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ANIMAL PRODUCTION

Typology of beef production systems according to bioeconomic efficiency in the south of Brazil

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ABSTRACT: *The objective of this study was to evaluate the bioeconomic efficiency of beef cattle production systems in the south of Brazil. A survey was conducted with 33 beef cattle farmers operating with complete cycle production systems in areas larger or equal to 900 ha. Answers were classified in two drivers, technology (TEC) and management (MAN), which were separated into subfactors with their respective components. Multiple correspondence analysis, Tukey test, cluster analysis, and Pearson correlation were the statistics procedures. The TEC components were above normal for Brazilian farmers, but the gross margin is still lower than that needed to generate financial resources for a proper remuneration of cattle farmer. Farmers were classified into three clusters according to bioeconomic efficiency: low (LEL), intermediate (IEL), or high-efficiency level (HEL). The TEC driver differentiated the LEL x HEL clusters and the MAN, mainly expressed in costs, the IEL x HEL. Positive correlation between age at first mating and age at slaughter in the HEL cluster explains the higher costs when compared to IEL because of the use of differentiated feed resources. Investments in technologies related to herd feeding in HEL cluster improved the productivity by only 20% and the cost per hectare by 95 USD ha^{-1} in comparison to IEL cluster. The main differences between farmers are because of the use of technologies related to feeding and cost management. Therefore, before implementing a new technology, an economic evaluation is necessary.*
Key words: *animal production, cattle, cluster analysis, production cost.*

Tipologia de sistemas de produção de carne bovina de acordo com a eficiência bioeconômica no sul do Brasil

RESUMO: O objetivo deste estudo foi avaliar a eficiência bioeconômica *em sistemas de produção de bovinos de corte no sul do Brasil. A pesquisa foi realizada com 33 pecuaristas que operam com sistemas de produção baseado em ciclo completo, em áreas maiores ou iguais a 900 hectares. As respostas foram classificadas em dois fatores: tecnologia (TEC) e gestão (GES), os quais foram separados em subfatores com seus respectivos componentes. A análise de correspondência múltipla, teste de Tukey, análise de cluster e correlação de Pearson foram os procedimentos estatísticos. Os componentes do TEC estavam acima do normal para os pecuaristas brasileiros, mas a margem bruta ainda é menor do que a necessária para gerar recursos financeiros para uma remuneração adequada ao pecuarista. Os pecuaristas foram classificados em três grupos de acordo com a eficiência bioeconômica: baixo (BNE), intermediário (INE) ou alto nível de eficiência (ANE). O driver TEC diferenciou os clusters BNE x ANE e o GES, expresso principalmente em custos, o INE x ANE. A correlação positiva entre a idade no primeiro acasalamento e a idade ao abate no agrupamento ANE explica os custos mais elevados quando comparados aos INE, devido ao uso de recursos alimentares diferenciados. Os investimentos em tecnologias relacionadas à alimentação de rebanho no agrupamento ANE melhoraram a produtividade em apenas 20% e o custo por hectare em 95 USD ha^{-1} em comparação ao cluster INE. As principais diferenças entre os pecuaristas se devem ao uso de tecnologias relacionadas à alimentação e ao gerenciamento de custos. Portanto, antes de implementar uma nova tecnologia, uma avaliação econômica é necessária.*
Palavras-chave: *produção animal, bovinos, análise de cluster, custo de produção.*

INTRODUCTION

Advances in animal production over the past decade, especially in the Mercosur countries, are challenging beef farmers to increase efficiency in the use of biological and economic resources to achieve satisfactory results and to maintain their activity (BARCELLOS et al., 2015). Productive and economic indicators of Brazilian livestock are inferior when compared to their main competitors,

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Australia and the USA (USDA, 2016). This lower productivity is mainly because of the low productive efficiency, low pregnancy, and growth rates, results which influence the sector's competitiveness (OAIGEN et al., 2013).

These indicators are observed in the different regions of the country, including southern Brazil, showing the need to increase the bioeconomic efficiency of the activity (MARQUES et al., 2017). MCMANUS et al. (2016) showed that the growth of cattle production in the southern region of Brazil has decreased, as well as a reduction in herd size or internal migration over the period studied (1977-2011), and so efficiency of production is necessary to maintain the importance of this farm activity within the region.

