Marginal Abatement Cost: Evaluation of Feed Diet Improvements of Dairy Cattle for a Brazilian Typical Farm

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Marginal Abatement Cost: Evaluation of feed diet improvements of dairy cattle for a Brazilian typical farm[1]

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1 Introduction

Brazil has assumed a proactive role in the world discussions about the climate change in the last years. In 1992, Brazil hosted the United Nations Framework Convention on Climate Change (UNFCC), the ECO-92, which recognized the need of cooperation among countries to succeed in reducing the Greenhouse Gases (GHG) emissions and, therefore, the climate change effects (Chichilnisky and Heal, 1994; Seroa da Motta, 2011). The 21st Conference of Parts (COP 21), in 2017, has also become another milestone in terms of the global effort toward a more sustainable policy on climate change. COP 21 ended to produce the Paris Agreement, in which Brazil has proposed targets of diminishing a significant amount of GHG emissions.

The *intended Nationally Determined Contribution* – iNDC, defined in the Paris Agreement, consists on a mechanism (not mandatory) aiming to get governments involved in achieving the proposed targets related to reduce the GHG emissions, while respecting the particularities pointed by the signatory nations (UNFCCC, 2015). The Brazilian iNDC is ambitious, once it proposes to reduce the GHG emissions to 1.3 GtCO2eq until 2025 and to 1.2 GtCO2eq until 2030. This amount refers to a cut of 37% and 43%, respectively, compared to emissions in 2005 (base year), estimated to have reached 2.1 GtCO2eq (Ministério do Meio Ambiente, 2018).

In comparison to other large emitters, some studies highlight that Brazil shows a different pattern in terms of sources of GHG emissions. That is the case reported by McKinsey & Company (2009), World Bank (2010), Fundação Getúlio Vargas - FGV (2016) and Imaflora (2018). The energy sector is, globally and in average, the main source of emissions, while in Brazil, the largest share relates directly or indirectly to agriculture and cattle raising, around 74% according to SEEG estimates for 2016 (Azevedo and Angelo, 2018). Two-thirds out of the 74% originated from the conversion of forests to pasture and/or to crops, while one-third, indeed, originated directly from agriculture and cattle raising. These direct emissions are mainly originated from the enteric fermentation process from bovines and from the soil management and the manure disposal (Azevedo and Angelo, 2018).

According to a report about the agriculture and livestock emissions, elaborated by Imaflora (2018), in collaboration with the Greenhouse Gas Emission and Removal Estimate System (*Sistema de Estimativas de Emissões e Remoções de Gases de Efeito Estufa*, SEEG in Portuguese), Brazil ranks as the third world largest emitter for this sector. However, once those emissions are disaggregated, livestock emerges as the responsible for the majority of the GHG emissions, mainly because of the enteric fermentation from bovines, but also because they contribute to emissions from soils due to the manure disposal and lixiviation. Unfortunately, that inventory of emissions does not consider the net emissions, since it does not account for the carbon sequestration that may occur in grassland.

The Brazilian cattle raising still shows a low productivity when measured in terms of animals per hectare. This poor performance contributes to raise domestic deforestation rates, as technical inefficiency pushes the livestock production toward new areas, instead of promoting optimization and a more sustainable land use. It reveals that the improvement of this sector productivity, by the adoption of more intensive systems of production, may constitute a feasible alternative to reduce GHG emissions from the livestock sector in Brazil (Anualpec, 2015; Imaflora, 2018; Margulis and Miranda, 2018).

[1] This paper is part of the Master thesis of the first author, which is an ongoing study.

Literature highlights that the low indexes for the average productivity relates to the presence of several diverse systems of cattle production in Brazil, for both sectors, beef and dairy. However, despite the available knowledge and technology, its adoption varies broadly across the regions, all over the country, characterizing a technologically very heterogeneous sector. Extensive systems, based on grazing, in natural or cultivated pastures, compared to semi-intensive or intensive systems (such as feedlots), usually show lower productivity indexes, but the outcome still will depend on the quality of pastures. This issue concerning cattle productivity is aggravated by the existence of millions of hectares of degraded pasture land in Brazil (Banco Mundial, 2010; Dias-Filho, 2011; Santos, 2016; Imaflora, 2018).

On the other hand, studies have also underlined measures that can make the livestock production less carbon-intensive. Some measures often listed by the specialized literature are: a) the integrated production systems, such as Crop-Livestock-Forest (iLPF, in Portuguese); b) the animal breeding (using artificial insemination or bulls of high performance) and the fodder breeding; c) some feeding improvements, such as using supplements, allows for a better performance of the zoo technical coefficients (by reducing the time for animals fattening and extending the period of lactation of dairy cows); and d) the anti-methane vaccine, which is still under development (McKinsey & Company, 2009; Banco Mundial, 2010; Santos, 2016).

It is worth mentioning that the feasibility of mitigation measures must be evaluate not only under an economic perspective, but also a politically one. This last can push or slow the adoption of mitigation actions in the livestock sector, considering its social and economic relevance for Brazil. According to the USDA (2018a, 2018b), Brazil is one of the largest world beef producers and exporters, besides ranking as a major beef and milk world consumer. Thus, the Brazilian cattle sector (beef and dairy) computed to a GDP of roughly US$82,708.22 million of dollars[2], at constant prices for 2017, which accounts for approximately 60% of the livestock share in the total of agribusiness (US$138.81 billions of dollars), more than 18% of the Agribusiness GDP and close to 4% of the national GDP (Barros, 2017).

Therefore, the discussion about GHG emissions in the cattle sector and its mitigation constitutes a great challenge for the Brazilian society and policy makers. This paper intends to estimate and analyse costs of production for a typical dairy farm, as well as its methane emissions (absolute and relative per milk litre) for two different scenarios, along 13 years, which corresponds to the period 2018 to 2030, the deadline for accomplishing with the Paris Agreement commitments.

Data describing a typical farm of Leopoldina, located in Minas Gerais state, one of the most important regions of milk production in Brazil, was obtained from CEPEA – USP. This case illustrates a low technology production system, which will probably face the greatest technical and economic challenges to keep viable while complying with eventual policies to push mitigation of these sector´s emissions. Scenario A (baseline) assumes that the farm does not adopt any mitigation action; otherwise, in Scenario B the farm is supposed to adopt mitigation measures.

Scenario B simulates the adoption of a new diet for milking cows. The literature has shown that a more balanced animal feeding can also reduce emissions per litre of milk produced (Banco Mundial, 2010; Margulis and Miranda, 2018), besides improving zoo technical coefficients.

The relevance of dairy cattle emissions in Brazil, accounting for 10% of the whole agriculture/livestock sector emissions (Imaflora, 2018), and the scarce literature about the economic and technological challenges for the dairy sector in complying to future requirements to reduce GHG emissions, have sparked interest for conducting this study. It is strategic to collect elements and knowledge that can fundament the discussion of a future policy on carbon pricing and promote mitigation of agriculture and livestock GHG emissions. The recent project of Partnership for Market Readiness (PMR)[3], a World Bank initiative, selecting Brazil to support a broad study about carbon pricing is a major sign that this policy issue will likely be in the spotlight in the near future.

2 Methodology and Data

The need of adjustments in production and consumption systems toward a lower carbon-intensive model requires more information about costs to reduce the GHG emissions. In order to that, an analytical tool frequently applied is the Marginal Abatement Cost Curve (MACC). The environmental economics framework

[2] The value was estimated in 263,955 million Reais, which was converted to dollar using a real exchange rate of R$3.1914/US$, annual average for 2017 (IPEADATA, 2019).
[3] Available at: https://www.thepmr.org/country/brazil-0

recognizes the MACC as an efficient tool, broadly used by policy makers to assess the economic and technological feasibility of measures to environmental mitigation (Böhringer and Vogt, 2003; Motta, Couto and Castro, 2012).

The MACC compares total abated emissions with the marginal costs associated to promote that reduction. Therefore, it allows analysing the most appropriate mitigation measure in each situation (Kesicki and Ekins, 2012). The MACC is usually plotted in a two dimension graph indicating the amount of the abated equivalent carbonic gas (CO_2) emission, usually measured by tonnes (in the *x* axis) and the monetary cost per abated ton of CO_2 (in the *y* axis). Besides measuring marginal costs, the MACC can be used to determine average costs and total costs of abatement (Kesicki and Strachan, 2011).

