C ratios were very close for the N fertilizer levels evaluated (Table 2): 0.26, 0.25, 0.28, and 0.25 for treatments of 0, 90, 180, and 270 kg N ha<sup>-1</sup> respectively. This standard occurred to the break-even point of the period (BEPp) and the daily one (BEPd). Smaller BEP values, considered better, were obtained for the treatment of 90 kg N ha<sup>-1</sup> (164.18 kg BW and 1.03 kg BW, respectively, for BEPp and BEPd). Higher BEP

values were obtained for the treatment of 270 kg N ha<sup>-1</sup> (169.94 kg BW and 1.07 kg BW, respectively, for BEPp and BEPd).

The NPV analysis (Table 3) showed that better results were obtained with 180 kg N ha<sup>-1</sup> for both taxes of 6% and 12% (US\$5,926.03 and US\$1,854.35 respectively). With the higher tax (18%) being used to compute NPV, no treatment resulted in a positive value (NPVs were -US\$643.67, -US\$539.05, -US\$853.94, and -US\$3,251.03 respectively for 0, 90, 180, and 270 kg N ha<sup>-1</sup>), showing that none of the treatments would be economically interesting, for practice in commercial farmers by owners, in this case. The principal component analysis (PCA showed all correlations among different variables, both economic and results and indexes (Figure 1)). Factor 1 explained 58.33% of the total data variability. Some inputs (CEO, CTO, GR, OP, FNI, and profitability) are positively correlated with this factor. These inputs are negatively correlated with other variables (NPV 12%, NPV 18%, and supplementation), which are positively correlated with each other. Factor 2 explained 27.34% of the total data variability and had positive correlation with three inputs (NPV 6%, animal, and fertilization).

#### **4. Discussion**

The weather conditions associated with market prices, which are mainly determined by the cattle cycle, led to the productive year 2014/2015 having better conditions, caused by corn prices lower than their average of the last ten years, and prices of finished bull higher than both its average of the last ten years and calf costs. This situation corroborates Zen and Barros (2010), who mentioned that the owner had control over farm costs, but the market prices will always be determined by the equilibrium between supply and demand. Another crucial factor that resulted in higher OP and FNI for the treatments (0, 90, 180, and 270 kg N ha<sup>-1</sup>) in this study was the duration of the

finishing phase. During 2014/2015, 84 days were needed to finish animals, and during 2015/2016, 112 days were needed. This increase in the animals' finishing days caused higher costs, and, consequently, a decrease in OP and FNI.

Following the rules of a production function (Keat, Young and Erfle, 2014), considering as input the increase in N fertilizer levels in beef cattle production systems developed using forage as the main food source, the economic results (CEO, CTO, GR, OP, FNI and CTOM in Table 1) showed a pattern of growth which appears hopeful according to the production function. However, it needs to be highlighted that the effect of the production scale is included in the costs (Barbosa et al., 2010). This effect can be observed clearly as described by Zen and Barros (2010), when they showed through graphics the different costs of traditional beef cattle farms in different countries and on different production scales. In these graphics, it can be observed that costs for both calves and finished bulls in Brazil are lower than those in Argentina. This condition allows Brazil to be competitive in international trade.

Increasing N fertilizer levels can be considered a management technique that consists of a technology package. Other related methods for forage management are stocking rate, sward height, and supplementation. Although some Brazilian farmers are averse to new technologies (SPRP, 2014), the aforementioned technology package is being used more frequently in beef cattle farms, which leads to an increase in costs, but also generates higher revenues (Zen and Barros, 2010). Considering that beef cattle production in Brazil is based on a tripod *Nellore-Cerrado-Urochloa* (Ferraz and Felício, 2010), it can be understood why management needs to be continuous, from foraging until the animal is finished, to obtain best results, corroborating Oliveira et al. (2017). These authors reported how improvement in pasture management enhanced both economic and environmental outcomes.

Brazilian beef cattle systems have changed drastically the production practices since the 1990s, when it was in need of higher efficiency for fitting economic results, which also resulted in great economic indexes. Efficiency is fundamental when observing Brazilian pastures' occupation and herd size. According to ABIEC (2018), pasture occupation decreased from 191 million hectares in 1990 to 165 million in 2017, a 13.6% reduction. However, herd size increased by 50.3%, which was associated to an increase in productivity, measured in kg BW ha<sup>-1</sup> year<sup>-1</sup>; productivity was 120.30 in 2017, compared to 48.90 in 1990. These numbers show the importance of great management of beef cattle farms.

The economic indexes (Table 2) obtained for treatments with higher N fertilizer levels are associated with those reported by Corrêa et al. (2010). These authors said that intensification in systems, caused by factors such as fertilization and animal supplementation, increase the system complexity and cause changes in the cost structure. These changes cause higher risks, but can also improve profitability, which would be a certain consequence if the system management were appropriate. Regarding intensification in Brazilian beef cattle production, Carvalho and Zen (2017) described the heterogeneity in these systems' economy. The authors reported two kinds of systems: one with high quality and the use of economy tools, and another with both low quality and productivity and without economy management. According to Carvalho and Zen (2017), planning associated with cost management could result in better use of resources and consequently higher productivity, improving sustainability, economy, and the social aspects of beef cattle production. The higher profitability obtained with the treatment of 180 kg N ha<sup>-1</sup> (17.76%) has a positive correlation with the results of N utilization in grasslands assessed in other studies by our research group in the same area.

Corroborating the profitability result, the NPV values (Table 3) showed that the treatment of 180 kg N ha<sup>-1</sup> was the best with taxes of 6% and 12% when compared to other treatments. This variable, NPV, when studied by other authors, has yielded negative values. Normally, this result is obtained during grassland degradation periods (Oliveira et al., 2017). Therefore, considering that our treatments produced a right pasture management, mainly due to by sward height and variable stocking rate management, the NPV results with a traditional tax rate (6%) were positive. Considering that only 13.42% of beef cattle slaughtered in Brazil are from feedlots (ABIEC, 2018), one can understand the importance of pastures in this chain. However, technological packages need to be used to improve results. According to Zen and Barros (2010), Brazilian conditions result in a higher potential for beef cattle production than in the rest of the world. These conditions are because of the weather, and costs that are normally lower than those in other countries.