Analysis of the bioeconomic efficiency allows the evaluation of how biological resources, as soil, pastures, animals, and economic resources are being used on farms. Thus, different combinations of land use, product price, production cost, productivity, and capital invested in animals determine the efficiency of the system (LAMPERT et al., 2012). Despite their importance, methods that use the typology of cattle farmers to evaluate their efficiency profile in the production system are still scarce (LAOUBI & YAMAO, 2009; MCDERMOTT et al., 2010; MARQUES et al., 2011; GABBI et al., 2013). These methods are necessary, since within the same region there are differences in the productive efficiency of cattle farmers and these needs to be measured and classified. Thus, we investigated the typology of farmers to evaluate the bioeconomic efficiency of beef production systems in Rio Grande do Sul State, Brazil.

MATERIALS AND METHODS

The research was conducted with beef cattle farmers from the western frontier region of the state of Rio Grande do Sul, Brazil (Figure 1), including eight municipalities that had the largest cattle herds (Alegrete, Santana do Livramento, São Gabriel, Rosário do Sul, Uruguaiana, Quaraí, Itaqui and São Borja), representing 90% of the regional beef cattle production.

We interviewed 33 beef cattle farmers, which represents 7% of the total farms, selected by

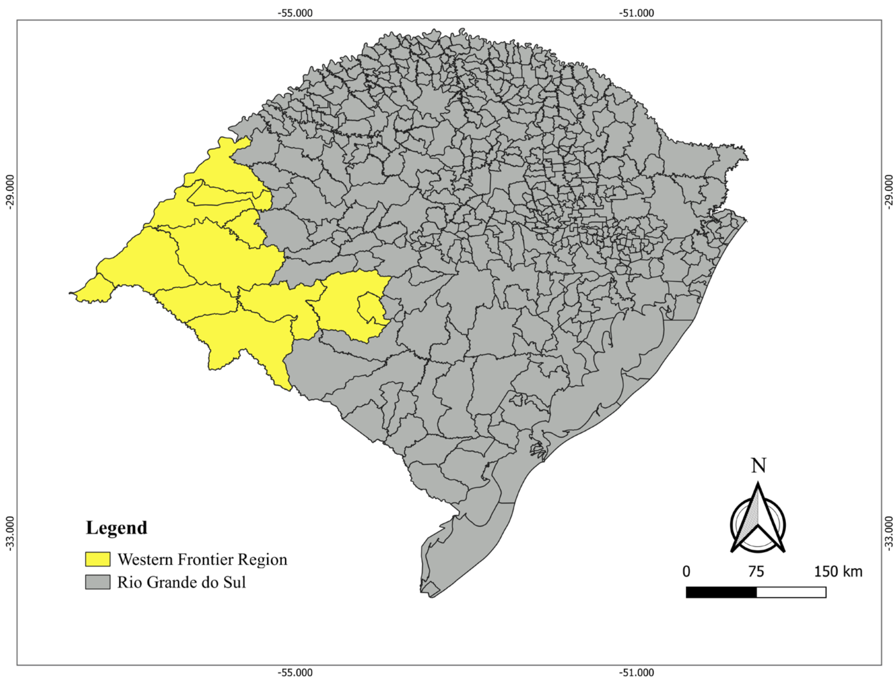

Figure 1 - The Wester Region of Rio Grande do Sul State, Brazil.

Map prepared by the QGIS program version 3.4.10.

a team of researchers, as they maintained complete cycle production systems on their farms. Six types of livestock production systems were identified: i) cattle + sheep; ii) cattle + sheep + horses; iii) crops + cattle + sheep + horses; iv) crops + cattle + horses; v) crops + cattle; vi) crops + cattle + sheep, stands out the importance of systems with agriculture in this region. The main breeds used were the British (Angus and Hereford) and the synthetic breeds (Braford and Brangus). The minimum area of farms was 900 ha (Table 1). The productive and economic records were from the base year of 2012.

As this research included complex livestock production systems, the definition of productive and economic indicators was conducted by a multidisciplinary team of researchers, consultants, and university lecturers, as well as collecting data from scientific articles and extension services. Two drivers were determined, technology (TEC) and management (MAN); these were separated into subfactors with their respective components (Table 2 and 3).

The TEC and MAN drivers, and their respective subfactors, were identified and analyzed in terms of intensity of contribution to the efficiency of the production system (positive or negative) in a quantitative manner, since all components analyzed had a numerical indicator as a response. In the final sum, the subfactors of each driver totaled 1.00. To determine the weight of each subfactor, the technical team considered the degree of importance of that subfactor for the efficiency of the productive system. Parameters for the formation of clusters of farmers were determined after interviews were carried out since each production system presented a final score for each driver and subfactor.

