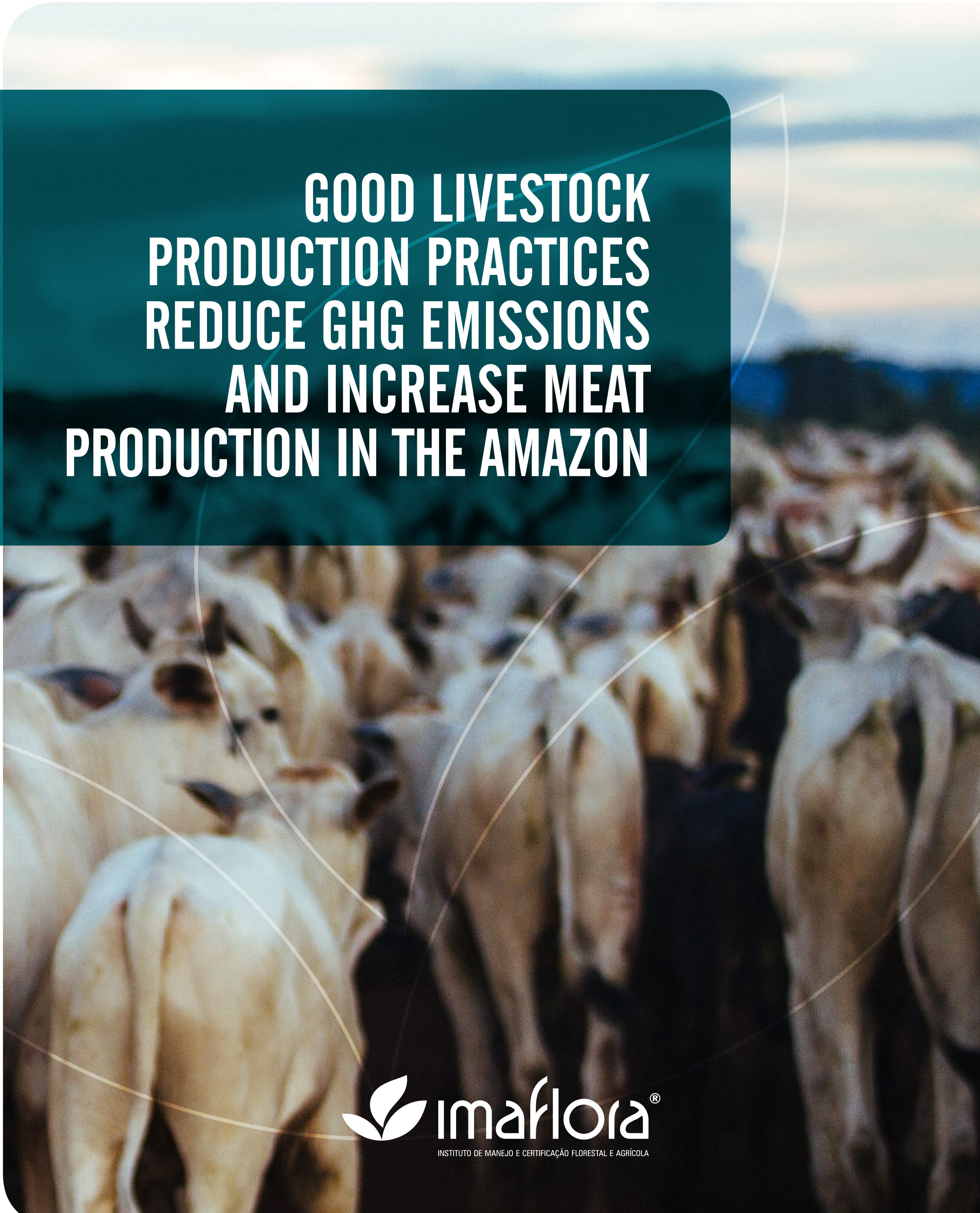
GOOD LIVESTOCK PRODUCTION PRACTICES REDUCE GHG EMISSIONS AND INCREASE MEAT PRODUCTION IN THE AMAZON



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Imaflora® *is a non-profit Brazilian organization created in 1995 to promote the conservation and sustainable use of natural resources and the generation of social benefits in forestry and agriculture sectors.*

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FOREWORD

The Brazilian agriculture/livestock sector is a major global food producer. However, it has been facing a double challenge: stepping up its production to meet the needs of a growing population and reducing greenhouse gas (GHG) emissions to mitigate global climate change.

These challenges have been on the global agenda of climate-related commitments, such as the one assumed during the 21st Conference of the Parties (COP 21) held in Paris in 2015, which culminated in the drafting of the Paris Agreement. On that occasion, the Brazilian government pledged to recover 15 million hectares of degraded pastures and to expand another 5 million hectares of integrated production systems as a strategy to reduce domestic GHG emissions by 2030.

However, there is limited evidence on how a set of Livestock Production Practices affect production efficiency and GHG emissions in Brazilian farms. imaflora has been working to fill this information gap by assessing regional initiatives under way that promote more sustainable production systems, combining production and conservation.

In this paper, imaflora presents GHG emission estimates calculated during the sustainable intensification of livestock production in the Amazon region, as applied to analyzing the Novo Campo Program being implemented in beef cattle farms in Mato Grosso state. By promoting integrated farm management, the program fosters the progressive adoption of Good Agricultural Practices - Beef Cattle (BPA, in the Brazilian acronym) developed by Embrapa and of the Guide on Sustainable Cattle Farming Indicators (GIPS, in the Brazilian acronym) developed by the Working Group on Sustainable Cattle Farming (GTPS, in the Brazilian acronym).

This analysis shows that the potential for reducing GHG emissions in farms taking part in the program will be as high as 50% per hectare and 90% per kilogram of beef produced, with a fivefold increase in beef production. During the first two *years of improvements in Livestock Production Practices in farms with a high pasture degradation rate alone, the program has already led to an increase of almost 100% in beef production and has reduced GHG emissions by 25% per hectare of pasture and by 60% per kilogram of meat produced.*

These results have been made possible by a strategy designed to recover about 10% of the pasture area of the farms taking part in the program initially. This percentage includes almost 500 of the 3,500 ha of degraded pastures covered by the program – 190 ha of which were renovated through an integrated crop-livestock (CL) system. Additionally, this strategy introduces and improves practices such as rotational grazing, animal supplementation, health and breeding techniques, and management systems to ensure the sustainability of the farms as a whole.

The assessment carried out by imaflora *shows that the strategy adopted by the Novo Campo Program has led GHG emission levels of participating farms to drop to levels similar to those recorded in other parts of the world with high production efficiency, such as New Zealand, the European Union, and the United States.*

This paper also shows the potential and capacity of beef cattle farming to reduce its GHG emissions and increase the production of animal protein and it can support farmers in adopting good practices on a large scale. At the same time, it can also help decision-makers, consumers, and other actors in the meat chain to realize the important role played by sustainable large-scale production in preventing climate change and meeting the demand for food.

The paper presented by imaflora *reinforces the consistency of the targets proposed by the Brazilian government to reduce domestic emissions. But it also draws the attention of decision-makers to the challenge of expanding technical assistance and disseminating technology to farmers. Renovating pastures will not be sufficient – it is also necessary to implement management systems that include a set of good Livestock Production Practices on a large scale in Brazil for the targets to be achieved.*

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MEAT PRODUCTION AND CLIMATE CHANGE

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IN ADDICTION to having the largest commercial beef herd in the world, Brazil is also a major beef producer, consumer, and exporter. Seventy-five percent of the current Brazilian meat production (eight million tons per year) is consumed domestically and the rest is mainly exported to countries in Europe and Asia (IBGE; ABIEC, n.d.).

With such figures, the Gross Value of Production (GVP) of meat has been estimated at R$ 70.4 billion in 2015 (second only to soybean production), meaning that beef production has become a major economic activity in the country (BRASIL, 2015a). In addition, these positions tend to remain at the same level, as beef production is projected to increase by 25% to meet the demand for meat in the coming decades (BRAZIL, 2015b).

On the other hand, beef cattle raising is also a major source of greenhouse gas (GHG) emissions from Brazil – in 2015, 274 $MtCO_2e$ were emitted by this activity. That same year, the country as a whole emitted about 1900 $MtCO_2e$, with the agricultural/livestock sector accounting for 22% of these emissions (425 $MtCO_2e$). Thus, the amount of GHG emitted by beef cattle raising alone accounts for 65% of all emissions from the agricultural/livestock sector and for 15% of the country's emissions currently (SEEG, n.d.). degradation of pasture land has also caused GHG emissions estimated at about 200 $MtCO_2e$, but these have not been accounted for in the national inventory (SEEG, 2016).