From PCA performed using data from this study (Figure 1), it is clear that the main costs affecting profitability were supplementation and animal purchases. Considering the increase in fertilizer levels, fertilization costs played a major role in profitability too, but less than the two aforementioned factors. Brazilian beef cattle production presented some similarity in the costs of these systems. Pini et al. (2014) reported that a farm developing growing and finishing phases attributed 61.17% of production costs to animal purchases, a value close to that observed in this study, which is an important implication for increasing profitability. Even if animal supplementation is applied only during the finishing phase, the practice costs are high, and they affect the systems' profitability. Animal supplementation needs to be used during the finishing phase, undertaken in the dry season, because tropical pastures will not supply the animals' requirements for appropriate gains. Therefore, supplementation is an important tool for management of beef cattle production, which causes an increase in average daily gains

(Reis et al., 2013; Barbero et al., 2015), allowing animals to be slaughtered at the end of the dry season. Animal supplementation during the dry season and fertilization during the wet season are both crucial intensification methods. Therefore, their costs can be considered as costs that increase future profitability (Corrêa et al., 2010). In this way, by understanding economical farming results, farmers can choose the best-suited method to increase their beef cattle indexes, and consequently economic results, making the farm a profitable organization (Pereira et al., 2017).

## 5. Conclusion

We conclude that increasing N fertilizer levels changed both economic results and indexes in Brazilian beef cattle production. For tropical pastures used in beef cattle production, it is recommended that an N level equal to  $180 \text{ kg ha}^{-1} \text{ year}^{-1}$  be applied. The principal component analysis results determined that the main costs associated to profitability were supplementation and animal purchases, thus both supplement formulation and moment to animal purchases into market can determine final economic results of beef cattle systems using tropical grasses as main food source.

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**Table 1.** Economic results (CEO, CTO, GR, OP, FNI and CTOm) obtained into each treatment (0, 90, 180 and 270 kg N ha<sup>-1</sup>) during different years of evaluation (2014/2015, 2015/2016 and 2016/2017) and total among experimental years

| Treatment (kg N ha <sup>-1</sup> ) | Year                   | Variable (US\$ ha <sup>-1</sup> )* |           |           |          |          |                   |
|------------------------------------|------------------------|------------------------------------|-----------|-----------|----------|----------|-------------------|
|                                    |                        | CEO                                | CTO       | GR        | OP       | FNI      | CTOm <sup>1</sup> |
| 0                                  | 2014/2015              | 1,919.66                           | 2,048.47  | 2,905.72  | 857.25   | 986.06   | 1.04              |
|                                    | 2015/2016              | 2,571.31                           | 2,708.68  | 2,929.12  | 220.44   | 357.81   | 1.35              |
|                                    | 2016/2017 <sup>‡</sup> | 1,536.65                           | 1,611.78  | 1,743.69  | 131.91   | 207.04   | 1.45              |
|                                    | Total                  | 6,027.62                           | 6,368.93  | 7,578.52  | 1,209.59 | 1,550.90 | 1.28              |
| 90                                 | 2014/2015              | 2,403.20                           | 2,551.80  | 3,530.19  | 978.39   | 1,126.99 | 1.07              |
|                                    | 2015/2016              | 2,898.76                           | 3,054.23  | 3,374.70  | 320.46   | 475.94   | 1.34              |
|                                    | 2016/2017 <sup>‡</sup> | 2,509.69                           | 2,616.81  | 2,873.43  | 256.61   | 363.74   | 1.43              |
|                                    | Total                  | 7,811.65                           | 8,222.85  | 9,778.32  | 1,555.47 | 1,966.67 | 1.28              |
| 180                                | 2014/2015              | 3,180.42                           | 3,364.81  | 4,985.03  | 1,620.23 | 1,804.62 | 1.02              |
|                                    | 2015/2016              | 3,347.54                           | 3,518.70  | 3,835.23  | 316.53   | 487.69   | 1.37              |
|                                    | 2016/2017 <sup>‡</sup> | 2,734.51                           | 2,847.64  | 3,007.07  | 159.46   | 272.56   | 1.48              |
|                                    | Total                  | 9,262.47                           | 9,731.15  | 11,827.34 | 2,096.18 | 2,564.87 | 1.29              |
| 270                                | 2014/2015              | 3,709.14                           | 3,915.15  | 5,554.95  | 1,639.80 | 1,845.81 | 1.06              |
|                                    | 2015/2016              | 3,774.76                           | 3,959.69  | 4,277.45  | 317.76   | 502.69   | 1.39              |
|                                    | 2016/2017 <sup>‡</sup> | 3,237.31                           | 3,367.11  | 3,539.58  | 172.47   | 302.27   | 1.49              |
|                                    | Total                  | 10,721.21                          | 11,241.95 | 13,371.98 | 2,130.03 | 2,650.77 | 1.31              |

\*CEO: cost-effective operating; CTO: cost-total operating; GR: gross revenue; OP: operating profit; FNI: financial net income; CTOm: CTO mean<sup>1</sup>(US\$ kg BW<sup>-1</sup>). <sup>‡</sup> 2016/2017: only developed growing phase.

