# Greenhouse gas emissions intensity assessment in beef cattle production systems: a data envelopment analysis (DEA) approach with variable returns to scale

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## Introduction

Cattle raising is carried out in around 75% of Brazilian agricultural properties. The importance of beef cattle production in Brazil is evidenced by its share in the Gross Domestic Product (GDP). In 2013, its participation in the agribusiness GDP was 39.94%.

Changes in the demand for beef cattle have been driven by the human population growth rate, income growth, and urbanization. The response of the different livestock systems has been the incorporation of science and technology and the consequent increase of productive indexes. On the other hand, livestock production is likely to be increasingly affected by policies related to the mitigation of greenhouse gases (GHG) emissions, i.e the 'decarbonization' of livestock systems, besides the animal welfare legislation and other environmental constraints (Thornton, 2010).

Two types of efficiency may be identified in a production system: technical and economical (Ferreira & Gomes, 2009). One production system may be considered technically efficient if no other system is able to achieve the same level of production by using less quantity

of at least one input. Economic efficiency is achieved if there is no other alternative production system that produces the same amount at a lower cost or with a higher profit margin.

This paper aims at evaluating the efficiency of beef cattle productive systems in the Cerrado, Pampa and Pantanal biomes, regarding their emissions intensity (CO2 equivalent per kilogram of carcass weight produced).

## Material and Methods

Primary data were collected by means of the panel system, with the definition of representative properties, according to Plaxico and Tweeten (1963). Despite the difficulty to characterize production systems that may be viewed as representative of the biomes studied, the method searches, through the experience of the participating producers, to characterize the ones that are most commonly found in the region, at different levels of technology (Pereira & Costa, 2014; Crespolini, et al., 2015).

Ten beef cattle modal production systems applied in the three biomes (Cerrado, Pampa, Pantanal) were analyzed. The data came from the Pecus Project. Five systems are located in the Cerrado (Cerrado_Básico_05; Cerrado_Básico_12; Cerrado_Intermediário_12; Cerrado melhorado a pasto - SM3; Cerrado melhorado com confinamento -SM4); three in the Pampa (Pampa_Extensivo; Pampa_Semi-Intensivo; Pampa_Intensivo); and two in the Pantanal (Pantanal_tradicional; Pantanal_30).

The emissions were calculated according to the IPCC tier 1 and tier 2 default models implemented in the "PECUS Emissions Model" spreadsheet. The indicator used was the emission intensity (kg CO2-e / kg of carcass for slaughter) in each of the systems analyzed.

We performed data envelopment analysis (DEA) for the efficiency

analysis, using Linear Programming. The objective was to determine the efficiency of productive units, called decision making units or DMUs, with information about the levels of resources employed and results achieved. The same method has been previously applied in analyses of beef cattle production systems (Abreu et al., 2008; Gomes, et al., 2015).

In this analysis, the objective was to verify the relative efficiency of the alterative production systems in minimizing the gas emission. We established three input variables: total pasture areas (native and cultivated), number of breeding cows, and number of bulls, and one product variable (output), that is, the emission intensity (kg CO2-e/ kg of carcass for slaughter). The inverse of the intensity was defined as output as the objective was to evaluate the product decrease (emissions).

We chose to apply the VRS input-oriented mode, which considers variable returns to scale in order to minimize the resources while keeping the production levels unchanged (Cooper et al., 2006).

## Results and Conclusions

Table 1 shows the results of DEA modeling with the variable returns to scale model.

Table 1. DEA index and returns to scale.

| DMU | VRS | DRS | IRS | SEff | RTS |
|---|---|---|---|---|---|
| Cerrado_Basic_05 | 91,99 | 91,99 | 73,01 | 79,37 | Decreasing |
| Cerrado_Basic_12 | 92,05 | 92,05 | 74,05 | 80,44 | Decreasing |
| Cerrado_Intermediate_12 | 78,35 | 78,35 | 76,84 | 98,07 | Decreasing |
| Cerrado_SM3_Pasture | 54,02 | 54,02 | 49,20 | 91,09 | Decreasing |
| Cerrado_SM4_Confinement | 53,10 | 53,10 | 43,67 | 82,24 | Decreasing |
| Pampa_Extensive | 100 | 100 | 74,17 | 74,17 | Decreasing |
| Pampa_Semi_intensive | 100 | 100 | 95,61 | 95,61 | Decreasing |
| Pampa_Intensive | 100 | 100 | 100 | 100 | Constant |
| Pantanal_Traditional | 71,14 | 32,44 | 71,14 | 45,6 | Increasing |
| Pantanal_30 | 100 | 27,29 | 100 | 27,29 | Increasing |