The impact of livestock farming could be reduced by enhancing the efficiency of beef production. It is estimated that meat production in Brazil can be at least doubled using existing pasture areas (STRASSBURG et al., 2014). Because their potential is not being explored as it should, grazing areas become susceptible to degradation. As a result, it is estimated that there are 40-50 million hectares of degraded pastures in Brazil today (Eduardo Assad/Embrapa-Personal Communication).

For Brazil to meet the beef demand expected for 2030 with its current productivity trends (IBGE, n.d.), it would be necessary to increase its herd by about 15% (30 million head). In this context, it is believed that only the states in the Amazon region would be able to accommodate 40% of these additional animals (BARBOSA et al., 2015). Therefore, attention has been drawn to the potential conversion of native areas and to the degradation of already established areas to accommodate these additional animals.

For these reasons, Brazilian beef production has been the focus of concerns over its current and future impact on global climate change. So much so that it has become a key topic for setting the GHG emission reduction targets presented by Brazil at the 21st Conference of the Parties (COP-21) held in Paris in 2015, a global event that resulted in the most comprehensive global climate agreement ever signed: the Paris Agreement (BRASIL, 2015c, d).

CLIMATE AGREEMENTS AND THE BRAZILIAN AGRICULTURE SECTOR

According to the decree regulating the National Policy on Climate Change - PNMC (BRASIL, 2010), Brazil voluntarily assumed a formal commitment to reduce its GHG emissions by 36.1% and 38.9% by 2020 in relation to their levels in 2005. To achieve that goal, the decree also provides for the development of Sectoral Plans with actions, indicators, and specific goals to reduce emissions, as well as mechanisms for monitoring compliance with the aim of guiding each sector on how to comply.

The sectoral plan for Agriculture is called the ABC Plan (BRASIL, 2012). It is a national plan designed to be implemented between 2010 and 2020 consisting of six programs related to mitigation technologies:

1. *Recovery of 15 million hectares of degraded pastures.*
2. *Expansion of 4 million hectares for integrated Crop-Livestock-Forestry (CLF) and Agroforestry (AF) systems.*
3. *Expansion of 8 million hectares for No-till Farming systems.*
4. *Introduction of Biological Nitrogen Fixation (BNF) in 5.5 million hectares.*
5. *Expansion of planted forests by 5.5 million hectares.*
6. *Processing of 4.4 million m^3 of animal waste.*

Meanwhile, the 21st Conference of the Parties (COP-21) of the UN Framework Convention on Climate Change, which was held in Paris in November 2015, brought together representatives of 195 countries and culminated in the drafting of the Paris Agreement. This agreement was designed to limit the increase in global average


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temperature to well below 2 degrees Celsius above pre-industrial levels. This goal is to be achieved through the joint efforts of those 195 countries, including Brazil, through its Nationally Determined Contribution (INDC).

After being ratified by President Michel Temer in September 2016, the Brazilian INCD ceased to be a claim and became a formal contribution commitment and is therefore called NDC now. The Brazilian NDC contemplates a commitment to reduce the country's emissions by 37% below 2005 levels by 2025 and subsequently to reduce these emissions by 43% below 2005 levels (2.1 GtCO^2e) by 2030 (BRASIL, 2015c, d). This means that Brazil assumed the commitment to reduce its emissions by 900 Mt CO^2e by 2030, which would result in estimated emissions of 1,200 Mt CO^2e in that year.

With regard to the agricultural sector, the Brazilian NDC is intended to strengthen the ABC Plan through the additional recovery of 15 million hectares of degraded pastures and an increase of 5 million hectares for integrated Crop-Livestock-Forestry (CLF) systems by 2030.

On that occasion, the Brazilian government, through its intended Nationally Determined Contribution (INDC), assumed the commitment to strengthen the ABC Plan (BRASIL, 2012) by recovering 15 million hectares of degraded pastures and promoting an expansion of 5 million hectares for crop-forestry integrated cattle farming systems in the country by 2030.

The Brazilian INDC was ratified in September 2016 by President Michel Temer, meaning that it is not an intention any longer and has become a formal contribution commitment. Therefore, it is now referred to as its NDC. The actions contemplated in the Brazilian NDC are intended to meet the demand for agricultural and livestock products and to keep emissions from the agricultural sector in 2030 at the same level recorded in 2005, the base year of the Brazilian NDC (BRASIL, 2015c, d).

However, there is little evidence of how a set of good practices affects GHG emissions and the production of beef cattle farms (HAVLIK et al., 2014; WOLLENBERG et al., 2016). In this context, it is necessary to evaluate actual initiatives that introduce practices based on the recovery of degraded pastures designed to enhance the efficiency of beef production in Brazil while reducing GHG emissions.

This is the case, for example, of the Novo Campo Program. Coordinated by the Centro de Vida Institute (ICV), the program was designed to promote sustainable meat production practices in cattle ranches in the Amazon region, improving their economic, social, and environmental performance. It thus contributes to reducing deforestation, to conserving or restoring natural resources, and to boosting the local economy (ICV, 2014).

The interventions promoted by the Novo Campo Program are based on the integrated management of farms with progressive adoption of Good Agricultural Practices – Beef Cattle (VALLE, 2011) developed by Embrapa and of the Guide on Sustainable Cattle Farming Indicators (GIPS) developed by the Working Group on Sustainable Cattle Farming (GTPS). Both are focused on recovering and intensifying degraded pastures, on promoting an appropriate supply of supplementation, on improving the herd's health and reproductive management, and on enhancing the environmental suitability of farms (MARCUZZO, 2015).

GOOD LIVESTOCK PRODUCTION PRACTICES DESCRIBED IN THE BPA-EMBRAPA AND GIPS-GTPS MANUALS

Good Agricultural Practices (GAP) can be defined as a set of standards and procedures to be observed with the aim of making production systems more efficient and profitable and of ensuring the supply of safe and sustainably produced food to consumer market (VALLE, 2011).

Embrapa and the Working Group on Sustainable Cattle Farming (GTPS) have developed and periodically update guides designed to disseminate good beef cattle farming practices in Brazil. These guides describe criteria and indicators for the entire production system, from farm management (environmental, social and production management) to the handling of animals and pastures.

BPA-EMBRAPA: developed by EMBRAPA since 2007, the Good Agricultural Practices - Beef Cattle (BPA) refer to a set of standards and procedures to be observed by farmers to make their production systems more profitable and competitive and to ensure the supply of safe and sustainably produced food. By adopting the GAPs, farmers can identify and control various factors that influence their production, contributing to more competitive production systems by consolidating the domestic market and creating more possibilities for entering new markets that value high-quality meat and leather (EMBRAPA, 2011).

GIPS-GTPS: the purpose of this material is to encourage all the links in the beef cattle value chain to use indicators as a tool to foster sustainability. For the GTPS, sustainability is a process of continuous improvement. These indicators are quantitative or qualitative parameters that can be evaluated according to certain criteria. In the GIPS, indicators are organized according to cumulative performance stages and criteria are defined to describe the highest level of the performance scale (GTPS, n.d.).

Embrapa
Gado de Corte

GTPS
Grupo de Trabalho da Pecuária Sustentável

During its pilot phase, implemented between 2012 and 2014 in the Alta Floresta region (Mato Grosso state) (Marcuzzo, 2015), it was seen that the interventions of the Novo Campo Program in the participating farms impacted in the following aspects.

Interventions from Novo Campo program were capable of:

- Reduce the average age of slaughter from 44 to 30 months for males and from 34 to 24 months for females;
- Increase the stocking rate from 1.2 AU/ha to 1.6 AU/ha, with stocking in the intensified areas on each farm hitting the mark of 2.7 AU/ha on average;
- Increase productivity from 4.7@/ha/year to 10.8@/ha/year on the farms, with an average of 20.8@/ha/year in intensified areas;
- Improve carcass finishing through slaughters that qualified 70% of carcasses as superior;
- Significantly increase farm profitability, from R$ 100.00/ha to R$ 680.00/ha.

As a result of the positive productive and economic results achieved by the Novo Campo Program, Imaflora estimated the impact of the sustainable intensification of cattle ranching, achieved by adopting good practices, on the assessment of the GHG emissions of the farms participating in the program. In this context, Imaflora presents the analysis of the first five farms that participated in the pilot phase of the Novo Campo Program. It also evaluates the potential impact of its strategy for the coming years and its impact on reducing emissions.

This study is expected to promote a discussion on forms of production that meet the demand for food and reduce GHG emissions and that may, ultimately, mitigate the effects of global climate change.

METHODOLOGY AND GENERAL DESCRIPTION OF THE PROGRAM

FIVE BEEF CATTLE FARMS were evaluated in this study. These farms are located in the municipality of Alta Floresta (Mato Grosso state) and were the first ones to participate in the pilot phase of the Novo Campo Program (Figure 1; Table 1; Annexes 1 and 2).