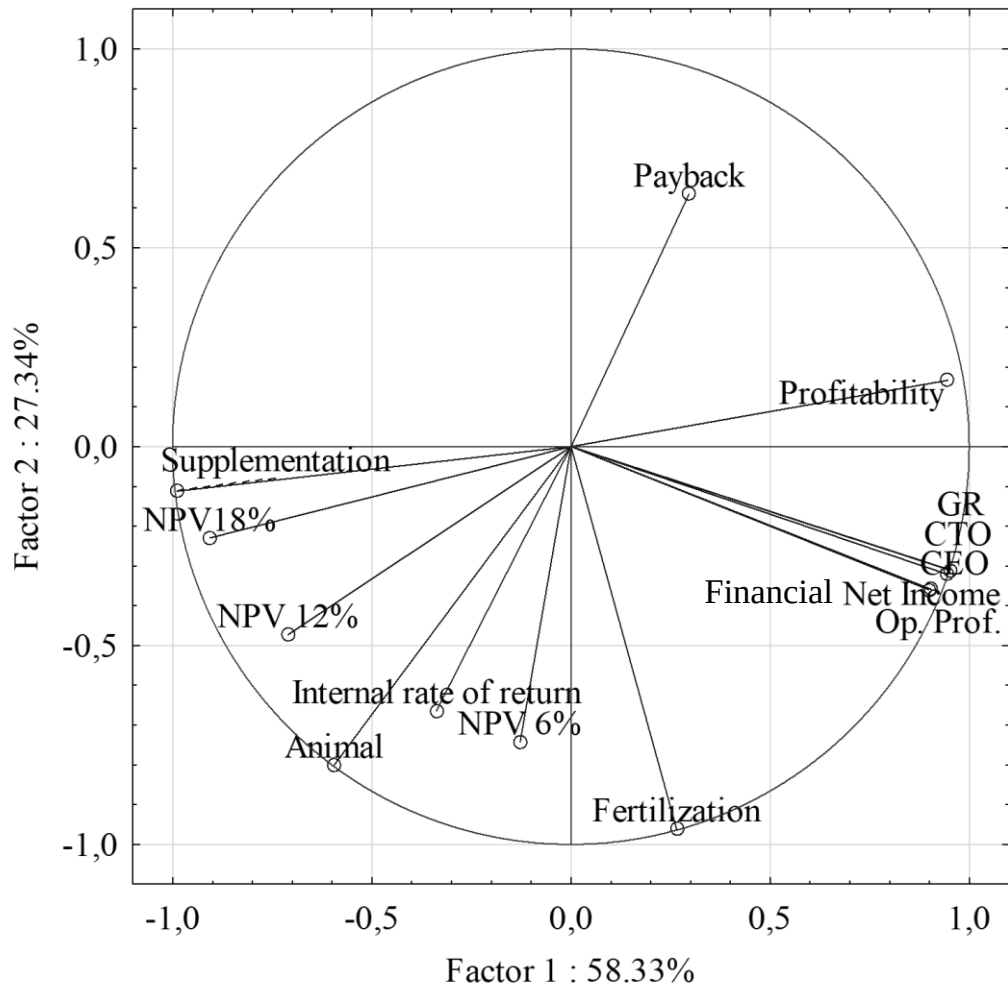


**Figure 1.** Principal component analysis (PCA) using factor analysis to understand main effects into economic evaluation

**Table 2.** Economic index (profitability, payback, IRR, B:C and BEP of the period and daily) total of all experimental year correspondent to each treatment (0, 90, 180 and 270 kg N ha<sup>-1</sup> year<sup>-1</sup>)

| Variable*         | Treatment (kg N ha <sup>-1</sup> year <sup>-1</sup> ) |        |        |        |
|-------------------|-------------------------------------------------------|--------|--------|--------|
|                   | 0                                                     | 90     | 180    | 270    |
| Profitability (%) | 15.92                                                 | 15.92  | 17.76  | 15.96  |
| Payback (years)   | 4.30                                                  | 4.25   | 2.79   | 2.30   |
| IRR (%)           | 23.26                                                 | 23.55  | 35.79  | 43.38  |
| B:C ratio         | 0.26                                                  | 0.25   | 0.28   | 0.25   |
| BEPp (kg BW)      | 168.38                                                | 164.18 | 169.26 | 169.94 |
| BEPd (kg BW)      | 1.06                                                  | 1.03   | 1.06   | 1.07   |

\*IRR: internal rate of return; B:C ratio: benefit:cost ratio; BEPp: break-evenpoint of period measured in kg of body weight (BW); BEPd: break-evenpoint daily same unity of BEPp.

**Table 3.** Net present value (NPV), in US\$, of each treatment (0, 90, 180 and 270 kg N ha<sup>-1</sup> year<sup>-1</sup>), according economic results for three different taxes (6, 12 and 18%) with ten years of investment

| Taxes (%) <sup>*</sup> | Treatment (kg N ha <sup>-1</sup> year <sup>-1</sup> ) |          |          |           |
|------------------------|-------------------------------------------------------|----------|----------|-----------|
|                        | 0                                                     | 90       | 180      | 270       |
| 6                      | 3,663.30                                              | 4,955.60 | 5,926.03 | 3,557.90  |
| 12                     | 1,089.26                                              | 1,672.97 | 1,854.35 | -544.03   |
| 18                     | -643.67                                               | -539.05  | -853.94  | -3,251.03 |

<sup>\*</sup>Taxes were determined following Brazilian Government savings rates (SELIC tax = 6%). Exchange rate used was a mean of all years this study (US\$1.00 = R\$3.33)

## CHAPTER 5 – PRACTICAL IMPLICATIONS

Brazilian beef cattle production is among the bigger than the world. Numbers can show the importance of this system. Brazil has around 222 million of head what result in 9.5 million tons of carcass weight yearly. Values are responsible by keep positive gross domestic product (GDP) on Brazil. The mainly Brazilian product for exportation is *in natura* or fresh meat. During the year of 2017, Brazil exported until September, close to 1.21 thousand tons of fresh meat. Total of the Brazilian exportation, if summed other products, is close to 1.54 thousand tons what results in about U\$6.28 billion.

If considered that the main production is extensive grazing system without the use of technologies. Its possible to say that Brazilian production has a bigger lack to improve yet. However, for this improvement, there are necessary a lot of changes, mainly on concepts used within livestock. Some farmers are very conservator when the matter is new technologies. This scenario causes reduction in productivity and consequently less profitability inside livestock farm. Increasingly the beef producers need insert technologies inside the system to keep the positive Brazilian GDP and the improve farm profitability.

A lot of new technologies, since mathematic models as artificial neural network until simple management practices as fertilization and supplementation during dry season, could to cause a big change into Brazilian beef cattle chain, making it stronger than any other in the world. The barriers need to be broken and the knowledge create into Universities and Research Centers need to be shared between every all inside chain. Just using new technologies and knowledge that our livestock (dairy and beef) will be strong and will can compete with other countries.