This paper builds the MACC adopting the Technological approach, which provides a more detailed description of the costs of technologies implemented to mitigate the GHG emissions. This method maps pathways for the CO2e emissions with and without the adoption of the mitigation measure. The cost of the mitigation measure consists on the difference of costs between the scenario with its adoption and the scenario without it (baseline). This approach allows for examining the potential of emissions' reduction and the correspondent cost for each measure or action analyzed. The next step is, then, ranking the measures of mitigation graphically, from the lowest cost to the more expensive measure (Kesicki and Ekins, 2012).

According to Kesicki (2010), the main advantage of the technological approach to obtain a MACC is the ease of its interpretation, as well as the possibility of deepening the costs analysis for the proposed mitigation measures. On the other hand, that author reports that the technological approach fails in not providing an evaluation of impacts that these measures might cause over the macroeconomic variables.

This research encompasses a comparison among different dairy production farms, which were selected to represent some of the major Brazilian regions of dairy production. The general goal is to evaluate how the technological improvements related to feeding supplement, pasture management; breeding and manure disposal can contribute to reduce the intensity of carbon emissions, measured by emissions per litre of milk, besides providing a better financial balance for dairy farming activities. This paper describes partial results from that ongoing research, specifically for the case of a typical dairy farm in Leopoldina, Minas Gerais state, representative of a low technology model of production.

Minas Gerais state is the largest milk producer in Brazil. However, the technology level varies across the state. In Leopoldina, the typical farm analysed shows a low technology level, with small economic returns, and poor zoo technical coefficients. This type of production system is largely found in several other Brazilian regions as well, where the dairy cattle is social or/and economically relevant, and commonly developed by family farmers (Margulis and Miranda, 2018). Any further discussion, in the future, about imposing public policies to enforce mitigation or even market-driven incentives with the same purpose will require more information on costs and benefits of the potential adjustments in the production systems and their impacts.

Data describing the typical farm was collected through a panel method, which provides a modal profile for the production system and a detailed worksheet on the production costs for the dairy activity. Cepea (ESALQ-USP), in collaboration with the National Confederation of Agriculture and Livestock (Confederação Nacional da Agricultura e Pecuária, CNA in Portuguese) collects and organizes the panel data for several regions in a systematic and periodical procedure.

The panel contains information about the zoo technical indexes for the typical (modal) farm. This study intends to take into consideration how the adoption of measures to promote emissions mitigation can affect those indexes. Among the measures to mitigate emissions of interest for this study, the literature highlights the improvement of feeding diets, the implementation of confinement systems (feedlots) and improvements on the pasture management system.

Using the initial zoo technical coefficients, collected by Cepea/CNA for Leopoldina region, the emissions for the base year are calculated for that typical dairy farm. In the sequence, two scenarios are simulated. The first scenario (A) is the baseline, considering "business as usual" in that farm, along the 13 years (2018-2030) projections, in terms of zoo technical indexes and cattle emissions.

The second scenario (B) assumes that changes will occur in terms of zoo technical indexes and methane emissions along the projected timeline, due to the implementation of a technological improvement. The case illustrated by this paper considers the improvement originated by the adoption of an optimal diet for milking cows (in lactation). Table 1 details the assumptions of scenarios A and B.

The basic data to project costs and revenues for each scenario, as well as the zoo technical coefficients, came from the panel database of CEPEA/CNA, as mentioned before, and the consultation with experts helped to make some adjustments in order to use the data to project the GHG inventory for the 13 years scenarios.

The panel database comprises detailed information on the typical dairy farm, such as: description of the property (size, existence of pasture land, agriculture land, forest) infrastructure – buildings, machinery, number, age and category of animals, labour force (temporary, permanent and hours used for each operation, wage), inputs use (fertilizers, veterinarian drugs or vaccines, diesel, etc.), services (veterinarian, agronomic etc.). It also includes energy use, taxes, sources of revenues (animals sale, milk, beef, manure and others) and the zoo technical indexes (productivity, lactation period, weight gain, birth rate, mortality indexes, pregnancy rate and so on).

Table 1. General assumptions to the simulated scenarios for the typical dairy farm of Leopoldina/MG to obtain a MACC. Evaluated technology to mitigate emissions: optimal feeding diet for milking cows

Scenario	**Description**
Scenario A	Zoo technical coefficients are kept constant along the13 years of projection, as the production system and the technology level are kept the same of the base year; likewise the emissions. Costs and revenues (in real values) are the same along the 13 years; investments are null; computing only depreciation and maintenance costs
Scenario B	Technology changes in response to adoption of an optimal diet for cows in lactation, and consequently the zoo technical coefficients improve along the 13 year-period of projection; Costs of production, productivity and revenues, and emissions increase along 13 years; investments are made to establish a semi-confinement infrastructure

CEPEA/CNA implements the panels in regions considered being locally representative of a broader region or of the whole state, or even representative of a prevailing technology level. Every each two or three years, the panel is recollected to monitor changes in economic, zoo technical and technological variables. The method to collect data for typical farms start with the contact and previous meeting between the technicians from CEPEA and a focus point in the region, before the panel itself. Then, a meeting with the cattle producers is organized in the municipality, and along 4 to 5 hours, they define what is perceived as a typical (modal) farm to raise dairy cattle in the region. In some regions, there might be other prevailing typical systems, and in this case, another panel will take place to collect information about that system as well.

The economic indicators built from the panel follow the methodology proposed by Matsunaga et al (1976), and provide the information necessary to estimate costs of production, the Effective Operational Cost (COE, in Portuguese) and the Total Operational Cost (COT, in Portuguese), besides the Total Cost, which will not be considered here. The COE comprises all the expenses to operate the farm during one year, comprising fixed and variable costs. Variable costs include feed (concentrated and roughage), vaccines, mineral supplements, buildings and machinery maintenance, as mentioned by Santos (2015). The COT comprises the COE added by the linear depreciation cost found for the farm inventory and by the farmer´s *pro labore*.

The collected data is used to build the baseline scenario (A), which considers that the production system will hold as the same along the whole 13 years-period of projection, in terms of zoo technical and economic indexes (in real terms). For Scenario B, investments will be necessary to improve the infrastructure that will provide the abatement of emissions through a better quality feeding and a more intensive system of production. This implies a less-intensive carbon production system or mitigation gains. Usually Brazilian farmers are more concerned about the COE. However, because this study focuses on the projection time and the costs of investments made to pursue a more sustainable way to produce milk, it is convenient to discuss the COT instead of COE as an indicator of the microeconomic impact for farmers.

2.1 Description of baseline and simulation feeding conditions

The typical dairy farm of Leopoldina characterizes as a production system of low technology, performing poorly in terms of milk productivity. The animals are *Girolando*, a mix of half-blood Gir (Indian race) and half-blood Dutch cattle. These cows are resistant to tougher conditions of cattle raising, but in Leopoldina region the modal property shows very low productivity, only 8 litres per day during the cow´s lactation period, although experts consider that this kind of animal has potential to produce 20 litres per day in average.

Besides the potential to produce more milk, dairy market experts from CEPEA consider that the higher quality feeding diets under analysis will improve other zoo technical indicators. In fact, the typical farm in Leopoldina characterises by a grazing based-system, and animals access the trough only to have some concentrate and supplementation. Table 2 details the diet adopted in the typical farm in 2018 and that will keep along the baseline, while Table 3 shows the diet evaluated in the abatement scenario, which evolved initially from the basic feeding found in the typical farm.

Experts from CEPEA gave technical support to define an optimal supplementary diet to compose the technological improvement simulated in Scenario B. In the baseline, the original (but insufficient) feed supplementation was kept constant, along the whole 13 years.