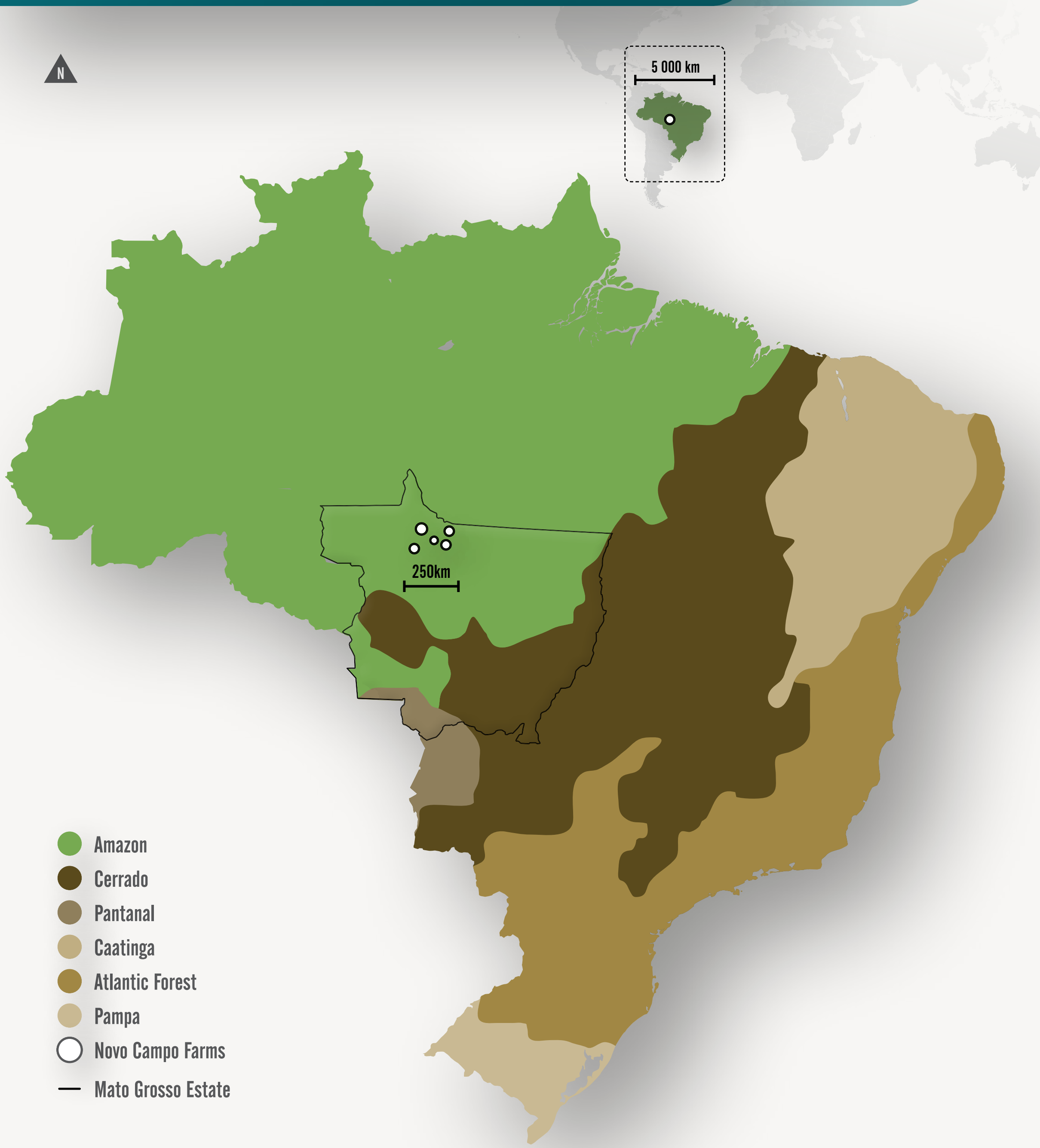
The farms are typical beef cattle ranches established in the region. After establishing their pastures by converting native Amazon vegetation from the 1980s to the 2000s, the farms didn't adopt any mechanisms for managing their production or adopted insufficient mechanisms for this purpose, such as: soil correction, rotational grazing, and reproductive control of the herd.

Thus, their pastures were established in fertile soil left by the forest and began to degrade over time. And the farms saw the efficiency of their meat production decline to levels that could jeopardize the economic feasibility of this activity (MARCUZZO, 2015).

TABLE 1: GENERAL DESCRIPTION OF PARTICIPATING FARMS WHEN THEY JOINED THE NOVO CAMPO PROGRAM FIELD IN LATE 2012

Farm	Pasture area (ha)	Average number of animals	Production system	Average meat production (kg ha^{-1} $year^{-1}$)
Bevilaqua	1400	3500	Full Cycle	79,0
Mitaju	580	1300	Full Cycle	73,2
São Matheus	550	650	Rearing - Fattening	72,4
Cinco irmãos	500	1000	Full Cycle	50,0
Paraíso	480	1100	Full Cycle	51,1

FIGURE 1: BRAZILIAN BIOMES AND LOCATION FOR THE NOVO CAMPO PROGRAM FARMS



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MEAT PRODUCTION SYSTEMS

Breeding, rearing, and fattening are the stages involved in beef cattle production. They may take place on the same farm or on separate ones.

- *<u>Breeding</u>: comprises the period from breeding until weaning.*
- *<u>Rearing</u>: comprises the period between weaning and finishing.*
- *<u>Fattening</u>: the last stage, which can take place on pasture or in confinement.*

These stages characterize the production system adopted on a certain farm (i.e. breeding farm; breeding and rearing farm; rearing and fattening farm). However, when these stages take place on the same farm, it is said that it has a full-cycle production system.

Implementation of the BPA Manual and GTPS Guide

Between 2012 and 2013, the farms joined the Novo Campo Program and began to follow the manual on Good Agricultural Practices – Beef Cattle (BPA) developed by Embrapa and the Guide on Sustainable Cattle Farming Indicators (GIPS) developed by the Working Group on Sustainable Cattle Farming (GTPS). The program has thus gradually introduced and improved practices designed to enhance the capacity of the farms to manage their pastures and animals.

One of the first steps of the program was to prepare a technical diagnosis of each farm. This diagnosis evaluated the current production and management status of each farm, identifying priority actions to raise their production levels and structure future activities with the aim of continuously improving them.

Due to the large area of degraded pastures in the region, the diagnosis of all farms evaluated in this study showed the need for pasture renovation or recovery. However, because this action has a relatively high financial cost, the Novo Campo Program found a solution: initially recovering only part of the pastures in those farms, ranging from 3 to 8% of their total area – approximately 40 hectares of pastures on average.

The renovation of these areas consisted in tillage (plowing and harrowing), liming, sowing, and applying fertilizers to the soil (urea and supertriple phosphate). The pastures were in turn recovered through the same interventions, except for soil preparation. The decision between renovating and recovering the pastures was determined by the degree of their degradation – the more degraded the pasture, the greater the need for renovating it.

Divided into plots, the recovered/renovated area was used for rotational grazing of animals during the breeding phase, at an average stocking of 3 AU per hectare. These animals were kept in each plot over a period of three to four days (until the pasture height was reduced to 90-40 cm on average). Right after that, the animals were placed in a new plot and urea (totaling 100 kg ha-1 year-1) was applied to the one in which they were kept before (MARCUZZO, 2015).

This management was associated with the introduction of other practices described in the BPA manual – Beef Cattle and in the GTPS, such as: supplementation with (corn-based) grains, installation of drinking water facilities in the pastures for protecting watercourses, and improvements in the management capacity of the farms at large and in the reproductive and health management of the herd (MARCUZZO, 2015).

FIVE KEY ACTIONS FOR SUSTAINABLE BEEF

- **Recovering degraded pastures:** as one of the main actions for sustainable beef cattle ranching, the recovery of degraded pastures allows for already deforested areas that are currently abandoned or underutilized to be reused, thus promoting productivity gains and increasing carbon sequestration in soil. One of the main advantages of recovering degraded pastures lies in the fact that it increases production and energy efficiency. Production systems established in recovered pastures can produce at least three times more meat as compared to systems established in degraded pastures. The first step for recovering pastures is to carry out a diagnosis of the farm for subsequent intervention.
- **Animal supplementation:** supplemental feeding of cattle on pasture results in better use of forage, increasing the efficiency of the entire system and contributing to the production of better quality meat, as it allows for younger animals to be slaughtered with better finishing. However, to ensure the production of good quality food, all inputs cannot contain components or residues that may pose problems for animal and human health.
- **Health management:** set of regularly planned veterinary activities designed to prevent diseases and keep the herds healthy. These actions are focused on: cleaning and sanitizing animal husbandry facilities, umbilical disinfection of newborn animals, early intake of colostrum; vaccination, worming, and acaricide bath.
- **Reproductive management:** arrangement of a set of practices designed to optimize the reproductive efficiency of the herd, especially in relation to characteristics linked to female

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reproduction. Optimization of the reproductive performance and production efficiency of the herd can be obtained through the following management practices:

a. Identification of animals and recording of events (births, abortions, deaths, etc.).
b. Choosing the estrous period.
c. Choosing the breeding system.
d. Preparation of heifers for replacement.
e. Pregnancy and disposal diagnosis.
f. Determination of the weaning age
g. Meeting nutritional requirements.
h. Health control of the herd.