Numbers showed some changes into beef cattle chain, but more and more changes needed to occur yet. Increasing the agronomic, and animal efficiency of the resources utilization can decrease the environmental impact due to the high field efficiency, as well fertilizer and feed in pasture production systems. Combination of these factors can result in lowest greenhouse gas emission and deforestation associated to more sustainable and profitable beef production systems. Brazil has good weather conditions, besides both forage and animal species, and knowledge, but our State need to change some practices relationship to agribusiness to follow it growth. So, changes in all points are crucial to allow increase on both production and economic indexes.

Considering all hypotheses evaluated within this Thesis, could be reported that:

- 1) is possible to predict results of production system using artificial neural network -Yes, the artificial neural network is a potential toll to predict future results for livestock production systems.
- 2) supplementation used at different conditions, years, not change the economic responses during rearing and finishing phases of beef cattle production developed in tropical pastures of Brazil – No, different scenarios during both, rearing and finishing phases, changed economic responses from the activity.
- 3) the economic results are no dependent of production system when pastures received diverse levels of nitrogen fertilizer – No, the economic results were dependent of production system when used diverse levels of nitrogen fertilizer.

## **SUPPLEMENTARY MATERIAL**

Supplementary material about every all Chapters developed within this Thesis.

### **Chapter II**

Figure 1 – Artificial Neural Network architecture for Forage production.

Figure 2 – Artificial Neural Network architecture for Animal production.

Figure 3 - Protocol from Ethics, Bioethics, and Animal Welfare Committee – Unesp.

### **Chapter III**

Figure 4 – Market prices ranges for ten years (2007 – 2017).

Table 1 – Weather information for wet season of four years (2011 – 2014).

Table 2 – Costs information about economic evaluation from different scenarios.

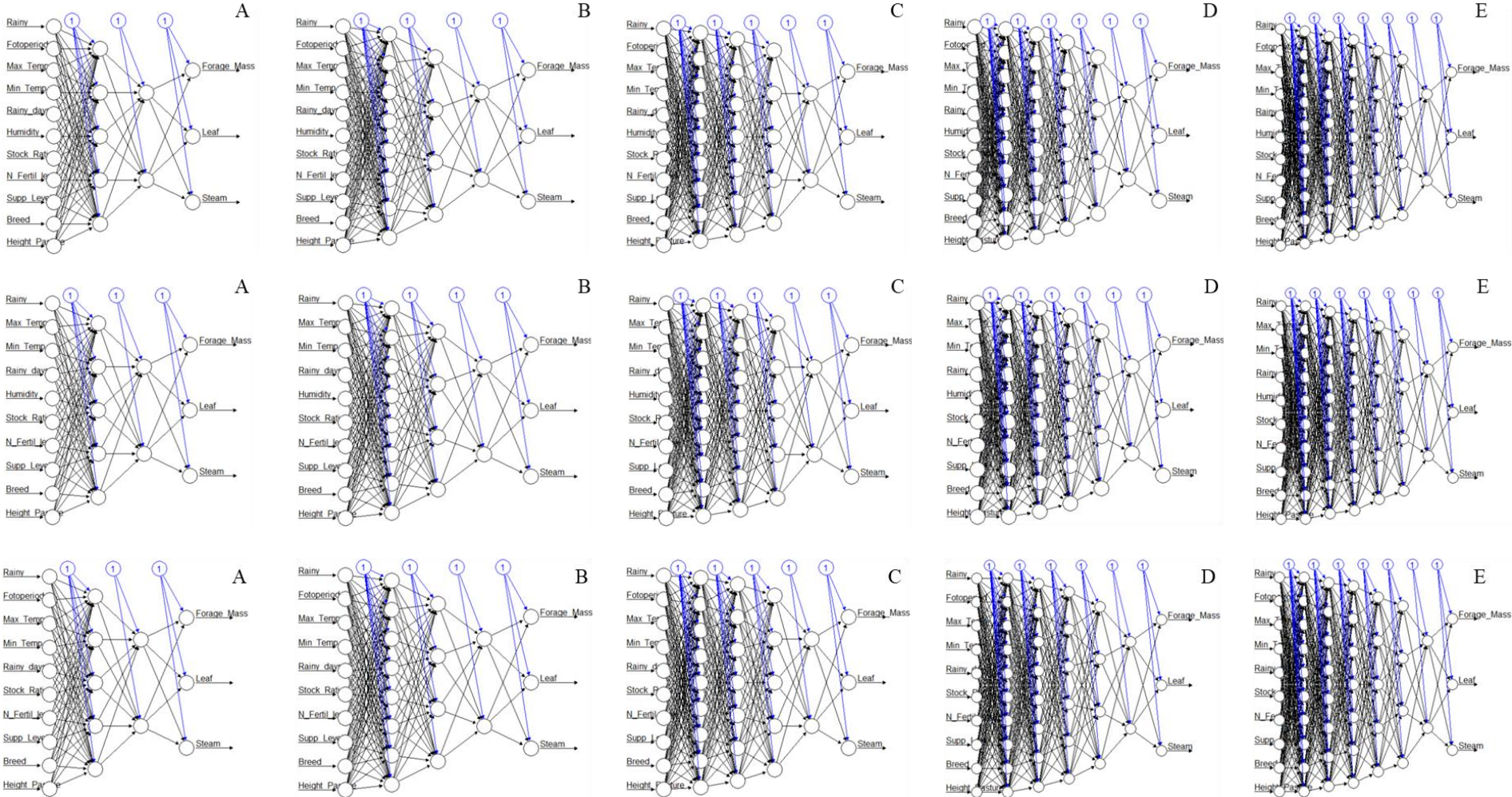
### **Chapter IV**

Figure 4 – Market prices ranges for ten years (2007 – 2017).

Table 3 – Weather information for four years (2014 – 2017).

Table 4 - Costs information about economic evaluation from different nitrogen fertilizer levels.

