Beef Cattle CO2-e Emission Intensity as a Product of Performance Ratios

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Introduction

Embrapa's PECUS project[1] aims to estimate greenhouse gas emissions (GGE) and recommend technological solutions for reducing CO2--e emission intensity from beef cattle production systems. PECUS project identified 23 typical production systems that represent most of the Brazilian beef cattle production and defined mathematical models for their technical and economic performance and CO2-e emission intensity. Choosing the right performance indexes can help to compare different production systems and identify opportunities for improvement. This work describes a way of splitting emission intensity from enteric fermentation and manure decomposition of a beef cattle production system as a product of performance ratios inspired by DuPont identity used for financial performance analysis (MATT, 2016). Selected production systems identified by the PECUS project were compared through these performance ratios in order to evaluate if they can help on identifying opportunities for the reduction of CO2-e emission intensity.

[1] https://www.embrapa.br/busca-de-projetos/-/projeto/38213/projeto-da-rede-pecus

Material and Methods

We propose an identity for CO2-e emission intensity from enteric fermentation and manure decomposition in CO2-e per Kg of carcass as the product of 4 performance ratios:

emission intensity, carcass production	(kg CO2-e / kg of carcass) =
emission intensity, dry mass consumption	(kg CO2-e / kg dry mass consumed) *
dry mass consumption	(kg dry mass consumed / kg cattle live weight) *
cattle turnover	(kg cattle live weight / kg live weight for slaughter) *
carcass yield	(kg live weight for slaughter / kg of carcass)

As in PECUS project, all values were calculated for one year of production, with all production systems assumed to be in a one year cycle (all variables repeat their values after 365 days). From the 23 typical beef cattle production systems defined by the PECUS project, 10 complete cycle production systems with negligible acquisition of animals were selected, so the performance ratios proposed can be used to compare similar systems. The performance ratios were calculated using mathematical models embedded in the "Modelo Emissoes" spreadsheet developed by the PECUS project, and normalized by dividing them by the minimum value found on the 10 systems evaluated. The normalized emission intensity is the product of the normalized performance ratios. The proposed equation is an "identity" because the numerators and denominators on the right side of the equation may cancel each other and become the expression on the left side. The last three performance ratios can be seen as a way of converting emission intensity per carcass produced to emission intensity per dry matter consumed, using three efficiencies in cattle production, respectively: 1) using less dry matter for maintenance and producingan excess on live weight; 2) generating an excess of live weight for slaughter; 3) generating live weight for slaughter with a high percentage of carcass. Although "cattle turnover" and "carcass yield" would be better represented by the inverse of the performance ratios above, these 2 ratios were kept for simplicity (higher values imply proportional higher emission intensities).

Results and Conclusions

Figure 1 shows the normalized CO2-e emission intensity (blue line, Y-axis on the right) and performance ratios (columns, Y-axis on the left) for each system per biome, from more traditional and extensive production systems to improved and intensive systems.

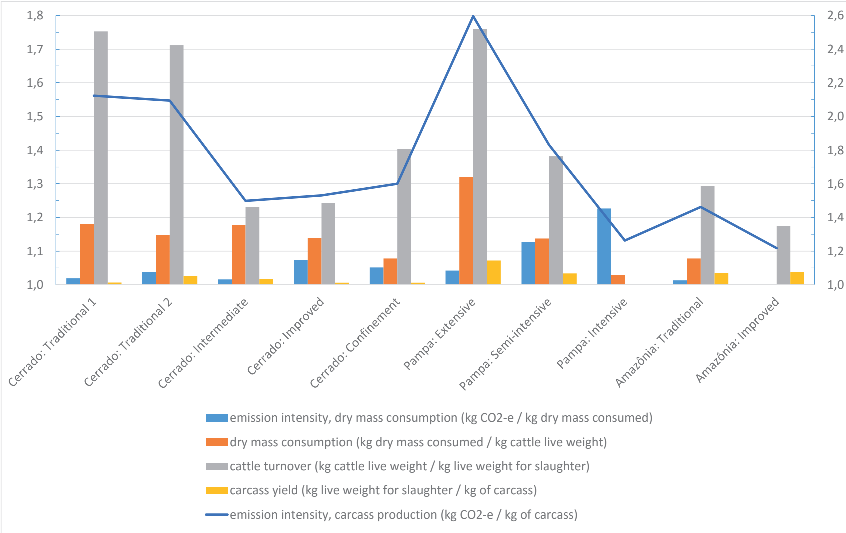

Figure 1: Normalized CO2-e emission intensity (blue line, Y-axis on the right) and performance ratios (columns, Y-axis on the left) for 10 Brazilian typical beef cattle complete cycle production systems.

Values in Figure 1 indicate that traditional and extensive systems have higher CO2-e emission intensities and that "cattle turnover" contributes more for the variation of emission intensity between systems, followed by "dry matter consumption", in a distant second place. Little change of CO2-e emission intensity is explained by "emission from dry matter consumption". The high values for this ratio for the "Pampa" biome production systems come from higher protein content estimated for the grass and the use of concentrate feed on that biome that leads to more N_2O emission from manure decomposition. "Carcass yield" almost does not change between systems, and its normalized value barely influences the emission intensity of any production system. As the normalized "emission intensity from dry matter consumption" and "carcass yield" ratios vary less between systems, there are probably less opportunities for reduction of emission intensities by improving (i.e., lowering) these performance ratios than what can be achieved by improving "cattle turnover" and "dry matter consumption" efficiencies, *ceteris paribus*. "Cattle turnover" can be improved through higher birth rates, lower death rates, shorter production cycles (early steer), less bulls per cow (or artificial insemination). "Dry matter consumption" requirement per live weight maybe decreased by animal selection and improvement. *Caveat*: the identity of the CO_2-e emission intensity to a product of these four performance ratios does not imply that these ratios are orthogonal or independent from each other: a strategy for improving one performance ratio will probably have to consider the worsening of another. For instance, changing the forage may improve cattle turnover but increase emission intensity per kg of dry matter consumed. The proposed performance ratios are easy to understand and to compare between systems. Three of them evaluate technical efficiency and are reasonable proxies for economic performance. The Kaya identity used for global or regional GGE estimation by the IPCC (NAKICENOVIC & SWART, 2000; KAYA & YOKOBURI, 1997). Bennetzen (2016) also presents an extension of Kaya identity for agricultural systems. These two identities have a much broader scope (regional and global GGE estimation) and are not so suitable for benchmarking production systems as the identity here proposed. The identity proposed was applied only to complete cycle production systems. For production systems that buy or supply calves, the live weight for slaughter must be replaced by the yearly net gain of live weight. Besides enteric fermentation and manure decomposition, other emissions can be included in the "emission intensity per dry matter consumption" performance ratio, by extending its scope to emissions from dry matter (forage) production (liming, fertilizing, ensilage, agricultural operations, energy, infrastructure, equipment, land use change) and transportation (fossil fuel and vehicles). In a Life Cycle Assessment approach (ISO, 2006), the inclusion of these "upstream" emissions would increase the influence of the dry matter source on the CO_2-e emission intensity. These extensions to the scope of the proposed identity must be evaluated.

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