- **Environmental Management:** proper management of natural resources on the farm, in accordance with environmental laws and recommended techniques for soil conservation, biodiversity, water resources, and landscape.
- **Farm Management:** meeting minimum management requirements, carrying out actions related to planning, organization, guidance, and control. Among these actions, the following ones stand out: reviewing objectives, anticipating revenues and expenses, coordinating and managing production processes, meeting legal requirements; and recording all the farm's activities and processes (social, labor, tax, health, and environmental activities and processes).

Calculating the balance of GHG emissions

Calculating tool

The GHG Agricultural Protocol's calculator (WRI, 2014) was used to assess the balance of GHG emissions from farms taking part in the Novo Campo Program before and after they joined the program. The tool was selected because it makes it possible to evaluate the main sources of GHG emissions and removal in cattle beef production systems at farm scale (COSTA JUNIOR et al., 2016): the herd, inputs applied to the soil, soil carbon variation, fossil fuel burning (Figure 2). It also has the advantage of using some emission factors that were specifically developed for specific Brazilian conditions – thus ensuring more precise results (IPCC, 2006; WRI, 2014; EMBRAPA, 2015a;b).

GHG EMISSION AND REMOVAL FACTOR AND CALCULATION OF EMISSIONS

A GHG emission (or removal) factor is the amount of GHG emitted (or removed/sequestered) in relation to the amount of consumed or processed material. Emission and removal factors are usually expressed in mass ratio (i.e. kg/kg) or percentage (%).

GHG Balance

=

Emissions (animals, waste, inputs and degraded soils)

–

Removals (well managed soils)

A system's balance of emissions comprises the sum of GHG emissions and removals (sequestration) from that system. For example, in beef cattle ranching, the GHG balance at farm scale (inside the fence) involves the sum of GHG emissions from animals and their waste plus application of inputs used (including machinery fuel) and soils under Degradation minus the GHG removed (C sequestration) from well-managed soils.

FIGURE 2: SCOPE OF ANALYSIS AND GREENHOUSE GASES EMISSION SOURCES USING THE GHG-AGRICULTURAL PROTOCOL TOOL

Regarding emission sources, the calculator estimates methane (CH_4) emissions caused by enteric fermentation and CH_4 and nitrous oxide (N_2O) emissions caused by herd waste management systems (Figure 2). These emissions are also relativized according to the age, category, and length of stay of the animals on the farms.

The GHG Agricultural Protocol also considers N_2O and CO_2 emissions caused by the application of (synthetic and organic) nitrogen fertilizers and limestone (dolomite and calcite) to soil, respectively. CO_2 emissions caused by pasture soil degradation and by the burning of fossil fuels used in machinery are also considered in the calculation. This tool also calculates CO_2 removal from the atmosphere by C sequestration in well-managed pasture soil (carbon sequestration) (Figure 2).

Finally, the tool calculates the balance (sum) of GHG emissions and removals from all sources at farm scale (Figure 2) and converts them into CO_2 equivalents (CO_2e) using Global Warming Potential (GWP) factors provided by the IPCC (1995; 2007; 2013).

The GHG balance calculated for each of the five analyzed farms was correlated with the respective production areas (GHG emissions per hectare of farm area) and beef production (GHG emissions per kg of meat produced) of these farms. The final result is presented here as a consolidated GHG balance for these five farms (their annual average). However, the GHG balance of the individual evaluations of each analyzed farm can be seen in Annex 1.

Data collection and parameterization of the calculating tool

Based on the scope of analysis considered in this paper (Figure 2), Imaflora® collected the data required for calculating GHG emissions from each of the five farms evaluated in this study during its pilot phase (2012-2014) (Annexes 1 and 2) and their potential emissions, considering a moderate intensification of pastures with the aim of promoting the full recovery of degraded areas.

Data collection in the pilot phase and the analysis of the production potential were carried out using data from the ICV database and through field visits by Imaflora® staff to the farms taking part in the program. Following this procedure, the data presented below were collected to parameterize the GHG Protocol tool used in this study (WRI, 2014):

GLOBAL WARMING POTENTIAL (GWP)

Global Warming Potential (GWP) is an estimate that standardizes the contribution from different greenhouse gases (GHG) in relation to the CO^2 gas. This estimate is necessary because each GHG has a different potential to warm the Earth when present in the atmosphere.

The IPCC sets the GWP figures be used and updated as progress is made in scientific research in this area. So far, three different GWP figures have been published in the Assessment Reports issued by the IPCC: AR2, AR4 e AR5 (IPCC, 1995; 2007; 2013).

The trend is that the most recent figures will be used globally. The GHG Agricultural Protocol's calculator (WRI, 2014) shows in its default mode the GWP figures reported in the fourth IPCC report (AR4), although users can change it to any other GWP figure. However, it should be noted that, for safe comparisons of results presented in CO_2e, it is necessary to check whether those figures were calculated using the same GWP factors.

	Assessment report		
	AR2	**AR3**	**AR5**
CO_2	1	1	1
N_2O	21	25	28
CH_4	310	298	265

Employed guidelines

1. Annual average amount of animals in the herds on the farms by category and age.
2. Annual average amount of urea, limestone, and fossil fuels used for pasture maintenance purposes.
3. Degraded and well-managed (renovated or recovered) pasture area.

As described, the data were analyzed annually; however, to prevent non-specific yearly soil liming interventions from causing emission peaks in the average results, these figures were processed as follows:

The amount of lime commonly used in a year in the same area was divided by 60 – which corresponds to five years (60 months), the average period of time between soil liming operations – and the resulting figure was relatively allocated to the months of the years of analysis.

Another detail that was taken into account in calculating the balance of GHG emissions from the production system refers to the condition of the pastures on the farms. Based on conversations with the farm owners and technical experts of the program, it was understood and assumed that:

Pasture conditions

- 100% of the pasture areas were moderately degraded (IPCC, 2006)
- non-recovered/renovated areas would continue to degrade, meaning that their status would shift from moderately to severely degraded (IPCC, 2006);
- Recovered/renovated areas shifted from the status of moderately degraded to an improved level by applying inputs to them (IPCC, 2006)

To keep the analysis at farm level, GHG emissions caused by the production of raw materials and manufacture of animal supplements and transportation (including of the animals) were not accounted for in this paper. However, it is recognized that these activities can be major sources of emissions and that they should be evaluated in future studies.

PILOT PHASE ANALYSIS AND PROGRAM POTENTIAL

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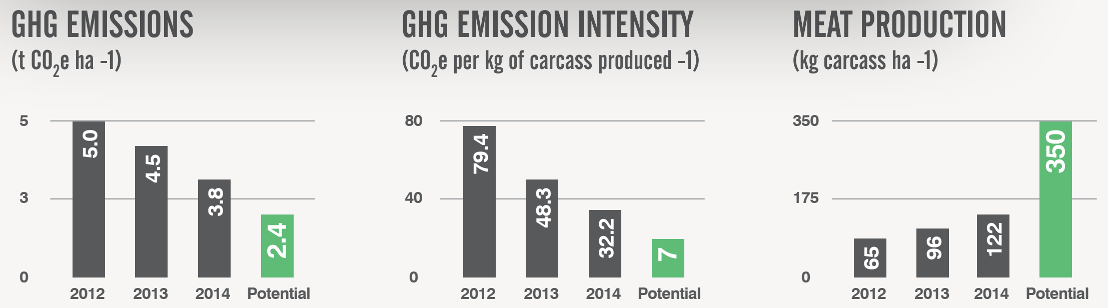
IN THE EARLY stages of this project, the first five farms taking part in the Novo Campo Program occupied a total area of 3,500 ha and had a 7,500-head herd. With predominantly degraded pastures and poor animal management, these farms produced about 70 kg of carcass (4.7@) per hectare annually - Table 1; Figure 3).

Under these conditions, the average level of GHG emissions from these farms was 5.0 tCO_2e/ha-1 a year and 79.4 kg of CO_2e per kg of meat produced (Figure 3). About 60% of these emissions were caused by the herd and 40% by soil degradation (Figure 4). Both the productive and environmental indices are seen as low performance indices as compared to the potential of this activity (CROSSON et al., 2011; BARBOSA et al., 2015; CARDOSO et al., 2016).