**Figure 1.** Artificial Neural Network – Multilayer perceptron - architecture for Forage Production (Forage Mass, Leaf and Steam percentages) different Inputs and number of hidden layers (A, B, C, D and E) evaluated within Chapter II



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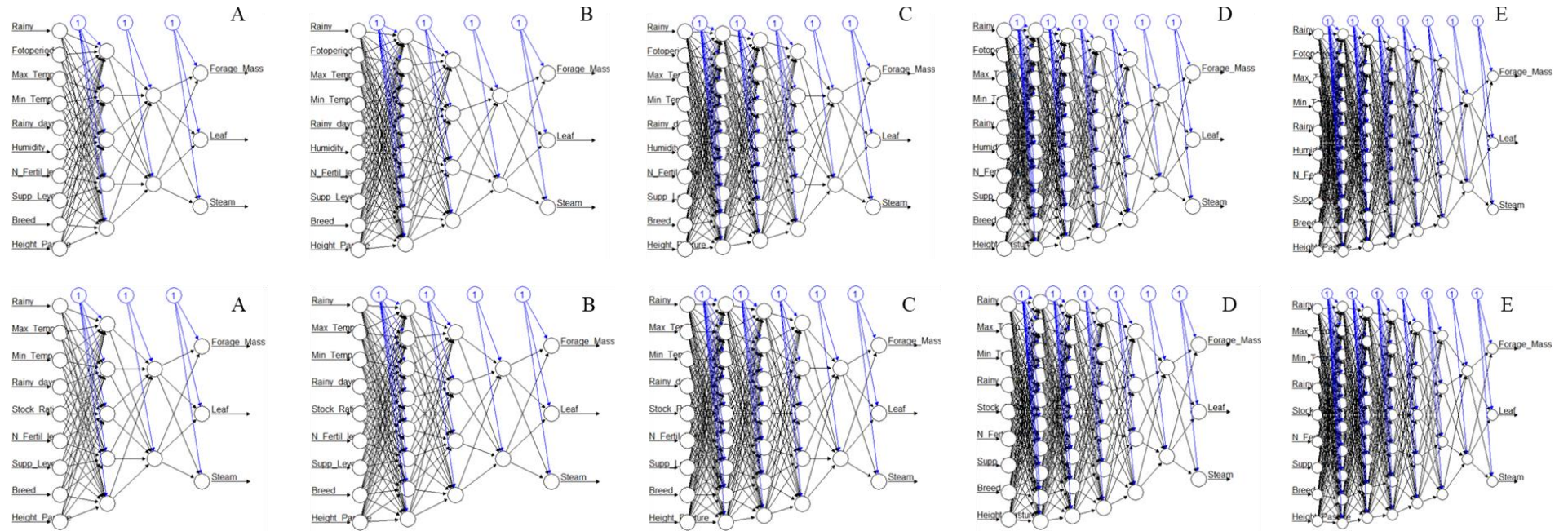


**Figure 2.** Artificial Neural Network – Multilayer perceptron - architecture for Animal Production (Average Daily Gain) different Inputs and number of hidden layers (A, B, C, D and E) evaluated within Chapter II

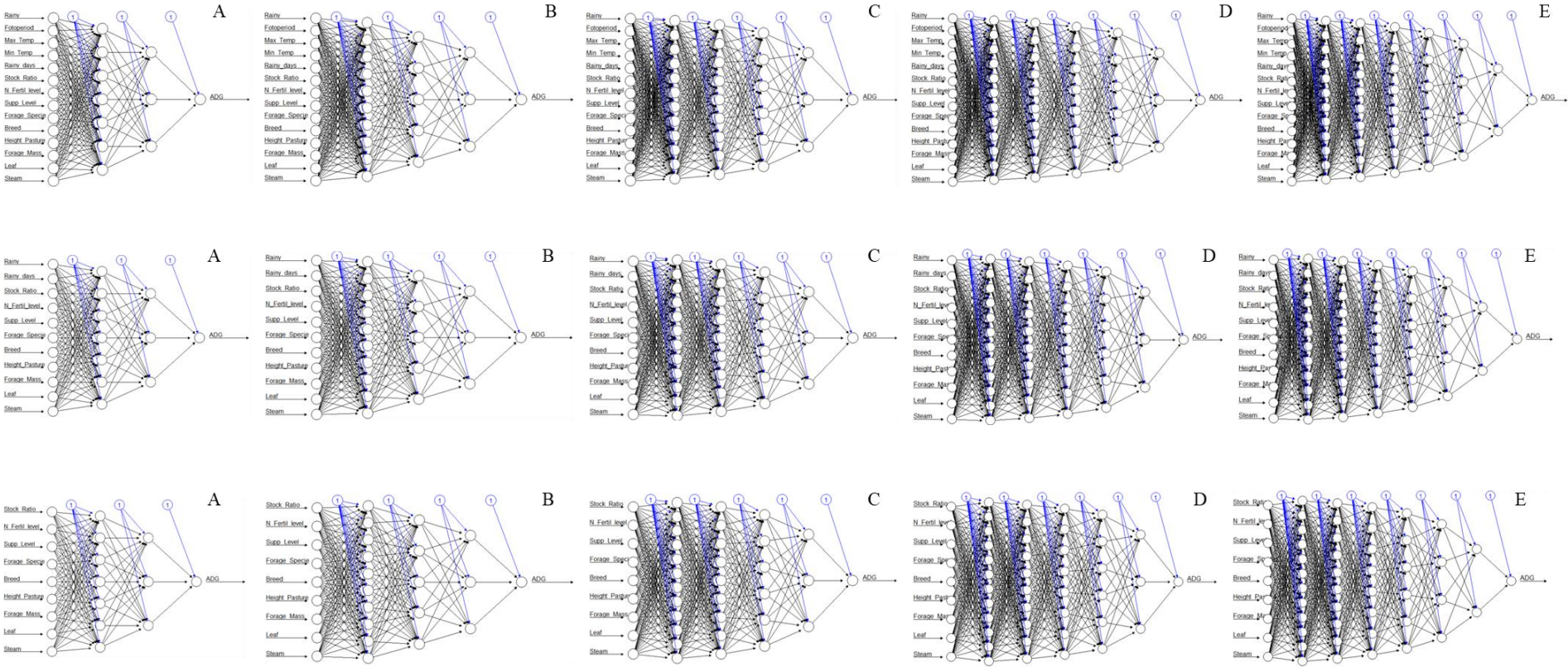


**Figure 3.** Protocol from Ethics, Bioethics, and Animal Welfare Committee – Unesp associated to Chapter II



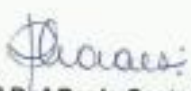
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**CEUA – COMISSÃO DE ÉTICA NO USO DE ANIMAIS**