For the responses of the cattle farmers interviewed, two results sheets were generated. In worksheet *A,* the numerical values of the components referring to each driver and subfactor were shown. In *B*, the simple harmonic mean of each interviewee in relation to the sample of respondents contained in worksheet *A*, called the “final score” (FS). The FS for each subfactor was used to evaluate how the interviewee scored in relation to the sample of cattle farmers assessed, obtained using the following equation:

$$FS: [(S_{prod.system} - S_{min}) / (S_{max} - S_{min})] *100$$

Where FS is the final score of the subfactor; $S_{prod.system}$ is the score given by the interviewee to the subfactor; S_{min} is the minimum score provided by the sample of farmers for the subfactor; S_{max} is the maximum score given by the sample of farmers for the subfactor.

Statistical analyses were conducted using Statistical Analysis System software (SAS Inc, Cary, North Carolina). Multiple correspondence analyses were used to identify the relationships between farmers and components (drivers and subfactors) using the Ward method and square Euclidean distances as measures of similarity. Results presented by the clusters in worksheet *B* were analyzed using the Tukey-Kramer test ($p < 0.001$). Relationship of the subfactors and their components was obtained using Pearson correlation analysis, which was considered strong for positive and negative values above 0.7.

RESULTS

Subfactor description of the productive system (PROD) (Table 4) presented mean values for stocking rate, age at first mating, and slaughtering of 0.90 AU ha-1 (Animal Unit= 450 kg BW), 24 months and 30 months, respectively. The mean values for the reproductive indexes were 74% for the pregnancy rate and 69% for the calving rate. In health management, the mortality rate was above 2%. Animal production indicators, such as productivity per area, off take, and weaning rates had mean values of 123 kg ha^{-1} per year, 26.8%, and 68.8%, respectively. Analysis of the MAN driver, through the evaluation of the economic

Table 1 - Description of the area, cattle herd, sheep herd and crop area of the farmers.

Description	Unit	Mean	SD
Total area of farms	ha	4189.78	±3429.38
Cattle herd	Head	2978.16	±2321.91
Sheep flock	Head	781.80	±1250.77
Area of crops	ha	940.58	±1520.89

SD = standard deviation.

Table 2 - Technology (TEC) driver with its subfactors and their components.

Subfactor and Variable(s)	Unit/weight
Description of the production system (PROD)	0.13
Overall stocking rate	AU ha^{-1}
Age at first mating	months
Slaughter age	months
Quality, management and pasture species (PAST)	0.19
Pasture stocking rate	AU ha^{-1}
Number of soil chemical analyses per year (CTC, Ph, P, K and Al)	n analysis
Applications of NPK per year	kg ha^{-1} per year
Types of pasture	[1]
ADG at pasture	kg day^{-1}
Animal supplementation (SUP)	0.19
ADG with supplementation	kg day^{-1}
Length of trough per animal	Cm per animal
TDN of the supplement	%
CP of the supplement	%
Productivity per area of the area supplemented	kg ha^{-1} per year
Reproductive management (REP)	0.13
Pregnancy rate	%
Calving rate	%
Abortion rate	%
Cows: bull ratio	nº cows per bull
Weight of heifer 30d before mating	kg
Genetics (GEN)	0.06
Breeds used	[2]
Weaning weight	kg
Health management (HEA)	0.19
Number of active principles used per year	n active principles
Overall mortality rate	%
Baths or tick treatments per year	n treatments
Interval between baths treatments	days
Mortality rate up to one year of age	%
Production control (PC)	0.06
ADG for production system	kg day^{-1}
Productivity per area of production system	kg ha^{-1}
Offtake rate	%
Weaning rate	%
Routine animal management (ROUT)	0.06
Number of weighing per year	n weightings
Carrying capacity evaluation per year	n evaluations
Number of dosing for endoparasites per year	n dosings

AU: animal unit = 450 kg BW; ADG: average daily weight gain; TDN: total digestible nutrients; CP: crude protein; n: number of samples; U: units; [1]unit referred as pasture type (summer, winter, or winter/summer); [2]qualitative unit of breed type.

indicators, showed an average cost of USD 141.20 ha^{-1}, representing USD 1.39/kg LW produced and gross margin for ha was USD 52.21.