The results for 2012, before the start of the project, were mainly determined by extensive production systems with low investment in a management system and in leading production systems appropriately. For lack of a strategy, the farms were not managing pastures, were not providing supplementary feeding to the herd, and were not managing the reproduction of their animals properly. Therefore, the pasture areas on the farms were undergoing degradation and the production efficiency of the herds was on the decline.

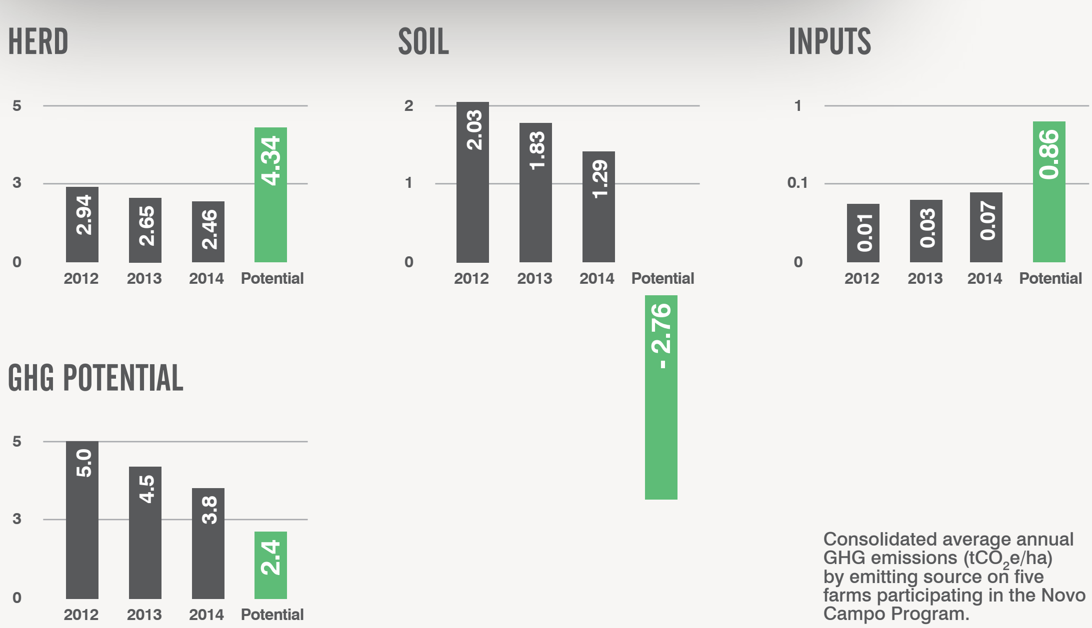
FIGURE 3: GHG EMISSION AND AVERAGE PRODUCTION ON FIVE PARTICIPATING FARMS



Pasture degradation can be defined as the process of loss in vigor, productivity, and natural recovery capacity of pastures, making them incapable of sustaining the production and quality levels required by the animals and of overcoming the harmful effects of pests, diseases, and weeds (MACEDO, 1995).

As a result, the animals are not treated as they should and the quantity and quality of the feed they are given are insufficient to ensure their healthy development and it thus takes longer for them to reach the appropriate weight for slaughter. Thus, animals in the herd become older, worsening the productive and environmental situation of the farms, since these animals are less efficient in gaining weight and therefore emit higher amounts of GHG per amount of food intake as compared to younger animals – especially during the dry season, when the supply of pastures is lower than during the rainy season.

FIGURE 4: GHG EMISSIONS (t CO_2 e / ha) ON FIVE PARTICIPATING FARMS



Consolidated average annual GHG emissions (tCO_2e/ha) by emitting source on five farms participating in the Novo Campo Program.

For this reason, one of the first interventions during the pilot phase of the Novo Campo Program was intended to improve the condition of pastures. During that phase, the farms taking part in the program recovered and renovated 13% of the area of degraded pastures covered by the program (453 ha of degraded pastures), in 190 ha of which this was done through crop-livestock integration (succession with soybean and corn; see the 5 Irmãos Farm - Annex 1).

With sufficient food production for raising the animals in terms of both quantity and quality, these renovated and recovered areas were used for rotational grazing of the herd. In addition, complementary good agricultural practices began to be progressively adopted on the farms – as defined in the BPA and GIPS manuals, which are based on animal supplementation, improvements in the reproductive and health management of the herd, and better farm management.

CARBON SEQUESTRATION IN SOIL

Carbon sequestration can be defined as the capture and storage of carbon from the atmosphere. In pastures, carbon storage in soil begins with the fixation of CO_2 from the atmosphere in forage through photosynthesis. Subsequently, the residues from this forage are decomposed by soil microorganisms and a part of it is stored in the soil organic matter (55% of C), while another part returns to the atmosphere as CO_2. A cycle is thus formed where the amount of organic matter is in equilibrium due to the balance between consumption and fixation of the carbon contained in the vegetal residues.

Pastures influence this cycle according to the management approach adopted. Pastures under Degradation due to tramping, overgrazing, or termite infestations tend to produce less forage, which reduces the entry of carbon into the soil and, consequently, they cannot maintain the same levels of organic matter – and as a result they end up emitting more CO_2 than they can sequester. In addition, other processes resulting from soil Degradation, such as erosion, also contribute to reducing carbon levels in the soil.

On the other hand, well-managed pastures produce enough forage to maintain or increase

Continues on the following page...

their levels of organic matter in soil. Additionally, increases in organic matter lead to improved soil conservation and fertility. However, there is a period of accumulation of carbon in soil estimated at 20 years (if sustainable management practices are applied during this period), after which this carbon stock reaches a balance (IPCC, 2006).

Supplementation of cattle is mainly instrumental to conserve pastures and improve animal nutrition by ensuring adequate food to the herd during the dry season (when there is insufficient forage in the pastures), making it possible to slaughter younger animals with improved carcass finishing. While health management consists of a set of regularly planned veterinary activities designed to prevent diseases and keep the herd healthy, reproductive management consists in adopting practices intended to optimize the reproductive efficiency of the herd that are mainly related to female reproduction. Finally, the improvements in farm management referred to here are intended to improve farm planning, organization, direction, and control (VALLE, 2011).

This set of practices made it possible to gradually improve production efficiency on the farms and, two years after good agricultural practices were adopted, their average meat production had risen by 85% and their GHG emissions had declined by 25% per hectare. Thus, GHG emissions per kilogram of carcass produced on the farms were reduced by 60% (Figure 3).

The reduction in emissions was a direct effect of adjustments in the herd by reducing animal slaughter time (by at least six months – due to a higher food supply and conversion efficiency) and identifying and disposing of older and more inefficient animals. And also by reducing pasture degradation rates. As a result of adopting these practices, emissions from animals were reduced by 15%, while carbon sequestration in soil in renovated and recovered pasture areas decreased GHG emissions caused by degradation by 35% over this period, despite an increase in emissions from applying and using inputs such as urea and Diesel oil oil to maintain the renovated area (Figure 4).

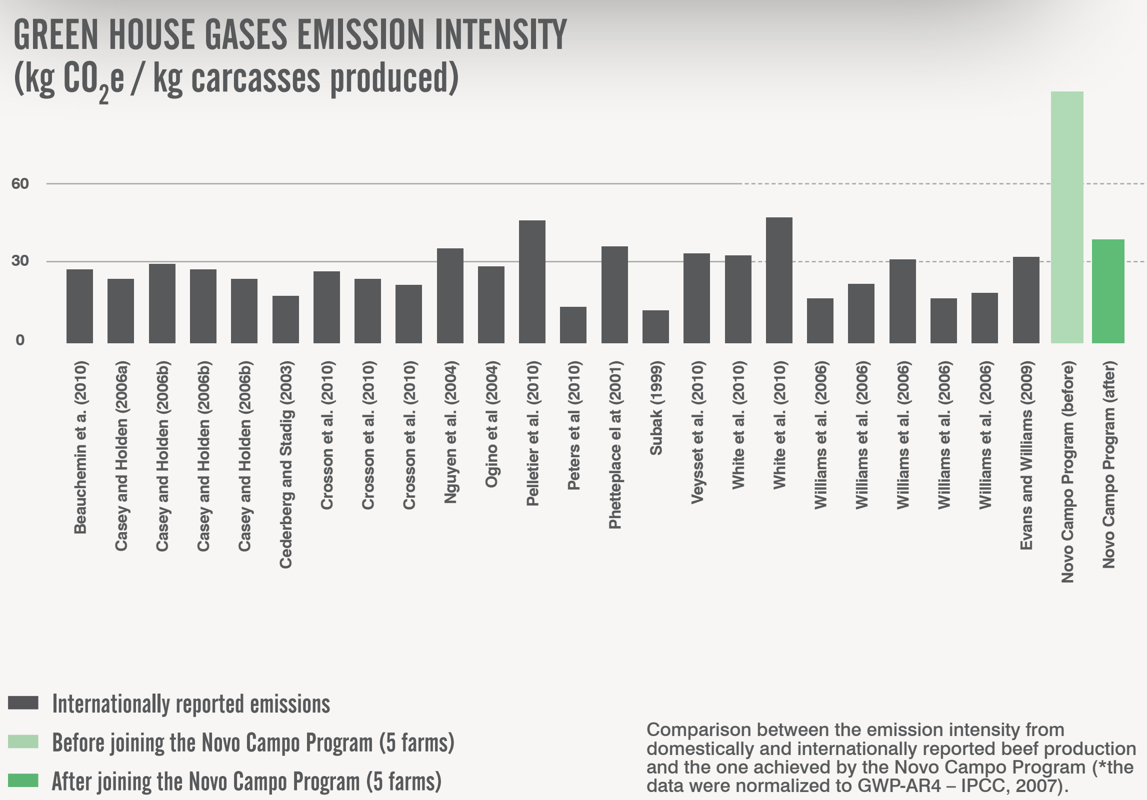
INTEGRATED CROP, LIVESTOCK AND FORESTRY SYSTEMS