Table 2- Daily feed and supplements per head, for different categories of dairy cattle, for a typical farm in Leopoldina - MG. Scenario A. Projection: 2018-2030

Bovine categories	Feed / Supplements	Description	Consumption (kg/head/day)
All animals	Roughage (forage)	Pasture*	-
Lactating cows	Concentrate	Ration	3.00 kg
All animals	Protein salt for dry cows		113.72 g
All animals	Mineral salt		34.11 g
All animals	White salt		18.95 g

* According to dairy experts from Cepea, based on very low production or milk per cow in the typical farm of Leopoldina, one can infer that the cows in lactation are consuming less fodder than the recommendation for those animals.
Source: elaborated by the authors based on CEPEA-CNA panel data for 2018.

Table 3- Daily diet - feed and supplements per head and category of dairy cattle in a typical farm of Leopoldina – MG. Scenario B. Projection: 2018-2030

Bovine categories	Feed / Supplements	Description	Consumption (head/day)
All animals except lactating cows*	Roughage (forage)	Pasture**	-
Lactating cows	Roughage (forage)	Silage[4]	22.50 kg
	Concentrate	Ration[5]	5.00 kg
Lactating cows (first calf)	Mineral salt		93.33 g
Lactating cows (multiparas)	Mineral salt		100.00 g
All animals	Protein salt for dried cows		114.63 g
Heifer (12 to 24 months old)	Mineral salt		47.78 g
Heifer (24 to 36 months old)	Mineral salt		74.44 g

* Categories: young animals, bulls, cows not in lactation, single cows
** In this scenario, once cows in lactation do not graze anymore, following recommendations from Cepea´s experts, the assumption was that the other categories will benefit from a larger feed supply from grazing.
Source: elaborated by the authors based on CEPEA-CNA panel data for 2018.

2.2 Evolution of zoo technical indicators for the typical farm in Scenario B (Abatement)

Scenario B assumes that the typical farm improves feeding level, by making adjustments to achieve an optimally feed diet for dairy cattle, both in quantity and quality. Thus, it is reasonable to expect a better performance also in terms of zoo technical indicators. This will result in positive impacts over economic and financial farm outcomes as well.

[4] The calculation of silage was developed according to Cepea´s experts for each category, following the following steps: a) Assumption of a diet of 2.5% live weigh in dry matter for a cow with 450 kg; b) A daily consumption of 11.25 kg of dry matter per lactating cow; c) Taking those previous steps, we can calculate a 60% ratio of roughage (6.75 kg dry matter) over that total dry matter consumption and a 40% of concentrate (4.5 kg dry matter); and d) Assuming that silage is 30% dry matter, a 22.5 kg of silage original matter is required.
[5] The quantity of concentrate was calculated by considering 90% of dry matter, which requires 5 kg of original matter.

Table 4. Number of bovines, per category, projected for Scenario A and Scenario B, considering a typical dairy farm in Leopoldina – MG. Projection: 2018-2030

Categories	Scenario A (2018) Heads	Scenario B (Abatement) – Heads												
		2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Bull	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Suckling calves	16	16	20	23	25	29	29	29	29	29	29	29	29	29
Weaned calves	16	16	19	22	24	29	29	29	29	29	29	29	29	29
Heifers (12 to 24 months)	16	16	19	22	24	28	28	28	28	28	28	28	28	28
Heifers (24 to 36 months)	15	15	19	22	24	27	27	27	27	27	27	27	27	27
Heifers (36 to 48 months)	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lactating cows (first birth)	10	15	19	22	24	19	19	19	19	19	19	19	19	19
Lactating cows (multiparas)	27	22	25	26	28	41	41	41	41	41	41	41	41	41
Single and dry cows (dried)	21	21	24	21	17	12	12	12	12	12	12	12	12	12
Total livestock	**123**	**123**	**145**	**159**	**167**	**186**	**186**	**186**	**186**	**186**	**186**	**186**	**186**	**186**
Daily average litres of milk/ lactating cow		**15**	**15**	**17**	**17**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**	**20**

Source: elaborated by the authors based on CEPEA-CNA panel data and experts consultation.

Therefore, Scenario B assumes that in order to increase the daily average production of milk per lactating cow and the revenues of milk sales, the farmer will have to make some investments to implement the optimal feed diet and will face increasing costs of production.

In this sense, the size of livestock will change along the projection timeline and becomes a relevant zoo technical indicator, by affecting outcomes of the technological changes. In Scenario A, the number of animals in farm keeps constant during the projection time (Table 4). On the other hand, in Scenario B, the implementation of a semi-confinement system, improving feed diet and increasing expenditures, is assumed to provide a gradual increase in the total number of animals raised in the farm, during the first five years, until reaching a stable herd, after 2022 (Table 4).

In Scenario B, the adoption of an optimal diet is supposed to affect the herd growth rate in a short term, in the second year after its implementation (2019); and that the livestock size will, stabilise in 2022. After 2022, the additional animals delivered in the dairy farm are supposed to be sold[6], in order to maintain the herd stable for the rest of the projected period.

Another relevant aspect is that the daily average production per lactating cow will remain fixed at 8 litres per cow, in Scenario A, where the assumption is that no technological changes will happen during 13 years. On the other hand, for Scenario B, the milk production will gradually increase up to reach a daily average of 20 litres per lactating cow, by year 2022. Table 4 presents the evolution of bovines, per category, in the dairy farm, for both scenarios.

2.3. Calculating the MACC

This paper adopts the technological approach in order to build the MACC and follows the mathematical model proposed by Banco Mundial (2010, p.157), which used the incremental cost conception, as shown below:

$$AC_n^{Ativity} = \frac{ANC_n^{Scenario\ B} - ANC_n^{Scenario\ A}}{AE_n^{Scenario\ A} - AE_n^{Scenario\ B}} \qquad (1)$$

Where n = 2018, … 2030 and:

$AC_n^{Ativity}$ = Cost for the abatement technology of GHG emissions in **n**;

$ANC_n^{Scenario\ B}$ = Annual net cost of the abatement technology (Scenario B) in year **n**;

$ANC_n^{Scenario\ A}$ = Annual net cost of the technology adopted by the typical farm in 2018 (base year) in Scenario A, in **n**;

$AE_n^{Scenario\ B}$ =Annual emissions of GHG with the adoption of abatement technology (Scenario B) in **n**;

$AE_n^{Scenario\ A}$ =Annual GHG emissions without abatement technology (baseline - Scenario A) in year **n**.

Equation (2) shows the calculation of the annual net cost of the technology of GHG emissions:

$$ANC_n = \frac{INV.r.\frac{(1+r)^t}{(1+r)^t - 1} + AOMC_n + AFC_n - AREV_n}{(1+r)^{(n-2018)}} \qquad (2)$$

Where:

[6] In Scenario A, there are also animals sold. However, in Scenario B, after 2022, a larger number of animals (cows and calves) are sold, which show better standards than in Scenario A, due to the optimal diet.

- ANC_n = Annual net cost of abatement technology (Scenario B) or baseline technology (Scenario A), measured in present values at base year 2018, for year **n**;
- INV = Total investment or cost of capital for the abatement technology (Scenario B) or in the reference scenario (A);
- $AOMC$ = Annual cost of operation and maintenance of abatement technology (Scenario B) or baseline technology (Scenario A);
- AFC = Annual cost of fuel in Scenarios A and B;
- AREV = Annual revenue obtained in Scenarios A or B;
- r = Discount rate (a 12% rate was adopted, following similar works of the World Bank)
- t = Technology lifetime in years.
- n = Year

The methodology to computing the emissions, for both scenarios, A (baseline) and the B (Abatement), is based upon the Third Brazilian inventory of anthropic GHG emissions and removals (Terceiro Inventário Brasileiro de Emissões e Remoções Antrópicas de GEE, in Portuguese). This inventory was issued by the Ministry of Science, Technology, Innovation and Communications (Ministério da Ciência, Tecnologia, Inovações e Comunicações, MCTI in Portuguese) (MCTI; EMBRAPA, 2015).