**CERTIFICADO**

Certificamos que o Protocolo nº 12703/15 do trabalho de pesquisa intitulado **"Management strategies to reduce environmental impacts of beef cattle production systems"**, sob a responsabilidade do Prof. Dr. Ricardo Andrade Reis está de acordo com os Princípios Éticos na Experimentação Animal adotado pelo Conselho Nacional de Controle de Experimentação Animal (CONCEA) e foi aprovado pela COMISSÃO DE ÉTICA NO USO DE ANIMAIS (CEUA), em reunião ordinária de 07 de agosto de 2015.

Jaboticabal, 07 de agosto de 2015.

  
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**Figure 4.** Brazilian historical prices during last 10 years of Corn (50 kg [first axis]), Calf (head [second axis]) and Finished Bull (@ [equal 15 kg of carcass, first axis]) and each mean price, every in dollar considering annual exchange rate associated to Chapters III and IV

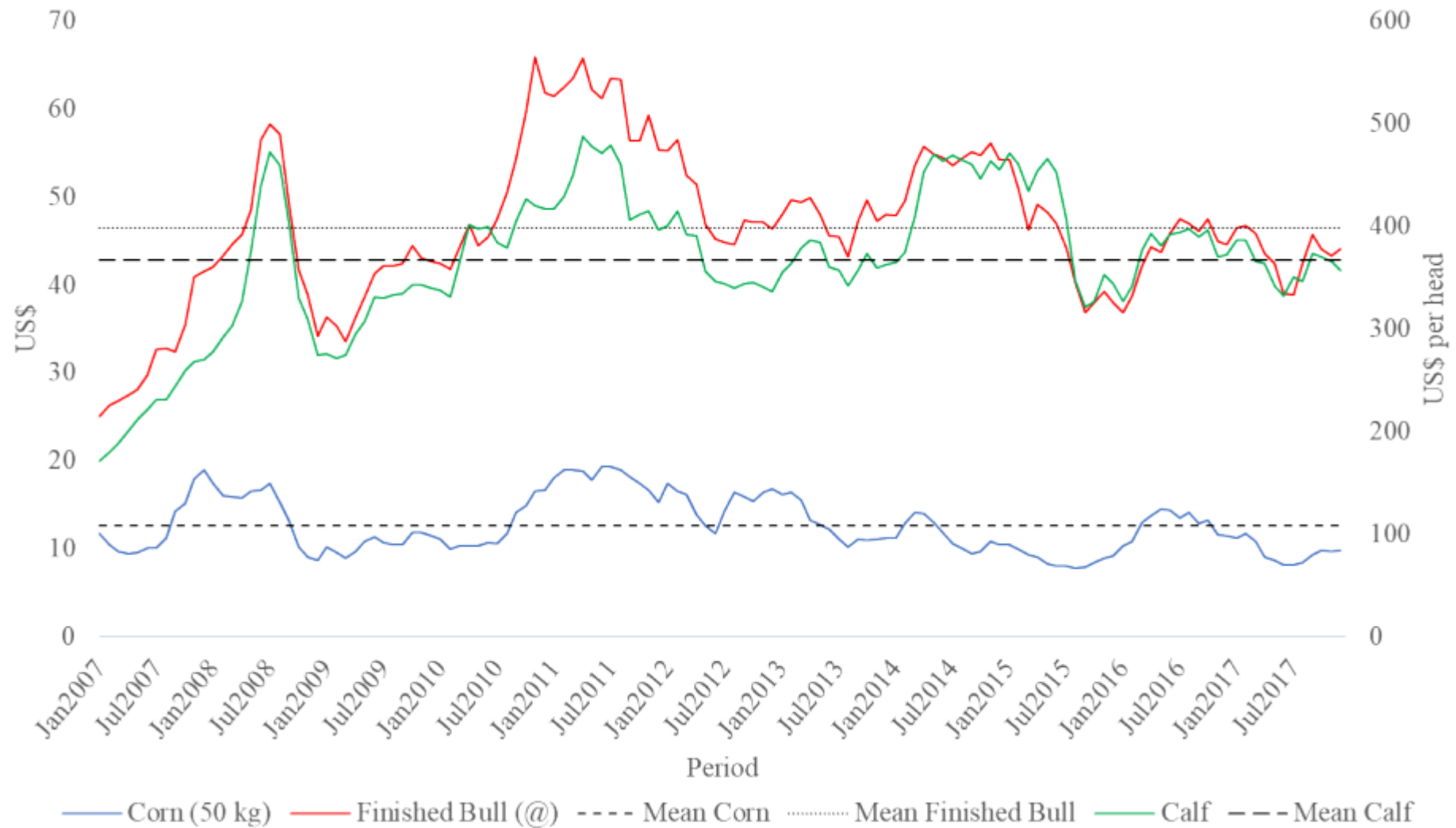


**Table 1.** Weather variables<sup>1</sup> (temperature, rainfall and rainy days) during rearing phase (wet season) of young bulls inside each scenario, since 2011 until 2014 in tropical pastures associated to Chapter III