Integration systems involve the production of grains, fiber, wood, energy, milk, or meat in the same area in rotational crops, intercropping, and/or succession crops. The system basically comprises growing, during the summer, annual crops (rice, beans, corn, soybeans or sorghum) and trees associated with forage species (brachiaria or panicum). There are several possibilities for combining agricultural, livestock, and forestry components, considering the available space and time, resulting in different integrated systems such as Crop-Livestock-Forestry (CLF), Crop-Livestock (CL), Silvopastoral (SP), or Agroforestry (AF) systems. This technological solution was developed by Embrapa in partnership with other institutions.

The CL system, for example, consists in growing a grain (e.g. maize) and forage simultaneously or sowing a forage crop 30 days after the grain germinates with the aim of producing grains in the summer and pasture during the dry season. Basically, maize plants grow faster and shadow the grass, slowing down its growth. However, after the maize is harvested, sunlight penetrates into the canopy of the crop and reaches the grass plants, which begin to grow and produce new leaves, forming high-quality forage for grazing in winter.

With such emission levels, the farms are close to the levels emitted by efficient production systems established in other major beef-producing countries (Figure 5). This suggests that, apart from increasing beef production with low greenhouse gas emissions, the production strategy adopted by the Novo Campo Program can also ensure a better positioning of Brazilian beef in the global scenario.

FIGURE 5. COMPARISON BETWEEN THE EMISSION INTENSITY OF CATTLE MEAT PRODUCTION



Comparison between the emission intensity from domestically and internationally reported beef production and the one achieved by the Novo Campo Program (*the data were normalized to GWP-AR4 – IPCC, 2007).

HERD ADJUSTMENTS

Less efficient meat production systems tend to have low offtake rates (proportion of animals slaughtered in relation to the total herd). This inefficiency is caused by several factors, such as insufficient food supply or poor herd management (i.e. poor health and reproductive management). However, with the same birth rate, a low slaughter rate leads to a "damming" of cattle on the farm. Therefore, as a production system becomes more efficient, birth and slaughter rates tend to become more balanced, adjusting the herd to the new condition. As a result, a farm can produce more meat and increase its profitability with less animals.

Potential of the Novo Campo Program – Sustainable pasture intensification

Recent developments in the Novo Campo Program indicate that it promoted substantial improvements in the production and environmental indexes of the farms taking part in it and that it stimulated a moderate intensification of pastures with the aim of fostering the full recovery of degraded areas and appropriate herd management.

In the coming years, it is estimated that GHG emissions from those farms will hit the mark of 2.4 t CO_2e ha^{-1} year^{-1} and 7.0 t CO_2e per kg of carcasses produced (Figure 7). This means that this strategy will make it possible to increase meat production fivefold, which will reduce GHG emissions by 50% per hectare and by almost 90% per kg of meat produced as compared to the levels seen at the beginning of the program's pilot phase in 2012 (Figure 3; 6).

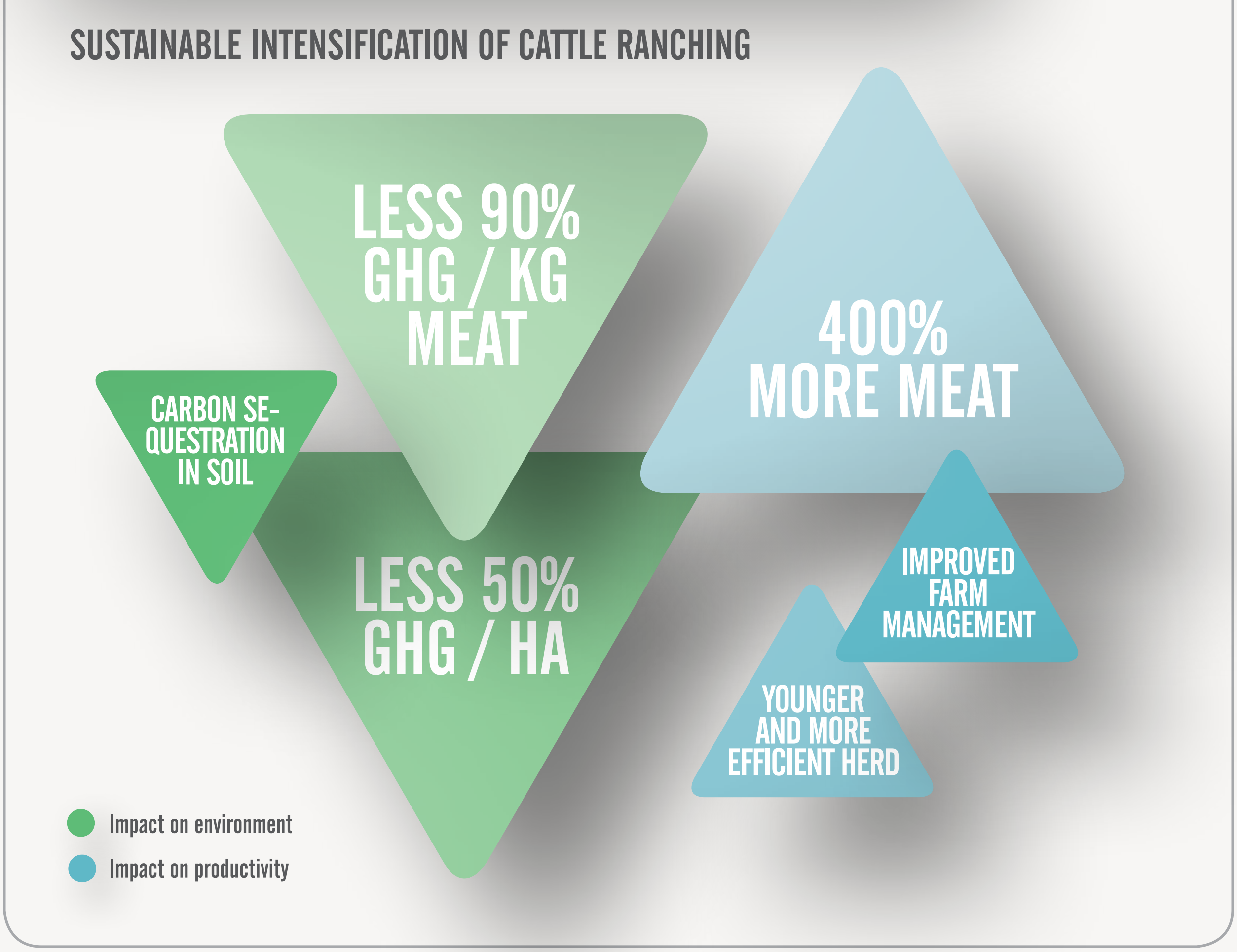
STRATEGY TO KEEP BEEF CATTLE SEQUESTERING CARBON

In the coming years, the Novo Campo Program is expected to increase meat production fivefold with the same amount of GHG emitted by the farms as compared to the beginning of the program.

However, it should be noted that it will only be possible to stop global warming by reducing greenhouse gas emissions to the atmosphere. Therefore, for the agricultural/livestock sector to reduce its emissions to zero after the important and fundamental step of recovering degraded pastures, it will be necessary to adopt management approaches capable of exploring other ways to sequester carbon. One of them consists in adopting integrated systems, especially with trees (integrated crop-livestock-forestry systems). In addition to enhancing the potential for carbon sequestration in soil, these systems can also sequester carbon in biomass (roots, trunks, branches, and leaves), opening up new opportunities for reducing the impact of agricultural/livestock systems on the climate.