DMU-decision making unit, VRS-variable returns to scale, DRS-decreasing returns to scale, IRS-increasing returns to scale, SEff-scale efficiency, RTS- returns to scale.

The Pampa_Intensivo system was the only one that uses the products without waste and that maximizes the inverse of emission intensity, i.e., it minimizes the emission intensity (kg CO2-e/kg carcass for slaughter). The DMU operates in optimal scale, and the production decrease occurs while keeping the factor use proportion.

The seven systems (five in the Cerrado Biome and two in the Pampa) evaluated operate in descending return and are inefficient in the scale. Therefore, they are operating above the optimal scale and they probably have technical inefficiency. These systems will have to eliminate the excessive use of inputs, which means to produce more with the same inputs. Alternatively, they will have to improve the technology, by increasing the factor productivity. The two systems in the Pantanal Biome operate below the optimal scale. It is necessary to increase production so that the relations between the quantities of inputs used and the production volume may be reduced.

The use of the DEA modeling enables the performance analysis of the DMUs with multidimensional perspective in different situations, by means of the functional relations between inputs and products. The study of the GHG emissions in livestock systems with the use of DEA will lead to evaluating the strategies' technical efficiency, productivity and effectiveness to minimize them.

## References

ABREU, U.G.P.; GOMES, E. G.; LOPES, P.S.; TORRES, R de A; SANTOS, H do N. Avaliação sistêmica da introdução de tecnologias na pecuária de gado de corte do Pantanal por meio de modelos de análise envoltória de dados (DEA). **Revista Brasileira de Zootecnia** Vol. 37, n. 11, p.2 069-2076, 2008.

COOPER, W.W; SEIFORD, L.M; TONE, K. **Introduction to Data Envelopment Analysis and its uses**. 1. ed. New York: Springer, 2006. 354 p.

CRESPOLINI, M. dos S.; De ZEN, S; ABREU, U.G.P.; CARVALHO, T. B.; GUARDA, G.M. Os ganhos de escala dos sistemas modais de pecuária de corte em Corumbá/MS.

In: **53º Congresso da Sociedade Brasileira de Economia, Administração e Sociologia Rural, 2015,** João Pessoa**.** Agropecuária, Meio Ambiente e Desenvolvimento. Brasília: SOBER, 2015.

FERREIRA, C.M.C.; GOMES, A.P. **Introdução à análise envoltória de dados. Teoria, modelos e aplicações**. 1. ed. Viçosa: Ed. Viçosa, 2009. 389 p.

GOMES, E. G.; ABREU, U.G.P.; MELLO, J. C. C. B. S. de; CARVALHO, T. B.; De ZEN, S. Economic and socio-environmental performance assessment of beef cattle production systems: a data envelopment analysis (DEA) approach with weight restrictions. **Revista Brasileira de Zootecnia**, Vol. 44, p. 219-225, 2015.

PEREIRA, M. de A.; COSTA, F. P. Sistemas modais de produção de carne bovina na região de Campo Grande: uma análise temporal sob a ótica de especialistas da cadeia produtiva. In: **52º Congresso da Sociedade Brasileira de Economia, Administração e Sociologia Rural, 2014, Goiânia.** Heterogeneidade e suas implicações no rural brasileiro. Brasília: SOBER, 2014.

PLAXICO, J. S., & TWEENTEN, L. G. Representative farms for policy and projection research. **Journal of Farm Economics**, 45(5), 1458-1465, 1963.

THORNTON, P. K. Livestock production: Recent trends, future prospects. **Philosophical Transactions Royal Society B: Biology Science**. Vol. 365, p. 2853–2867, 2010.