In the cluster analysis, the formation of three groups was identified: low (LEL), intermediate (IEL), and high (HEL) level of efficiency (Table 5). The TEC driver with the components' age at first mating, soil chemical analyses, pregnancy rate, productivity per area, weaning rate, number of weighing, and supplementation were responsible for statistically differentiating the LEL and HEL clusters. The IEL and HEL clusters differed in the components' age at first mating and slaughter, with consequences in the MAN driver components.

For farmers classified as HEL, a correlation was reported between age at first mating and age at slaughter (0.790, p=0.006); between productivity and offtake rate (0.711, p=0.03) and cost ha $^{-1}$ (0.760, p=0.001); and between soil chemical analyses and variation of the stock in the last five years (0.666, p=0.025). In the IEL cluster, the correlation between age at first mating and slaughter was negative (−0.708, p=0.001). In the same cluster, a correlation was observed between productivity and offtake rate (0.794, p<0.0001) and cost ha $^{-1}$ (0.694, p=0.001); between stocking of pastures and selling price of steers (0.751, p=0.0003); and between the frequency of budget control and the evaluation of cash flow (0.690, p=0.001).

DISCUSSION

Productivity of the farms found through defining the typology of cattle farmers (BRAITO et al., 2011) characterized production systems with levels of efficiency above the normal for Brazilian cattle ranching (BARCELLOS et al., 2015), which justifies the high level of regional competitiveness (MARQUES et al., 2011). However, the gross margin is still lower than that needed to generate financial resources for a proper remuneration of the cattle farmer and to maintain/restore costs involved with the acquisition of fixed production resources, such as machinery, equipment, and facilities. Alternatively, the gross margin is adequate for the economy of the system, providing that the scale of the farm exceeds the minimum area for the region (ANUALPEC, 2015).

Variation among cattle farmers occurred basically in the aspect related to physical productivity, which shows that the investments made to increase the efficiency of the systems produced positive

Table 3 - Management (MAN) driver with its subfactors and their components.

Subfactor and variable(s)	Unit/weight
Labor training (TRA)	0.16
Number of training sessions per year	n sessions
Patrimonial control (PAT)	0.05
Percentage of leased area over total area	%
Variation of stock over last five years	Kg
Quantity of tractors and implements bought over the last five years	n tractors and implements
Budget control (BUD)	0.11
Frequency of cash flow evaluation per year	n times
Frequency of budget elaboration per year	n times
Production cost control (PCC)	0.16
Cost per area of farm per year	USD ha^{-1}
Cost per kg of LW produced per year	USD kg^{-1} of LW produced
Calculation of financial indicators (FI)	0.11
Gross margin per hectare per year	USD ha^{-1}
Acknowledgment of total cost composition	1
Herd identification (HI)	0.11
Manner of use of ear tags	2
Number of animal counts per year	n counts
Marketing (MKT)	0.11
Mean price of cull cow sales per year	USD kg^{-1}
Mean price of steer sales per year	USD kg^{-1}
Mean price of calf sales per year	USD kg^{-1}
Informatization of the farm (INF)	0.05
Manner of using worksheets	3
Scale of production (SP)	0.16
Offtake rate	%
Gross margin per area per year	USD $year^{-1}$
Number of staff on farm	n staff

LW: live weight; [1]yes or no; [2]unit referred as how ear tags are used (i.e., individual control, genetic control, management control); [3]unit referred as how worksheets are used (i.e., cash flow, herd control).

responses (GOMES et al., 2015). Alternatively, when the analysis considered economic results, this difference practically disappears between the clusters, especially in the IEL x HEL comparison. This may be associated, mainly, with cost management efficiency or the choice of higher risk or costly technologies to obtain the expected physical results (PEREIRA et al., 2016). Thus, the technology driver differentiated the LEL x HEL clusters and the management, mainly expressed in costs, the IEL x HEL. This shows that intensifying the systems requires greater management capacity, particularly for costs, and the technological efficiency is responsible for productive responses, since the adoption of certain practices does not always allow proportional appropriation of better economic results (NUTHALL, 2009; LAMPERT et al., 2012).

The LEL group, in relation to HEL, showed lower overall animal production indexes, especially for age at first mating and slaughter, and less efficient routine management; although, the cost was less per hectare. Generally, a lower cost in the production system is just one of the components that affect the result, since this is a combination of productivity and cost of production (HILL, 2014).