Under this scenario, the farms are projected to adopt a full-cycle production system (breeding-rearing-fattening), with 100% of their pastures recovered and well managed, which would be able to support a stocking rate of 3.09 head ha^{-1} (70% higher than the average capacity in 2014) and to produce 23.8 @ of beef ha^{-1} year^{-1}. Under these conditions, the soil of pastures would receive, on average, 100 kg of urea and 300 kg of lime ha^{-1} year^{-1} and the herd would be composed of 120 cows, 95 calves, 1 bull, 68 steers and 25 heifers (for each 100 hectares).

FIGURE 6: MAIN RESULTS OF THE STRATEGY OF THE NOVO CAMPO PROGRAM



The drastic reduction in emissions projected for the coming years on the farms taking part in the program, as shown in the chart above, is mainly a result of carbon sequestration in soils during the process of fully restoring degraded pastures, which makes up for additional emissions from the herd and from using inputs (Figures 3 and 4). The significant increase in meat production (Figure 3) is in turn a function of the total pasture area providing food in sufficient quantity and quality to optimize the production performance of a young and efficient herd.

These results show that investments in the production system make it possible for GHG emissions from agricultural/livestock activities to be significantly reduced in a relatively short period of time concurrently with an increase in production.

RECOVERY OF DEGRADED PASTURES – BENEFITS BEYOND CARBON

The recovery of degraded pastures can be defined as a process of making land areas productive and self-sustainable, as proposed by the Brazilian Institute for the Environment and Renewable Natural Resources (Ibama,1990).

Maintaining the vegetal cover is one of the main requirements for recovering degraded pastures, mainly to avoid erosion, which is one of the most serious problems in rural areas from both an environmental and a production point of view. Loss of nutrients and organic matter, changes in texture, structures, and drops in water infiltration and retention rates are some of the effects of erosion on the characteristics of soils. Once recovered, soils restore important functions for the proper functioning of production systems, such as those of promoting better conditions for seed germination, increasing soil fertility and moisture, and reducing water runoff and hence the carrying of sediments to watercourses (WORLD BANK, 1992).

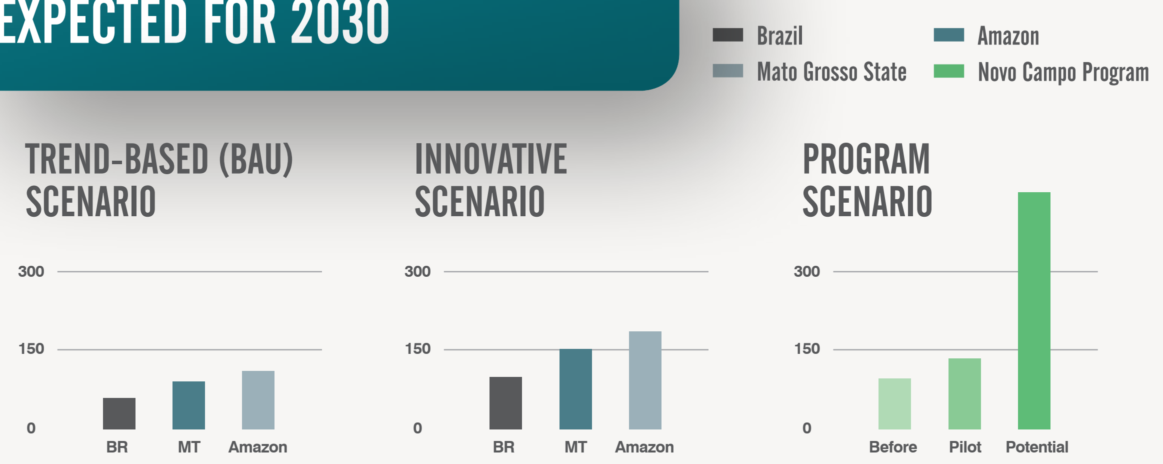
Sustainable intensification of cattle ranching is key for meeting production demands in rural areas

For Brazil to meet the demand for beef anticipated for 2025, the Ministry of Agriculture, Livestock and Supply projects the need for a 25 percent higher production than the 8 million tons of carcasses produced in 2014 (BRAZIL, 2015b).

In this context, states in the Amazon region alone are expected to contribute about 40 percent to this total production and Mato Grosso state is likely to continue to be the main producer (IBGE, n.d.; BARBOSA et al., 2015). Outlook-2025 projections made by the Mato Grosso Institute of Agricultural Economics (IMEA, 2015) suggest that this state is likely to increase its meat production by 46% between 2014 and 2025 to meet this demand (from 1.33 to 1.94 million tons of beef carcass).

With only the increase in meat production promoted by the Novo Campo Program on farms participating in its pilot phase (+85%), the result is already 25% higher than the increase projected for the state of Mato Grosso over the next 15 years (IMEA, 2015). However, this increase in production made possible by the program is similar to that expected to be promoted by innovative meat production systems (BARBOSA et al., 2015) (Figure 7).

FIGURE 7. MEAT PRODUCTION EXPECTED FOR 2030



A trend-based (BAU) and an innovative (BARBOSA et al., 2015) scenario, as compared to the Novo Campo Program.

An innovative production scenario refers to cattle farms that adopt agricultural technologies designed to promote moderate intensification with the aim of meeting future demand for beef using already established areas. These farms would also have the potential to allow areas to be used for other agricultural purposes and to eliminate possible environmental liabilities (PIATTO et al., 2015; BARBOSA et al., 2015).

For one to have an idea of the potential of the Novo Campo Program as applied on a large scale, based only on the average percentages of the increase in beef production projected for the coming years in Brazil (25%) and on the farms during the pilot phase (85%) and the future phase (405%), it was estimated that for every hectare on a farm that joins the program, demand for meat is met and from 3 to 15 hectares could be set apart for another modality of production or conservation.

ECONOMIC ANALYSIS OF THE NOVO CAMPO PROGRAM

Bioeconomic analyses carried out under the Novo Campo Program show that efficiency gains in the participating farms can increase the net current value (NCV) of those farms by approximately R$ 2,000.00 per hectare, apart from substantially reducing the risk of losses from 99% to 15% (IIS, 2015).

Thus, by recovering degraded pastures and adopting good Livestock Production Practices, unprofitable beef production activities can become profitable, reducing production costs through increased productivity.

These calculations are based on an initial investment of R$ 2,000.00 per hectare of pasture (including the value of the herd, facilities, machinery, and equipment), excluding the value of the land in the model or environmental compliance costs. For intensified areas, an additional investment of R$ 2,400.00/ha was considered (R$ 1,000.00 for renovating pastures and R$ 1,400.00 for inputs such as those used for soil correction and fertilization). Fixed costs include depreciation, maintenance of regular pastures, or intensified pastures. Variable costs include health management, mineralization, and reproductive management. After profits before interest rates and income tax were calculated, financial expenses that the farm would have with loans and income tax payments were deducted (IIS, 2015).

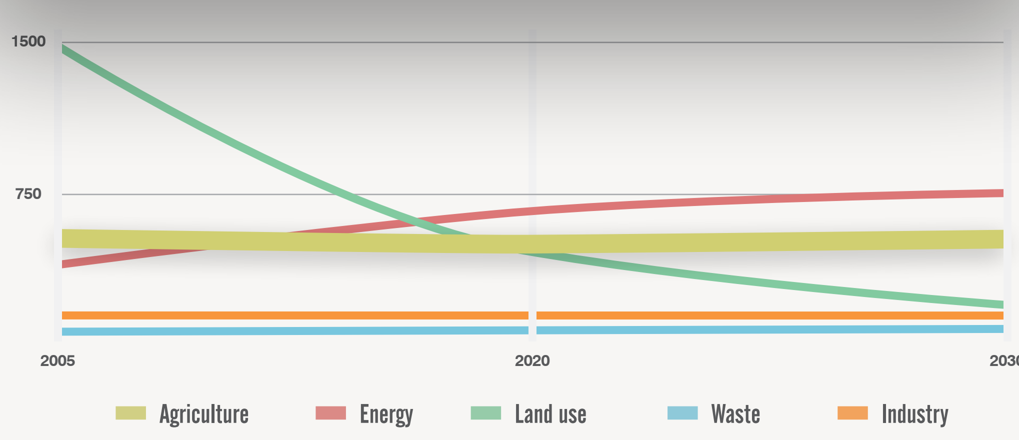
Sustainable cattle ranching protagonises the goals set in the Paris Agreement for brazilian agriculture/livestock

The 21st Conference of the Parties (COP-21) of the United Nations Framework Convention on Climate Change, which was held in Paris in November 2015, culminated in the drafting of the Paris Agreement. That agreement is aimed at keeping the average global temperature rise below two degrees Celsius above pre-industrial levels and at mobilizing efforts to limit this increase to 1.5ºC.