| Scenario | Date     | Temperature (°C) |      |      | Rainfall<br>(mm) | Rainy<br>days |
|----------|----------|------------------|------|------|------------------|---------------|
|          |          | Max.             | Min. | Mean |                  |               |
| 1        | Jan/2011 | 30.3             | 20.6 | 24.3 | 267.1            | 13            |
|          | Feb/2011 | 31.1             | 20.1 | 24.3 | 202.2            | 14            |
|          | Mar/2011 | 27.6             | 19.6 | 22.6 | 495.0            | 21            |
|          | Apr/2011 | 29.2             | 17.7 | 22.6 | 92.3             | 10            |
| 2        | Jan/2012 | 28.9             | 19.0 | 22.8 | 219.0            | 22            |
|          | Feb/2012 | 31.8             | 19.7 | 25.0 | 119.0            | 11            |
|          | Mar/2012 | 31.5             | 19.0 | 24.2 | 31.0             | 8             |
|          | Apr/2012 | 30.2             | 18.2 | 23.2 | 85.0             | 7             |
|          | May/2012 | 26.2             | 14.4 | 19.4 | 73.0             | 7             |
| 3        | Jan/2013 | 30.2             | 19.9 | 24.0 | 384.0            | 18            |
|          | Feb/2013 | 31.0             | 20.1 | 24.3 | 145.0            | 15            |
|          | Mar/2013 | 30.1             | 19.5 | 23.8 | 141.0            | 13            |
|          | Apr/2013 | 28.5             | 17.1 | 21.8 | 66.3             | 9             |
| 4        | Dec/2013 | 31.0             | 19.6 | 24.4 | 234.5            | 15            |
|          | Jan/2014 | 32.2             | 19.5 | 25.2 | 98.8             | 13            |
|          | Feb/2014 | 32.1             | 19.6 | 25.5 | 95.2             | 13            |
|          | Mar/2014 | 30.5             | 19.2 | 24.1 | 97.3             | 10            |
|          | Apr/2014 | 29.5             | 17.8 | 23.0 | 63.3             | 8             |
|          | May/2014 | 27.6             | 14.5 | 20.4 | 6.7              | 4             |
|          | Jun/2014 | 28.0             | 13.9 | 20.3 | 1.8              | 2             |
|          | Jul/2014 | 26.6             | 13.4 | 19.2 | 30.0             | 4             |

<sup>1</sup> Data were available by Agroclimatological Station of the Department of Exact Sciences of FCAV / Unesp - Jaboticabal Campus.

**Table 2.** Costs measured in Dollar (US\$) from each supplement used during different phase (rearing and finishing phases) from scenarios evaluated, since 2010 until 2014 in tropical pastures associated to Chapter III

| Scenario | Phase     | Supplement | Cost     |            |                                  |                         |                         |                           |
|----------|-----------|------------|----------|------------|----------------------------------|-------------------------|-------------------------|---------------------------|
|          |           |            | Steer    | Supplement | Supplement Practice <sup>1</sup> | Fertilizer <sup>2</sup> | Management <sup>3</sup> | Depreciation <sup>4</sup> |
| 1        | Rearing   | Supp. 1    | 2,861.39 | 289.60     | 471.54                           | 417.78                  | 9.70                    | 73.02                     |
|          |           | Supp. 2    | 2,861.39 | 223.73     | 471.54                           | 417.78                  | 9.54                    | 73.02                     |
|          |           | Supp. 3.1  | 2,861.39 | 55.48      | 33.73                            | 417.78                  | 9.43                    | 62.35                     |
|          | Finishing | Supp. 4    | -        | 305.88     | 466.86                           | -                       | 5.79                    | 48.67                     |
|          |           | Supp. 5    | -        | 443.33     | 466.86                           | -                       | 5.70                    | 48.67                     |
|          |           | Supp. 6    | -        | 589.31     | 466.86                           | -                       | 5.63                    | 48.67                     |
| 2        | Rearing   | Supp. 7    | 2,641.30 | 559.62     | 564.71                           | 283.20                  | 9.72                    | 78.48                     |
|          |           | Supp. 8    | 2,641.30 | 728.98     | 564.71                           | 283.20                  | 10.12                   | 78.48                     |
|          |           | Supp. 3.2  | 2,641.30 | 56.18      | 34.22                            | 283.20                  | 8.44                    | 66.97                     |
|          | Finishing | -          | -        | -          | -                                | -                       | -                       | -                         |
| 3        | Rearing   | Supp. 9    | 2,285.73 | 171.82     | 318.04                           | 315.78                  | 7.42                    | 42.60                     |
|          | Finishing | Supp. 10   | -        | 405.92     | 321.83                           | -                       | 4.43                    | 31.35                     |
| 4        | Rearing   | Supp. 11   | 2,675.95 | 98.84      | 476.27                           | 471.19                  | 8.28                    | 63.07                     |
|          |           | Supp. 12   | 2,675.95 | 384.16     | 476.27                           | 471.19                  | 8.96                    | 104.43                    |
|          |           | Supp. 13   | 3,866.57 | 277.80     | 476.27                           | 471.19                  | 11.57                   | 37.36                     |
|          | Finishing | Supp. 14   | -        | 533.11     | 525.03                           | -                       | 6.91                    | 43.23                     |

<sup>1</sup>Costs with supplementation activity: tractor + labour; <sup>2</sup>Costs with fertilizer activity: fertilizer + tractor + fertilizer machine + labour; <sup>3</sup>Costs with medicine + animal markers + power; <sup>4</sup>Depreciation costs: cattle shed + balance + containment of cattle + forage + electric fence + feed bunk + water drinker + tractor + tractor trailer + fertilizer machine + shed.

**Table 3.** Weather variables<sup>1</sup> (temperature, rainfall and rainy days) during wet season (growing phase of young Bulls) for each experimental year, since 2014 until 2017 associated to Chapter IV