An intra-cluster analysis showed a positive correlation between age at first mating and age at slaughter in the HEL, explained by the simultaneous use of differentiated feed resources (cultivated pastures and/or supplementation) in two productive processes replacement heifers rearing and steers feeder/finishing (MARQUES et al., 2017). However, spending on these technologies also explains the higher costs in this group of producers when compared to IEL. In this cluster, the correlation between the two animal production parameters was negative, i.e. when mating at two years of age, the age of slaughter is delayed. This may be related to the feed deficit to improve both processes (STYGAR et al., 2014), since supplementation is performed only once per year; conversely, in the HEL cluster this practice is used, on average, three times a year. Moreover, producers classified as LEL use feeding improvement as a priority to sell the animals for slaughter up to 30 months, a similar parameter to those of IEL, and this age is considered appropriate for the region. However, these cattle farmers fail with respect to age at first mating of heifers (36 months), a variable that severely restricts productivity and economic outcome (BERETTA et al., 2001).

The HEL cluster presented an additional cost around 95 USD ha $^{-1}$ in relation to IEL, and a productivity superiority of only 25 kg ha $^{-1}$. The difference between HEL and IEL is probably because of investments in technologies related to herd nutrition by producers classified as HEL, which increased the cost by 84% and productivity by only 20%. These additional costs were not offset

Table 4 - Mean values presented by beef cattle farmers interviewed for the components belonging to the TEC and MAN drivers.

Component (unit)	Subfactor	N	Mean	SEM
TEC				
Age at first mating (months)	PROD	31	24.12	7.20
Slaughter age (months)	PROD	31	30.23	8.61
Overall stocking rate (AU ha^{-1})	PROD	31	0.91	0.42
ADG at pasture (kg day^{-1})	PAST	31	0.83	0.23
ADG with supplementation (kg day^{-1})	SUP	29	1.050	0.298
Pregnancy rate (%)	REP	31	74.23	9.41
Calving rate (%)	REP	31	69.12	10.21
Abortion rate (%)	REP	31	4.38	2.74
Cows: bull ratio (nº cows $bull^{-1}$)	REP	31	33.31	15.51
Weight of heifer 30d before mating (kg)	REP	31	305.12	34.10
Weaning weight (kg)	GEN	31	175.35	20.51
Mortality rate (%)	HEA	30	2.43	13.00
ADG for production system (kg day^{-1})	PC	31	0.560	0.247
Productivity per area of production system (kg ha^{-1})	PC	30	123.09	44.67
Offtake rate (%)	PC / SP	31	26.80	8.80
Weaning rate (%)	PC	31	68.83	10.51
MAN				
Cost per area of farm per year (USD ha^{-1})	PCC	31	141.20	83.39
Cost per kg of LW produced per year (USD kg^{-1} produced $year^{-1}$)	PCC	31	1.39	0.03
Mean price of cull cows sales per year (USD kg^{-1})	MKT	31	1.51	0.08
Mean price of steers sales per year (USD kg^{-1})	MKT	31	1.74	0.08
Mean price of calves sales per year (USD kg^{-1})	MKT	20	2.08	0.27
Gross margin per area per year (USD ha^{-1})	FI / SP	30	52.21	32.97

ADG: average daily weight gain; PROD: description of the productive system; PAST: quality, management and pasture species; SUP: animal supplementation; REP: reproductive management; GEN: genetics; HEA: health management; PC: production control; PCC: production cost control; SP: scale of production; LW: live weight; MKT: marketing; FI: calculation of financial indicators. SEM: standard error of mean.

by increased productivity in the same proportion (STYGAR et al., 2014), reflecting a 16% reduction in gross margin; although, this was not significant ($p > 0.05$). In addition, higher costs for ha were required to ensure greater productivity and offtake. In IEL, budget and cash flow control are performed less frequently, which did not prevent the cost ha^{-1} from being lower than in HEL. Therefore, from the point of view of bioeconomic efficiency, the IEL production systems were more efficient and with a gross margin per hectare higher.

These results confirmed that productivity gains are not always associated with economic gains in beef cattle (LAMPERT et al., 2012; ÁVILA et al., 2014). Furthermore, it is important to highlight that in the HEL cluster there is a special care in the monitoring of soil fertility, a variable that supports the intensification of forage resources with the maintenance of a stock of animals over a relatively long period. Thus, from the point of view of system management, the farmers of this cluster, regardless of the economic outcome, have a better overall view of the production system in the long term (TANURE et al., 2013).