Equation 4 shows the parameters and formulae to calculate the emissions originated from the enteric fermentation of bovines (EFi), measured in Kg CH4/head per year:

$$EF_i = GE_i \times Y_m \times 365\ days/year\ /55{,}65\ MJ/kg\ CH_4 \quad \textbf{(3)}$$

Where:

- GE_i = Intake of gross energy (MJ/head/day)[7];
- Y_m =Conversion rate of methane (0.06)

The estimation of emissions generated by manure management also used the emissions factors proposed in the Third Brazilian Inventory of GHG Anthropic Emissions and Removals (MCTI; EMBRAPA, 2015).

The original calculation of all monetary values was in Reais, following the currency of the collected data in panels. Monetary values were firstly converted into constant Reais, relative to year 2018, and finally they were converted into dollars using the official exchange rate, issued by the Brazilian Central Bank (in purchasing operations), which was R$ 3.1914/US$, annual average for 2018 (Ipeadata, 2019).

3 Results and Discussion

3.1 Relative decoupling of emissions and economic performance

The timeline in Table 4 hhighlights that the total number of cows, particularly lactating cows, in a typical farm of Leopoldina increases significantly, once it faces an evolution toward a more intensive production system, given by Scenario B. The typical farm had 37 lactating cows

[7] The third Brazilian inventory for emissions and removals presents a set of equations applied to calculate the intake of gross energy (MJ/head/day) by bovines (MCTI; EMBRAPA, 2015), which were considered here, together with the zoo technical indicators from Cepea/CNA panel and experts consultation, in order to estimate the cows emissions in a typical dairy farm of Leopoldina.

(first birth and multiparas) in 2018, reaching 60 lactating cows in 2022 in Scenario B; and the herd jumped from 123 heads to 186 heads, in 2022, keeping this level until 2030.

Obviously, a larger herd emits more tCO2e by enteric fermentation and manure management in Scenario B, than the herd kept in baseline; although the ratio of CO_2e emissions per litre of milk decreased. Thus, it is noteworthy that when the feed diet enhances in the typical farm, the intensity of emissions reduces, even the absolute emissions augment. This finding is relevant in the scope of the public policy discussion regarding the need to mitigate or reduce emissions from bovines, and notably because it has been verified for farming conditions of very low productivity.

Most importantly, considering the same type of animal (*Girolando*), it was economically feasible to augment milk production, raising the daily average from 8 litres per cow in lactation (Scenario A) to 20 litres in the Scenario B. In the baseline, the emission per litre of milk standed constant on 0.0016 tCO2e, while the relative emission coefficient in Scenario B (Abatement) dropped to 0.0008 tCO2e per litre, half of the initial amount and the baseline projection.

Therefore, the improvement of feed diets, pointed by the specialized literature as a tool to mitigate GHG emissions from enteric fermentation, can contribute to a relative decouple of dairy production in terms of climate change effects. Figure 1 shows the comparison between results of Scenario B and Scenario A. It is given by the difference between the two of them, in annual variation of total emissions and relative emissions/litre of milk. Despite an increase of almost 100% in the volume of emissions, the milk production increased as well, by 351% along the 13 years. Consequently, the intensity of emissions per litre of milk decreased, confirming that providing more balanced feed for bovines can turn the system more environmental-friendly.

This result is better understood and a wider public policy application when examined jointly with the economic outcomes resulting from the simulated scenarios, and specifically those found when Scenario B runs comparatively to the baseline. The base year is 2018 also for the economic and financial variables. Costs of production in Scenario B are higher than costs of production kept in baseline.

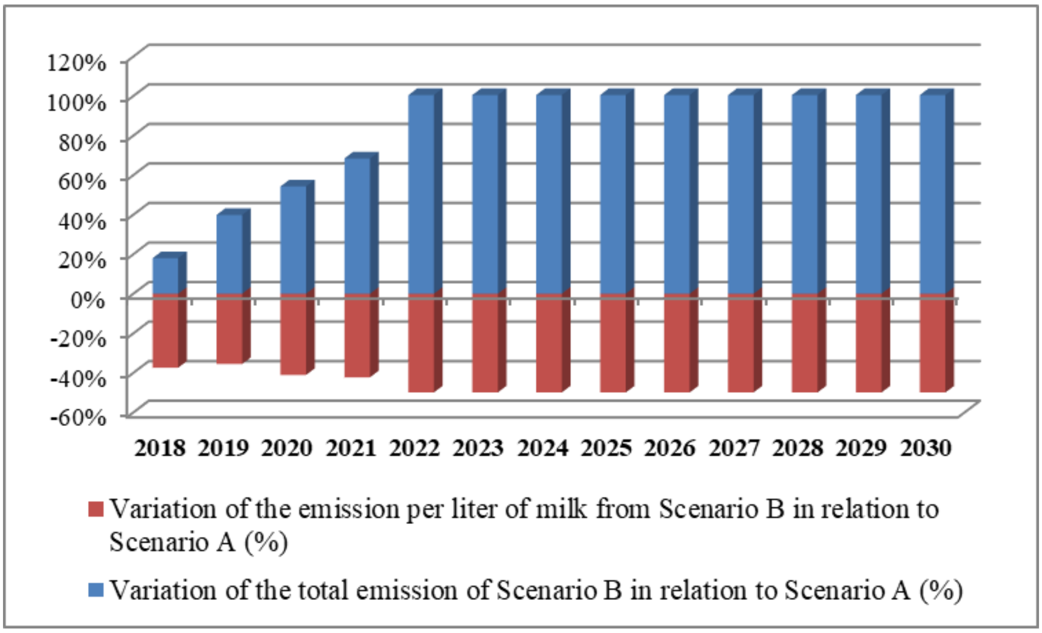

Figure 1- Percentage difference between total emissions and between relative emissions (tCO2e/litre of milk) in Scenario B (Abatement) and Scenario A (Baseline). Typical dairy farm - Leopoldina/MG. Projection: 2018-2030

Source: estimated results.

However, the new diet for the dairy cattle boosted production of lactating cows, and augmented the size of herd, which resulted from reduced mortality rate, reduced intervals between birth, and other improvements in zoo technical coefficients. As a result, the revenues mounted in Scenario B, due to increases in milk and animal sales and manure commercialization. Several financial indicators upgraded in Scenario B due to the investments to supply better feed for the cattle. Annex I details these indicators.

The economic performance of the dairy farm is clearly superior in Scenario B compared to that in Scenario A. For instance, the profit of the dairy farm increased from a negative value of US$31,910.23 (R$ 116,587.21) to a positive balance of US$10,899.92 (R$ 39,823.93), computed the total costs. The capital remuneration jumped from a negative rate of 4.2% to 7.6%, after 2022.

Regarding the annual costs of the dairy farm, they gradually increase in Scenario B, reaching US$127,243.52 (R$ 464.896,94) in 2022, a value 228% higher than the annual cost for the dairy farm in the baseline, which amounted to US$55,929.03 (R$ 204.342,30. Figure 2 presents the percentage difference between the total production cost in the typical farm for Scenario B and baseline. It also depicts the percentage difference between the costs per litre of milk between the two compared situations. It is also noticeable positive impacts on the zoo technical coefficients since the very beginning of the technological changes and the investments. One example is volume of milk produced per lactating cow still in the first year.

The significant increase of cows´ productivity in Scenario B explains the behaviour shown by the red bars in Figure 2. Despite the total costs arose more than 128% in Scenario B compared to Scenario A, along the whole period, the costs per litre dropped by 35%.