| Variable      | Year | Month |       |       |       |       |       |      |      |       |       |       |       |
|---------------|------|-------|-------|-------|-------|-------|-------|------|------|-------|-------|-------|-------|
|               |      | Jan   | Feb   | Mar   | Apr   | May   | Jun   | Jul  | Aug  | Sept  | Oct   | Nov   | Dec   |
| T. Max (°C)   | 2014 | 32.6  | 32.5  | 30.9  | 30.1  | 28.0  | 28.6  | 27.1 | 31.0 | 32.1  | 34.2  | 31.1  | 31.0  |
| T. Min (°C)   |      | 19.9  | 19.9  | 19.5  | 17.9  | 14.6  | 13.7  | 13.1 | 13.9 | 17.2  | 18.4  | 19.8  | 20.1  |
| T. Mean (°C)  |      | 25.5  | 25.5  | 24.1  | 23.0  | 20.2  | 20.0  | 19.1 | 21.7 | 23.7  | 25.6  | 24.4  | 24.6  |
| Rainfall (mm) |      | 99.8  | 83.0  | 106.8 | 63.3  | 6.7   | 1.8   | 30.0 | 0.2  | 45.0  | 46.8  | 180.9 | 150.3 |
| Rainy days    |      | 13    | 12    | 10    | 8     | 4     | 2     | 4    | 1    | 8     | 3     | 15    | 15    |
| T. Max (°C)   | 2015 | 33.9  | 30.9  | 29.1  | 30.1  | 26.4  | 27.2  | 27.0 | 30.3 | 31.3  | 34.1  | 31.1  | 31.0  |
| T. Min (°C)   |      | 21.1  | 20.0  | 19.8  | 18.0  | 15.7  | 14.2  | 14.7 | 14.0 | 18.1  | 19.9  | 20.3  | 20.9  |
| T. Mean (°C)  |      | 26.5  | 24.3  | 23.3  | 22.9  | 20.0  | 19.7  | 19.7 | 21.3 | 23.8  | 25.8  | 24.8  | 24.8  |
| Rainfall (mm) |      | 101.5 | 283.7 | 183.3 | 86.4  | 98.0  | 11.6  | 45.0 | 4.4  | 120.2 | 149.7 | 255.8 | 372.3 |
| Rainy days    |      | 9     | 19    | 21    | 7     | 8     | 2     | 5    | 2    | 12    | 8     | 16    | 17    |
| T. Max (°C)   | 2016 | 29.9  | 31.9  | 31.4  | 31.5  | 27.4  | 25.7  | 28.5 | 29.1 | 31.1  | 32.3  | 30.9  | 31.5  |
| T. Min (°C)   |      | 20.6  | 21.1  | 20.2  | 18.0  | 15.0  | 12.9  | 12.6 | 14.0 | 15.5  | 17.9  | 18.7  | 20.0  |
| T. Mean (°C)  |      | 24.4  | 25.2  | 24.6  | 24.0  | 20.1  | 18.1  | 19.3 | 20.7 | 22.5  | 24.2  | 23.9  | 24.7  |
| Rainfall (mm) |      | 449.4 | 201.0 | 132.9 | 9.1   | 118.2 | 115.8 | 0    | 67.8 | 21.8  | 64.0  | 246.5 | 184.4 |
| Rainy days    |      | 18    | 14    | 17    | 2     | 9     | 8     | 0    | 5    | 6     | 7     | 9     | 19    |
| T. Max (°C)   | 2017 | 30.2  | 32.0  | 31.9  | 30.0  | 28.0  | 26.7  | 26.2 | -    | -     | -     | -     | -     |
| T. Min (°C)   |      | 20.6  | 20.0  | 19.3  | 17.9  | 16.5  | 13.2  | 11.1 | -    | -     | -     | -     | -     |
| T. Mean (°C)  |      | 24.1  | 25.0  | 24.4  | 22.8  | 21.2  | 19.0  | 17.8 | -    | -     | -     | -     | -     |
| Rainfall (mm) |      | 217.7 | 118.3 | 126.3 | 135.7 | 113.4 | 4.7   | 0    | -    | -     | -     | -     | -     |
| Rainy days    |      | 19    | 8     | 11    | 9     | 5     | 3     | 0    | -    | -     | -     | -     | -     |

<sup>1</sup> Data were available by Agroclimatological Station of the Department of Exact Sciences of FCAV / Unesp - Jaboticabal Campus.

**Table 4.** Costs measured in Dollar per hectare (US\$ ha<sup>-1</sup>) from each nitrogen (N) fertilizer level evaluated, since 2015 until 2017 in tropical pastures associated to Chapter IV

| Variable                         | Year | Treatment (kg N ha <sup>-1</sup> ) |          |          |          |
|----------------------------------|------|------------------------------------|----------|----------|----------|
|                                  |      | 0                                  | 90       | 180      | 270      |
| Steer (head)                     | 2015 | 1,243.35                           | 1,554.19 | 2,220.27 | 2,486.71 |
| Supplement                       |      | 465.19                             | 542.91   | 558.32   | 667.28   |
| Supplement Practice <sup>1</sup> |      | 87.85                              | 87.85    | 125.50   | 175.69   |
| Fertilizer <sup>2</sup>          |      | 119.37                             | 213.20   | 269.21   | 371.28   |
| Depreciation <sup>3</sup>        |      | 255.68                             | 286.93   | 230.19   | 184.03   |
| Steer (head)                     | 2016 | 1,644.18                           | 1,895.46 | 2,166.24 | 2,527.28 |
| Supplement                       |      | 690.17                             | 671.58   | 725.57   | 661.67   |
| Supplement Practice <sup>1</sup> |      | 122.41                             | 122.41   | 174.87   | 244.81   |
| Fertilizer <sup>2</sup>          |      | 109.58                             | 203.35   | 273.93   | 332.86   |
| Depreciation <sup>3</sup>        |      | 280.30                             | 314.58   | 238.63   | 181.15   |
| Steer (head)                     | 2017 | 1,378.85                           | 2,206.17 | 2,363.75 | 2,757.71 |
| Supplement                       |      | 16.00                              | 26.22    | 27.57    | 32.44    |
| Supplement Practice <sup>1</sup> |      | 8.19                               | 8.19     | 11.70    | 16.38    |
| Fertilizer <sup>2</sup>          |      | 129.32                             | 262.11   | 323.86   | 421.74   |
| Depreciation <sup>3</sup>        |      | 146.91                             | 192.06   | 142.85   | 115.06   |

<sup>1</sup>Costs with supplementation activity: tractor + labour; <sup>2</sup>Costs with fertilizer activity: fertilizer + tractor + fertilizer machine + labour; <sup>3</sup>Depreciation costs: cattle shed + balance + containment of cattle + forage + electric fence + feed bunk + water drinker + tractor + tractor trailer + fertilizer machine + shed.