The best economic result observed in the IEL cluster can be attributed to a set of managerial concerns identified by the positive correlation between productivity, offtake, and cost of production. Positive association between selling price and stocking of cultivated pastures also indicates the concern for technologies used in the fattening process (THUROW et al., 2009) and the possibility of selling animals for slaughter when the price is more favorable, usually between July and August in this region (NESPro, 2015). During this period, there is a shortage of animals for the industry, since the fattening of cattle, mainly occurs to grass fed; thus, the climatic effects of winter decrease the growth of natural forages and negatively influence in the

Table 5 - Comparative analysis of the three different clusters for the components related to technology (TEC) and management (MAN) drivers.

Component (unit)	LEL	IEL	HEL	SEM	P
---TEC---					
Age at first mating (months)	36a	24a	20b	3.1	<0.01
Slaughter age (months)	30ab	33a	25b	2.7	<0.01
Soil chemical analyses per year (n analysis)	0a	1a	1.9b	0.03	<0.01
Pregnancy rate (%)	64a	73ab	79b	6.2	<0.01
Productivity per area (kg ha^{-1})	60a	12ab	145b	10.2	<0.01
Weaning rate (%)	56a	67.5ab	74b	4.9	<0.01
Number of weighing per year (n times)	4a	3a	8b	0.43	<0.01
Suplementation (n times $year^{-1}$)	1a	1ab	3b	0.5	<0.01
---MAN---					
Cost per area (USD ha^{-1})	98.74a	113.57a	208.22b	16.0	<0.01
Budget control (n times $year^{-1}$)	1a	1a	3b	0.7	<0.01
Cash flow (n times $year^{-1}$)	2a	1a	3b	0.89	<0.01
Manner of using of worksheets	2ab	1a	3b	0.9	<0.01
Number of animal counts per year (n counts)	3ab	2b	3a	0.15	<0.01
Manner of use of ear tags	1ab	1a	2b	0.43	<0.01
Gross margin (USD ha^{-1})	31.72	57.81	48.40	3.2	NS

LEL: low, IEL: intermediate and HEL: high efficiency levels; P value was calculated with Tukey test ($p<0.01$); SEM: standard error of mean.

amount of cattle for sale, causing an increase of the price of finished cattle (NESPro, 2016). However, the use of nutritional technologies in fattening can reduce the off-season, fetching the balance of price during the year (NESPro, 2018). Another factor that may have influenced the difference between clusters is the intensity of the technologies used, such as energy supplementation, which allows stabilizing the system (PÖTTER et al., 2008). In addition, it is important to note that there is a high prevalence of forage shortage in winter and summer because of drought (PAULINO et al., 2004).

The intention of cattle farmers to use practices that potentiate the use of natural pastures (BORGES et al., 2016), as well as the adjustment of the animal load according to the pasture availability (NABINGER et al., 2009) and the pasture types within the system, were the key variables in the dynamics of animal productivity. Alternatively, among the cattle farmers interviewed, there was a tendency to present a stocking rate superior to the carrying capacity of the pasture (CARVALHO et al., 2010), since there is a constant concern, in the three clusters, with the stability in the minimum herd size.

The year 2012 was favorable for animal production in the region, as the prices paid for steers were above the average in recent years (NESPro, 2015). In a complementary analysis, adjusting values for a 10-year period did not change the components that differentiated the clusters. This shows the lack of control that farmer has over the selling price of his animals and the importance of managing the variables under his control, especially the cost of production (HILL, 2014) and productivity. Therefore, the cattle farmer needs to improve his managerial capacity, since the vast majority of rural companies are unaware of their cost of production or do not measure their technical-financial indicators (OAIGEN & BARCELLOS, 2008).

Although this research is concentrated in a specific region with expressive beef cattle production, it is understood that the evaluation of 33 famers is a limited number to measure the productive efficiency, mainly due the diversity of production systems. However, our proposal is innovative and with possibilities to expand to other regions and contribute to the decision-making of farmer managers to implement new technologies. Moreover, it is important to highlight that the limitation caused by the evaluation of only one year in this research, can be compensated by simulation studies repeating scenarios of other years.

CONCLUSION

The evaluation of the level of bioeconomic efficiency of cattle farmers, through typology, showed that the main differences are because of the use of technologies related to feeding and cost management. The decision to increase productivity from an intermediate level does not always ensure better economic results. Then, before implementing a new technology, it is imperative to assess whether the benefit generated will be proportional to the increase in cost.

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DECLARATION OF CONFLICT OF INTERESTS

The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

AUTHORS' CONTRIBUTIONS

The authors equally contributed to the manuscript.

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