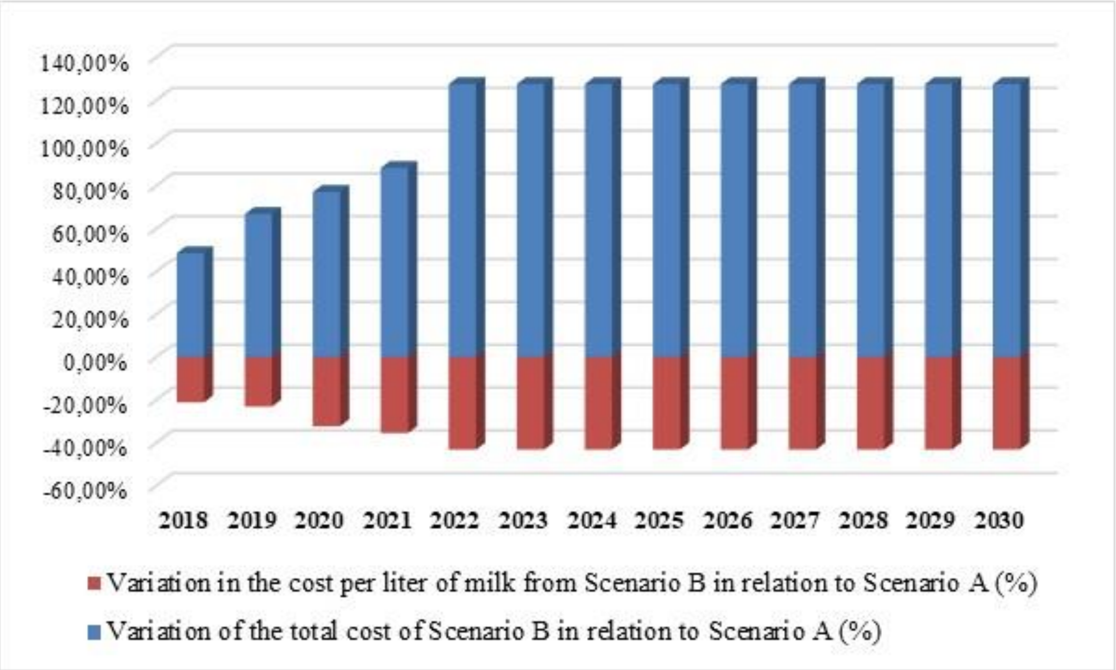

Figure 2. Percentage difference between the total cost and cost per litre of milk comparing Scenario B with Scenario A. Typical dairy farm – Leopoldina/MG. Projection: 2018- 2030

Source: estimated results.

Annex II describes the main costs and their pathway along the 13 years for the Scenario computing feed diet improvements and the related investments. While in the baseline, the main item in the total cost was the labour hired to work with the animals (US$14,642.54/year or R$ 53,498.00/year in real values for 2018), followed by the expenditure with concentrate (US$13,523.65/year or R$ 49,410.00/year). On the other hand, in Scenario B, once the costs of production stabilise (along 2022-2030), the concentrate becomes the major cost item to produce milk in the farm, accounting for 39% of COT (US$50,081.91/year or R$ 182,979.27/year).

There is a significant increase of annual revenue in Scenario B, which achieved the amount of US$161,739.74 or R$ 590.932,33 in 2022 and stabilised for the rest of timeline. It is roughly 399.5% above the annual revenue obtained in Scenario A (US$40,485.64/year or R$ 147.918,33/year). Figure 3 highlights the gap between the two scenarios.

Another interesting comment to make about the changes promoted by the adoption of an optimal feed diet relates to revenue gains with the commercialization of other products derived from dairy activity – specifically of live animals and manure.

Thus, another differential took in consideration in Scenario B, is the additional revenue due to manure sales, estimated around US$12,587.58 or R$ 45,990.00, annually, after 2022. In Scenario A, 15% of revenues came from animal sales and 85%, essentially, from milk sales. In Scenario B, the share in the farm total revenues were 86% from milk sales, 6% from animal sales and 8% from manure sales.

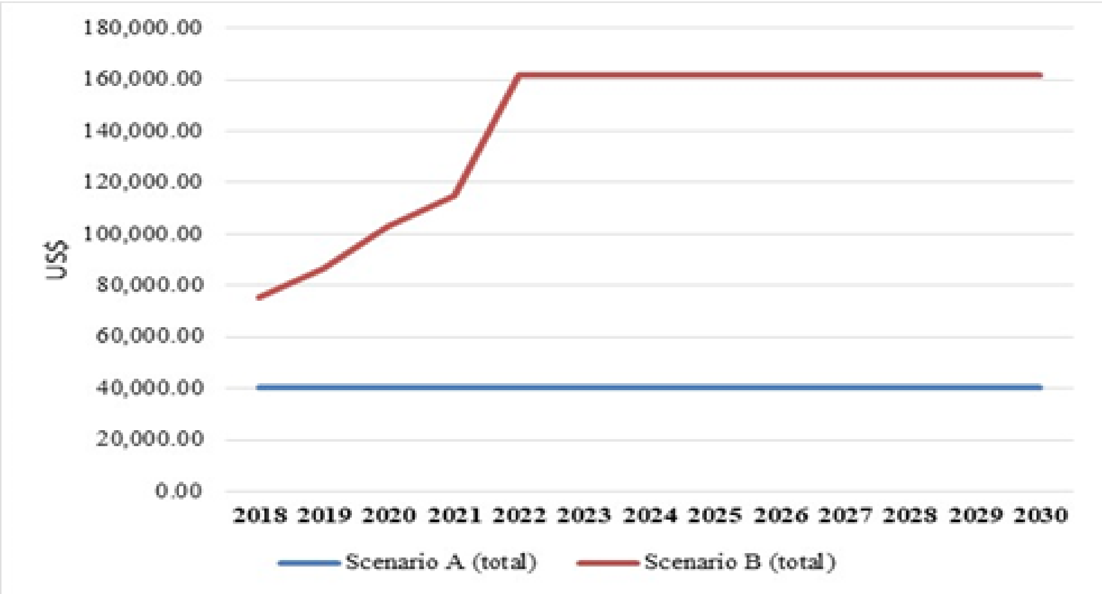

Figure 3. Revenues obtained in Scenarios A and B. Typical dairy farm - Leopoldina/MG. Projection: 2018-2030.

Source: estimated results.

3.2. The Marginal Abatement Cost Curves for changes in feed diet in a low technology dairy farm

Figure 4 and Table 5 present the results for the Marginal Abatement Cost. For 2018 and 2019, the negative results for the abatement costs mean a favourable situation, once this kind of outcome usually would underline that the adoption of the technology could be generating positive profits in those years. However, by examining data, it is remarkable that during these two years, the investments required to implement the less carbon-intensive technology (the optimal feed diet) were high compared to revenues obtained and that, in addition, the livestock increases in total and in lactating cows. Therefore, the emissions rise faster in Scenario B than in Scenario A, as well as do the cost, and that difference was not enough compensated by the increasing revenues by that moment.

On the other hand, from 2020 to 2030, although the GHG emissions increased (because the number of animal augments[8]), the marginal abatement costs decreased, due to revenues that

[8] Another factor pushing up the emissions relates to animals consuming more feed, which generates more emissions via enteric fermentation and manure disposal. The methodology for carbon inventory allows

started reacting as milk productivity enhances and healthier animals are available to be sold than in Scenario A. In fact, in 2022, the revenue in Scenario B reached a variation of 399.5% in relation to the annual revenue obtained in the baseline, where the dairy farm maintained "business as usual".

Table 5- Estimation components of the Marginal Abatement Costs of an optimal feed diet adopted by the typical dairy farm of Leopoldina – MG. In US$ constant for 2018. Projection: 2018-2030

Variable	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	2024
ANCn B	24,244.70	21,010.56	9,964.58	4,967.39	-11,376.88	-10,157.92	-9,069.58
ANCn A	15,443.39	13,788.74	12,311.38	10,992.30	9,814.55	8,762.99	7,824.10
AEn A	49.22	49.22	49.22	49.22	49.22	49.22	49.22
AEn B	58.07	68.83	75.93	82.87	98.67	98.67	98.67
ACn	-272.31	-100.82	24.05	49.00	117.31	104.74	93.52
Variable	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**Total Cost of Abatement or Emissions (2018-2030)**
ANCn B	-8,097.84	-7,230.21	-6,455.54	-5,763.88	-5,146.32	-4,594.93	**-7,705.87**
ANCn A	6,985.81	6,237.33	5,569.04	4,972.36	4,439.61	3,963.93	**111,105.53**
AEn A	49.22	49.22	49.22	49.22	49.22	49.22	**639.88**
AEn B	98.67	98.67	98.67	98.67	98.67	98.67	**1,173.69**
ACn	83.50	74.55	66.56	59.43	53.06	47.38	**60.92**

Notes: AC =Cost for the abatement technology of GHG emissions; ANC = annual net cost of the abatement technology; and AE = annual emissions of GHG.
Source: estimated results.

The marginal abatement cost depicted in Figure 4, year by year, shows positive values for most of the projection period analysed. Thus, the adoption of the new feed diet caused an increase of herd, productivity gains per lactating cow, but also caused more emissions. By summing up all the abatement costs along the 13 years, the final abatement cost for the diet improvement in the dairy farm resulted in a positive amount of US$ 60.92, in constant values of 2018.

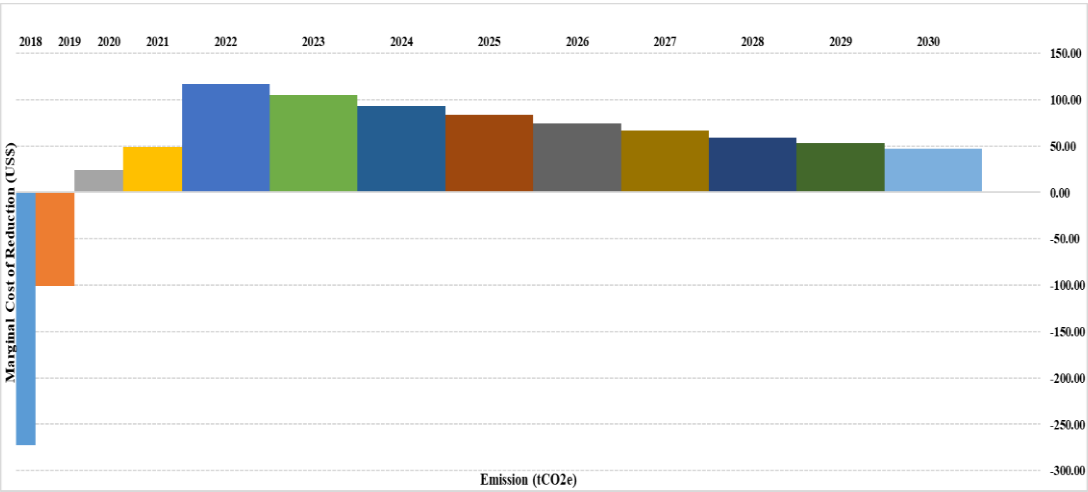

Figure 4. Annual Marginal Abatement Cost Curve for a typical dairy farm of Leopoldina/MG, Brazil. Projection: 2018-2030. In real dollar values of 2018

Source: Estimated results.

The expectation is that this kind of mitigation measure is still cheaper than others available, cited by literature. Among them, we have pasture breeding, pasture recovery, animal

measuring the impacts of changes in feed consumption, by considering the increase in milk productivity per lactating cow in Scenario B compared to Scenario A.

breeding, and confinement system, which will be further examined in this research. In addition, it is very important to ponder that feed diet improvements seem to be economically more reachable at a first sight, for thousand hundreds farmers, than those above mentioned. In Brazil, not only in Minas Gerais state, there a huge number of small and medium scale dairy farmers who also present a low technology level as the one represented by the typical farm of Leopoldina/MG.

This paper also proposes to present the MACC for the relative emissions per litre of milk, in order to highlight the improvements in the production system, originated from the adoption of a better feeding technology. This technology expressed by the change to an optimal diet, although increased the absolute emissions, it also allowed for diminishing the relative intensity of GHG emissions in dairy production. This outcome is an indicator of relative decoupling in that dairy activity.

Table 6 and Figure 5 highlight negative marginal abatement costs, meaning that the optimal feed diet implemented is a tool to reduce emissions per litre of milk produced, while simultaneously drops the cost per litre of milk itself. The consolidated abatement cost, for the whole period 2018 to 2030, totalized roughly a negative amount of R$ 371.3 per litre of milk.

Tabela 6. Disaggregated results of components for the model to build the MACC per litre of milk. Typical dairy farm - Leopoldina/MG. In US$ of 2018. Projection: 2018-2030

Variável	2018	2019	2020	2021	2022	2023	2024
ANCn B	0.1176	0.0886	0.0348	0.0156	-0.0260	-0.0232	-0.0207
ANCn A	0.1410	0.1259	0.1124	0.1004	0.0896	0.0800	0.0715
AEn A	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004
AEn B	0.0003	0.0003	0.0003	0.0003	0.0002	0.0002	0.0002
ACn	-38.2529	-64.1568	-115.1994	-122.1872	-141.0979	-125.9803	-112.4824

Variável	2025	2026	2027	2028	2029	2030	Abatement cost in US$/ltr (2018-2030)
ANCn B	-0.0185	-0.0165	-0.0147	-0.0132	-0.0117	-0.0105	**-0.0015**
ANCn A	0.0638	0.0570	0.0509	0.0454	0.0405	0.0362	**0.0781**
AEn A	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	**0.0004**
AEn B	0.0002	0.0002	0.0002	0.0002	0.0002	0.0002	**0.0002**
ACn	-100.4307	-89.6703	-80.0627	-71.4846	-63.8255	-56.9871	**-101.6241**

Notes: AC =Abatement cost for the abatement technology of GHG emissions; ANC = annual net cost of the abatement technology; and AE = annual emissions of GHG

Source: Estimated results.

The main factor contributing to the negative marginal abatement cost is the boosting cow productivity. While in Scenario A, the daily average milk production per lactating cow was 8 litres, in Scenario B, after 2022 the cows reached a productivity of 20 litres per day.

The results found by simulating the adoption of an optimal diet for dairy cattle in a typical farm, small scale, characterized by low technology and poor zoo technical performance, are very interesting. This is true, particularly under the perspective of providing information to help policy makers by the moment they decide to establish a carbon pricing policy or another policy intervention to promote the emissions reduction in the livestock sector.

As previously mentioned, this is a relevant topic, regarding an important sector for Brazilian agribusiness, and that faces many challenges to accomplish to the targets that Brazil has assumed in the Paris Agreement. There is also a social aspect, concerned to the presence of small-scale dairy producers, showing a very low productivity and far from catching up with the best technology for milk production. They are located all over the country, as well as the high technology producers, and their presence increase the technical, economic and political challenges to the implementation of future and tougher policies targeting the reduction of GHG emissions in agriculture and livestock sector.

Brazil has a program - the ABC (Agriculture of Low Carbon Emissions), which established some goals such as recovery of degraded pastures, manure treatment, forest plantation and the consortium of agriculture –livestock and forest, to pursue more balanced production systems for agricultural and livestock sectors. In order to promote this Program, the agricultural policy provides official support, through credit lines offered at low interest rates, for technical projects to implement those measures. However, this program still faces operational difficulties that restrict the scope of the ABC adoption and effective implementation and monitoring. Despite these difficulties, the ABC can show synergy with future policies to reduce the GHG emissions in this sector, as underlined by Margulis and Miranda (2018).

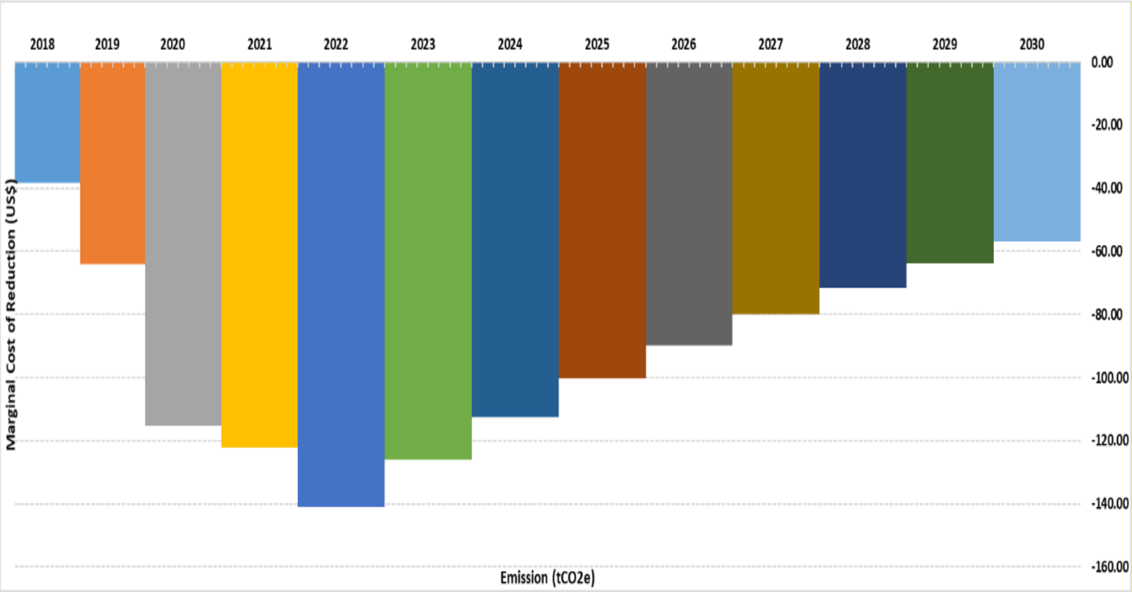

Figure 5. MACC per litre of milk for Scenario B. Typical dairy farm. Leopoldina/MG. In US$ real values of 2018. Projection: 2018-2030
Source: Estimated results.

Kimura and Santos (2016) studied the mitigation of GHG emissions through the recovery of degraded pastures, considering financial resources provided by the credit line of the ABC Program. The authors applied the technological MACCs, and also found negative abatement costs for that mitigation measure examined (Kimura; Santos, 2016).

McKinsey & Company (2009) concentrated on discussing the potential of adopting measures to mitigate GHG emissions, for 21 countries, and it highlighted the specific case of Brazil, regarding some measures that could be implemented to reduce emissions in cattle production. That study pointed measures such as: the management of nutrients in pastures, investments in research to the development of an anti-methane vaccine, use of breeding for grasses as well as the addition of feed supplements for the animals. Thus, the choice of simulating Scenario B, based on the implementation of an optimal feeding diet was comprised in that list of mitigation options.

The report of the World Bank examines all the Brazilian sectors that show potentiality to implement mitigation measures. In order to that, the World Bank applied the technological approach to build the Curves of Marginal Cost of Abatement (MACCs). They also found some negative marginal costs for mitigation measures accessible to the cattle sector. Negative costs were found for technologies that make the production systems more intensive, for instance, the adoption of optimal feed diets that require semi-intensive production systems (Couto; Castro; Motta, 2011).

Silva et. al (2015) also estimated the marginal costs of abatement using the technological approach, analyzing the case of livestock, in the Brazilian savanna bioma, evaluating mitigation strategies and comparing their results. The authors also chose mitigation measures related to feed management, such as the use of mineral and protein supplements; pastures recovery, feedlots implementation and the use of soil nitrification inhibitors.

4 Final Comments

This paper reports some partial results of a broad study that aims to obtain the MACCs for some technologies already available to the adoption by the dairy sector and that are expected to contribute to the reduction of bovines´ emissions in Brazil. When we analyze studies focused on the estimation of MACCs for the livestock sector in Brazil, the McKinsey & Company (2009) and the World Bank report (Banco Mundial, 2010) emerge as some of the most relevant.

However, most of that literature focuses on the beef cattle sector, which is, indeed, the most important sector in terms of agriculture and livestock emissions category. We hardly found literature specifically treating the dairy cattle estimations related to GHG mitigation in Brazil. Thereby, the current study intends to contribute to that literature.

Similar to the mentioned literature about the mitigation options for cattle sector, this research showed that the adoption of tools to mitigate the emissions of Greenhouse Gases, while being less carbon intensive, they are simultaneously making the production system more intensive, and, therefore more economically efficient. This finding is very convenient in the sense that farmers could realize that adopting this kind of technology perceived as less carbon intensive also brings them better economic and financial results.

Thus, this study shows that considering the scope 1 in the emissions inventory (which comprises emissions originated from manure disposal and enteric fermentation), there is space to intensify milk production in some dairy farms, providing potential to reduce the number of farms in the dairy business. This means that there is room to reduce GHG emissions in Brazil per unit of milk produced. The simulation of adopting an optimal feed diet for lactation cows pointed that emissions could drop by 50%, resulting in negative abatement costs for such a mitigation measure. Moreover, the financial results for dairy farmers showed to be very favorable toward the technological change.

Ongoing research is also assessing the other mitigation measures listed in the literature, and by applying the MACC technological approach, for dairy cattle sector and for different Brazilian regions. Despite the main goal is to support the environmental debate, specifically in regards of the feasibility to comply with the Paris Agreement commitments, there are other relevant aspects, with great synergies with the environmental policy. For the livestock sector in Brazil, there are many opportunities to enhance cattle productivity and the economic sustainability of low-technology production systems. Thus, our findings support that agricultural policy and environmental policy may benefit from the same technological improvements on the production systems. This is an important message for farmers and environmentalists, as well as for policy makers.

5 Bibliography

ANUALPEC (2015) *Anuário da Pecuária Brasileira*. São Paulo: Informa Economics / FNP – Consultoria e Agroinformativos.

AZEVEDO, T. R. AND ANGELO, C. (2018) *Emissões de GEE no Brasil e suas implicações para políticas públicas e a contribuição brasileira para o Acordo de Paris*. Available at: http://seeg.eco.br/wp-content/uploads/2018/08/Relatorios-SEEG-2018-Sintese-FINAL-v1.pdf (Accessed: August 24, 2018).

BANCO MUNDIAL (2010) *Estudo de Baixo Carbono para o Brasil*. Washington: The World Bank.

BARROS, G. S. de C. (2017) *PIB Cadeias do Agronegócio*. Piracicaba. Available at: https://www.cepea.esalq.usp.br/upload/kceditor/files/Relatorio PIBAGRO Cadeias_1_sem_2017_.pdf (Accessed: September 2, 2018).

BÖHRINGER, C. AND VOGT, C. (2003) "Economic and environmental impacts of the Kyoto Protocol," *Canadian Journal of Economics/Revue canadienne d'économique*, 36(2). Available at: http://dx.doi.org/10.1111/1540-5982.t01-1-00010.

CHICHILNISKY, G. AND HEAL, G. (1994) "Who should abate carbon emissions? An international viewpoint," *Economics Letters*, 44, pp. 443–449. Available at: https://ac.els-cdn.com/0165176594901198/1-s2.0-0165176594901198-main.pdf?_tid=0638613c-fc93-11e7-a511-00000aacb362&acdnat=1516309585_de685be8a016171509fc969f34b8a927 (Accessed: January 18, 2018).

DIAS-FILHO, M. B. (2011) "Os desafios da produção animal em pastagens na fronteira agrícola brasileira Challenges of animal production in pastures in the Brazilian agricultural frontier," *Revista Brasileira de Zootecnia*, 40, pp. 243–252. Available at: https://www.researchgate.net/publication/261025809 (Accessed: February 1, 2018).

FGV (2016) *Intensificação da Pecuária Brasileira: seus impactos no desmatamento evitado, na produção de carne e na redução de emissões de gases de efeito estufa*. Brasília. Available at: https://bibliotecadigital.fgv.br/dspace/bitstream/handle/10438/17724/Intensificação_da_Pecuária_Brasileira_Relatório_Completo.pdf (Accessed: July 26, 2018).

IMAFLORA (2018) *Relatório SEEG 2018 - Emissões do Setor de Agropecuária*. Available at: http://seeg.eco.br/wp-content/uploads/2018/06/relatorios-SEEG-2018-agro-final-v1.pdf (Accessed: June 30, 2018).

IPEADATA (2019) "Taxa de câmbio comercial para compra: real (R$) / dólar americano (US$) - média." Available at: https://translate.google.com.br/?hl=pt-BR#view=home&op=translate&sl=auto&tl=pt&text=.

KESICKI, F. (2010) "Marginal abatement cost curves for policy making – expert-based vs. model-derived curves," in *33rd IAEE International Conference*. Rio de Janeiro. Available at: http://www.homepages.ucl.ac.uk/~ucft347/Kesicki_MACC.pdf (Accessed: January 20, 2018).

KESICKI, F. AND EKINS, P. (2012) "Marginal abatement cost curves: a call for caution," *Climate Policy*, 12, pp. 219–236. doi: 10.1080/14693062.2011.582347.

KESICKI, F. AND STRACHAN, N. (2011) "Marginal abatement cost (MAC) curves: confronting theory and practice," *Environmental Science and Policy*, 14, pp. 1195–1204. doi: 10.1016/j.envsci.2011.08.004.

MARGULIS, S. AND MIRANDA, S. H. G. (2018) *Elaboração de estudos setoriais (energia elétrica, combustíveis, indústria e agropecuária) e proposição de opções de desenho de instrumentos de precificação de carbono: Diagnóstico de Agropecuária*. Piracicaba. Available at: http://mediadrawer.gvces.com.br/pmr-brasil/original/relatorio-para-consulta-p4-agropecuaria.pdf (Accessed: July 30, 2018).

MATSUNAGA ET AL (1976) "Metodologia de custo de produção utilizado pelo IEA," *Agricultura em São Paulo*, 23, pp. 123–139.

MCKINSEY & COMPANY (2009) *Caminhos para uma economia de baixa emissão de carbono no Brasil*. São Paulo: McKinsey & Company,. Available at: http://www.mckinsey.com.br/sao_paulo/carbono.pdf.

MINISTÉRIO DO MEIO AMBIENTE (2018) *iNDC (Contribuição Nacionalmente Determinada)*. Available at: http://www.mma.gov.br/informma/item/10570-indc-contribuição-nacionalmente-determinada (Accessed: August 6, 2018).

MOTTA, R. S., COUTO, L. C. AND CASTRO, L. (2012) "Curvas de Custos Marginais de Abatimento de Gases de Efeito Estufa no Brasil: resenha e oportunidades de mitigação," *Textos pra Discussão IPEA*, 1781(1), p. 64. doi: 10.1007/s13398-014-0173-7.2.

SANTOS, K. A. (2016) *Curvas de Custos Marginais de abatimento de Gases de Efeito Estufa: oportunidades de mitigação para pecuária de corte*. Universidade Federal da Grande Dourado. Available at: http://files.ufgd.edu.br/arquivos/arquivos/78/MESTRADO-AGRONEGOCIOS/CUSTOS MARGINAIS DE ABATIMENTO DE GASES DO EFEITO ESTUFA OPORTUNIDADES DE MITIGAÇÃO PARA PECUÁRIA DE CORTE.pdf.

SANTOS, M. C. (2015) *As mudanças da bovinocultura de corte no Brasil : evidências a partir de Mato Grosso do Sul (2004 - 2015)*. Unicamp. Available at: http://repositorio.unicamp.br/jspui/handle/REPOSIP/304746 (Accessed: January 28, 2019).

SEROA DA MOTTA, R. (2011) *Climate Change in Brazil: economic, social and regulatory aspects*. Rio de Janeiro. Available at: http://www.ipea.gov.br/agencia/images/stories/PDFs/livros/livros/livro_climatechange.pdf (Accessed: January 17, 2018).

UNFCCC (2015) "Conferência das Partes - Vigésima primeira sessão - Adoção do Acordo de Paris," in. Paris: Organização das Nações Unidas. Available at: https://nacoesunidas.org/wp-content/uploads/2016/04/Acordo-de-Paris.pdf (Accessed: November 5, 2017).

USDA (2018a) *Brazil: Livestock and Products*. Available at: https://gain.fas.usda.gov/Recent GAIN Publications/Livestock and Products Semi-annual_Brasilia_Brazil_2-28-2018.pdf (Accessed: September 2, 2018).

USDA (2018b) *Livestock and Poultry: World Markets and Trade, Foreign Agricultural Service*. Available at: https://apps.fas.usda.gov/psdonline/circulars/livestock_poultry.pdf (Accessed: July 22, 2018).

Annex

Annex I – Financial Indicators of Scenarios A and B. Typical dairy farm. Leopoldina – MG. In US$ dollars (at 2018 prices) Projection: 2018-2030

Indicadores financeiros	Scenario A: 2018-2022	Scenario B: 2018	Scenario B: 2019	Scenario B: 2020	Scenario B: 2021	Scenario B: 2022-2030
Gross annual margin (RB-COE) (US$)	-4,314.13	7,050.60	7,667.66	18,699.93	24,220.67	49,101.23
Net annual margin (RB-COT) (US$)	-15,443.39	-7,649.94	-6,937.07	4,095.19	9,615.94	34,496.49
Profit (RB-CT) (US$)	-31,910.23	-28,168.03	-28,634.88	-18,140.16	-12,985.76	10,899.91
Gross margin/Area in ha (US$)	-68.48	111.91	121.71	296.82	384.46	779.38
Gross margin/Lactating cow (US$)	-115.04	187.18	176.95	393.06	470.57	818.35
Gross margin/animal (US$)	-73.96	120.33	113.75	272.12	352.93	681.96
Net margin/hectare (US$)	-245.13	-121.43	-110.11	65.00	152.63	547.56
Net margin/lactating cow (US$)	-411.82	-203.10	-160.09	86.08	186.82	574.94
Net margin/animal (US$)	-264.74	-130.56	-102.91	59.59	140.12	479.12
Capital stock (US$)	364,265.51	420,005.93	434,499.21	440,569.29	443,549.01	453,280.56
Net margin (US$)	-15,443.39	-7,649.94	-6,937.07	4,095.19	9,615.94	34,496.49
Rate of capital return	-4.2%	-1.8%	-1.6%	0.9%	2.2%	7.6%

Source: Estimated results based on CEPEA-CNA database and experts´ consultation.

Annex II – Annual costs for the dairy farm. Scenarios A and B. Typical farm. Leopoldina – MG. In US$ real values for 2018. Projeção: 2018-2030

Total Operational Cost (COT)	Scenario A: 2018-2022 (US$)	Scenario B: 2018 (US$)	Scenario B: 2019 (US$)	Scenario B: 2020 (US$)	Scenario B: 2021 (US$)	Scenario B: 2022-2030 (US$)
Administration costs, taxes and fees	2,234.90	2,689.35	2,835.83	3,069.19	3,225.01	4,158.15
Energy and fuel	2,574.99	2,574.99	4,874.10	4,874.10	4,874.10	4,874.10
Silage (Raw material, inputs and labor)	1,970.66	6,418.33	7,518.61	7,793.68	9,169.04	13,753.56
Maintenance - Betterments	1,636.47	2,258.32	2,258.32	2,258.32	2,258.32	2,258.32
Maintenance – Machinery, implements, equipment and vehicles	748.85	2,605.38	2,605.38	2,605.38	2,605.38	2,605.38
Maintenance – Perennial forage (inputs + labor)	511.82	511.82	600.51	600.51	1,481.83	2,363.16
Veterinary producsts	2,763.44	2,763.44	2,763.44	2,786.02	2,786.02	3,149.36
Milking equipement	902.67	902.67	2,242.82	2,242.82	2,242.82	2,242.82
Artificial insemination	617.20	617.20	617.20	617.20	959.33	1,016.81
Contracted labor for handling herd	14,642.54	21,484.83	21,484.83	21,484.83	21,484.83	22,251.20
Technical assistance	985.33	985.33	985.33	985.33	985.33	985.33
Mineral supplements	1,687.24	1,909.69	2,167.43	2,367.05	2,526.65	2,898.71
Concentrate	13,523.65	22,639.59	27,744.28	32,791.66	36,129.43	50,081.91
Buildings, facilities (betterments)	1,726.84	2,397.96	2,397.96	2,397.96	2,397.96	2,397.96
Machinery, implements, equipment and vehicles	1,343.70	4,363.19	4,363.19	4,363.19	4,363.19	4,363.19
Service anima	606.71	606.71	510.91	510.91	510.91	510.91
Perennial forage	2,751.99	2,632.65	2,632.65	2,632.65	2,632.65	2,632.65
Pro labore	4,700.02	4,700.02	4,700.02	4,700.02	4,700.02	4,700.02
Total	**55,929.03**	**83,061.47**	**93,302.80**	**99,080.83**	**105,332.82**	**127,243.52**

Source: Estimated results based on CEPEA-CNA database and experts´ consultation.