This goal is to be achieved through the joint efforts of almost 200 signatory countries, including Brazil, through its NDC (Nationally Determined Contribution). The Brazilian NDC estimates that the country's GHG emissions will amount to 1,208 Mt in 2030, with the agricultural/livestock sector accounting for 490 Mt CO_2e, or 40% of total national emissions (BRAZIL, 2015c, d).

GHG emissions from the agricultural/livestock sector projected for 2030 are close to those caused by this sector in 2005 (484 Mt CO_2e) - the NDC baseline year (Figure 8). However, the emissions projected for 2030 will be potentially associated with an agricultural/livestock production that will be about 30% higher than the current one (BRASIL, 2015b, c, d).

FIGURE 8. BRAZILIAN GHG EMISSIONS BY SECTOR BY 2030 AS CONTEMPLATED IN THE BRAZILIAN NDC



*In Mt CO_2e. Adapted from Brasil (2015d)

The increase in agricultural production associated with the GHG emissions projected for 2030 is due to proposals contained in the Brazilian NDC that are focused on carbon sequestration in soil through livestock-related actions: recovery of 15 million ha of degraded pasture and expansion of 5 million hectares of integrated crop-livestock-forestry (CLF) production systems.

With the implementation of these actions, it is estimated that carbon sequestration will largely offset GHG emissions caused by the necessary increase in the herds and in agricultural production to meet the demand for agricultural and livestock products in 2030.

However, the evidence of how the recovery of degraded pastures and the implementation of integrated systems affect production efficiency and GHG emissions on Brazilian farms is still in the process of being appropriately understood. In this context, the Novo Campo Program has also become a major example of how to check the impact of these actions.

According to the analysis contained in this report, the actions contemplated in the NDC for the agricultural/livestock sector are consistent for beef cattle farms in the Amazon region: by recovering pastures and implementing integrated systems, productivity can be increased while GHG emissions can be reduced on a large scale (Figure 3; 6).

However, the Novo Campo Program also shows that in addition to the actions proposed in the Brazilian goal, it is necessary to improve herd management (by providing supplementary feeding and adopting good reproductive and health practices, for example) and farm management – which are directly dependent on the provision of technical assistance to the farmers. It should be noted that the ongoing assistance provided by the Novo Campo Program was crucial to promote improvements in production while reducing GHG emissions.

It is evident that Brazil's goals are on the right path to reduce emissions in the agricultural/livestock sector, but in order to actually ensure the implementation of the climate commitment it will be crucial to expand technical assistance to farmers while monitoring the expected increase in production efficiency. In this context, the Novo Campo Program is presented as an example to be replicated on a national scale.

RESULTS AND CONCLUSIONS

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THE IMPLEMENTATION OF good agricultural practices, integrated farm management, and monitoring of GHG emissions under the Novo Campo Program show that:

Program evidence

1. The Novo Campo Program has the potential to increase meat production fivefold and to reduce GHG emissions by 50% per hectare of productive area and 90% of emissions per kilogram of meat produced.
2. Two years after progressively adopting good Livestock Production Practices (recovery of degraded pastures, animal supplementation, improvements in the health and reproductive management of the herd and in farm management), beef production on the farms taking part in the program increased by 120% on average, while GHG emissions declined by 20% per hectare – resulting in 60% less GHG per kilogram of carcass produced.
3. The transition of farms to more efficient production systems in already disturbed areas (deforested many years ago) is seen as a viable means to meet an increasing demand for agricultural/livestock products while contributing to mitigate global climate change.
4. The Novo Campo Program provides a major case study for farmers to increase their productivity through sustainable means and for decision-makers to implement policies designed to ensure compliance with global climate agreements.

Beef cattle ranching is the sector with the greatest potential to reduce GHG emissions and promote carbon sequestration in Brazil. More efficient production systems increase the profitability of farmers while contributing to maintaining the climate. The public and private sectors should support farmers for this transition to be effective and of a sufficient scale to meet the demand for meat and for them to stop being the largest emitters of greenhouse gases and become the largest carbon-sequestering entities in the world.

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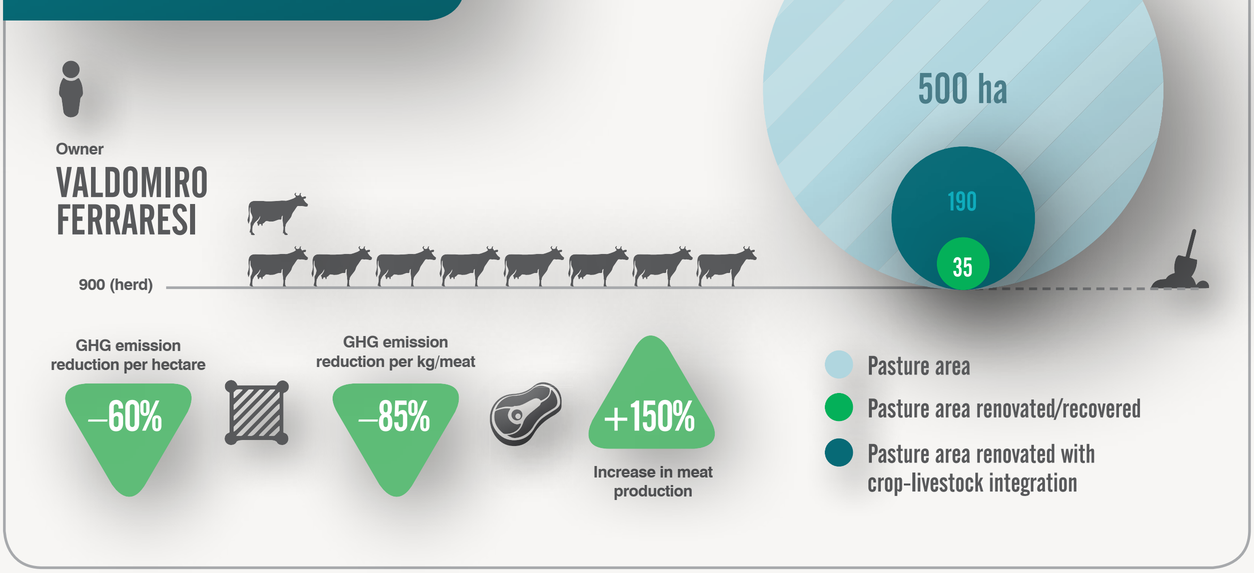
ANNEX

Annex 1. Individual analyses of the first 5 farms taking part in the Novo Campo Program.

5 IRMÃOS FARM



With 500 ha of pasture area and an average herd of 900 animals in full-cycle production, the 5 Irmãos Farm was not, like most average farms in Brazil, exploring its potential appropriately, as it was producing no more than 50.4 kg of meat per ha^{-1} $year^{-1}$ (Annex 2).

This was mainly due to the Degradation of pastures, which did not provide forage in sufficient quantity and quality to the animals - because of the lack of guidance for implementing a more efficient production management.

With such profile, average GHG emissions from the 5 Irmãos Farm amounted to 5.2 t CO_2e ha^{-1} $year^{-1}$ and it was the farm with the highest levels of GHG emissions to produce one kilogram of meat (104 kgCO_2e) among the first farms participating in the Novo Campo Program (Table 2).

TABLE 2: GHG EMISSIONS AND BEEF PRODUCTION BEFORE AND DURING THE NOVO CAMPO PROGRAM

Source	GHG Emissions (t CO_2e / ha)		
	2012	2013	2014
Beef cattle	3.1	2.6	2.3
Enteric fermentation	2.9	2.4	2
Waste	0.3	0.2	0
Inputs	0.024	0.038	0.217
Urea	0.014	0.028	0.208
Limestone	0.010	0.010	0.009
Diesel oil	0.002	0.002	0.011
Pasture	2	1.7	-0.6
Degraded	2	1.9	1.7
Reformada	0	-0.2	-2.3
GHG emissions/ha	**5.2**	**4.3**	**1.9**
Meat production*	**50**	**87.4**	**124.4**
Intensity**	**103.9**	**50.7**	**16**

* Meat production (kg carcarcarcass ha-1). **Intensity of the emission (kg CO_2e/kg meat).

However, with the support from the Novo Campo Program, the 5 Irmãos Farm initially reformed 7% of its pasture area (35 ha), which was used for rotational grazing of part of the cattle bred on the farm, and introduced other production practices described in the BPA and GIPS-GTPS manuals, such as supplementary feeding of animals and improved reproductive and health control of the herd.

One year later, these interventions led to a reduction in emissions per hectare of pasture on the 5 Irmãos Farm of almost 20% (from 5.2 to 4.3 t CO_2e ha^{-1}), even with regular application of urea and use of diesel oil in machinery for maintaining the renovated area (Table 2).

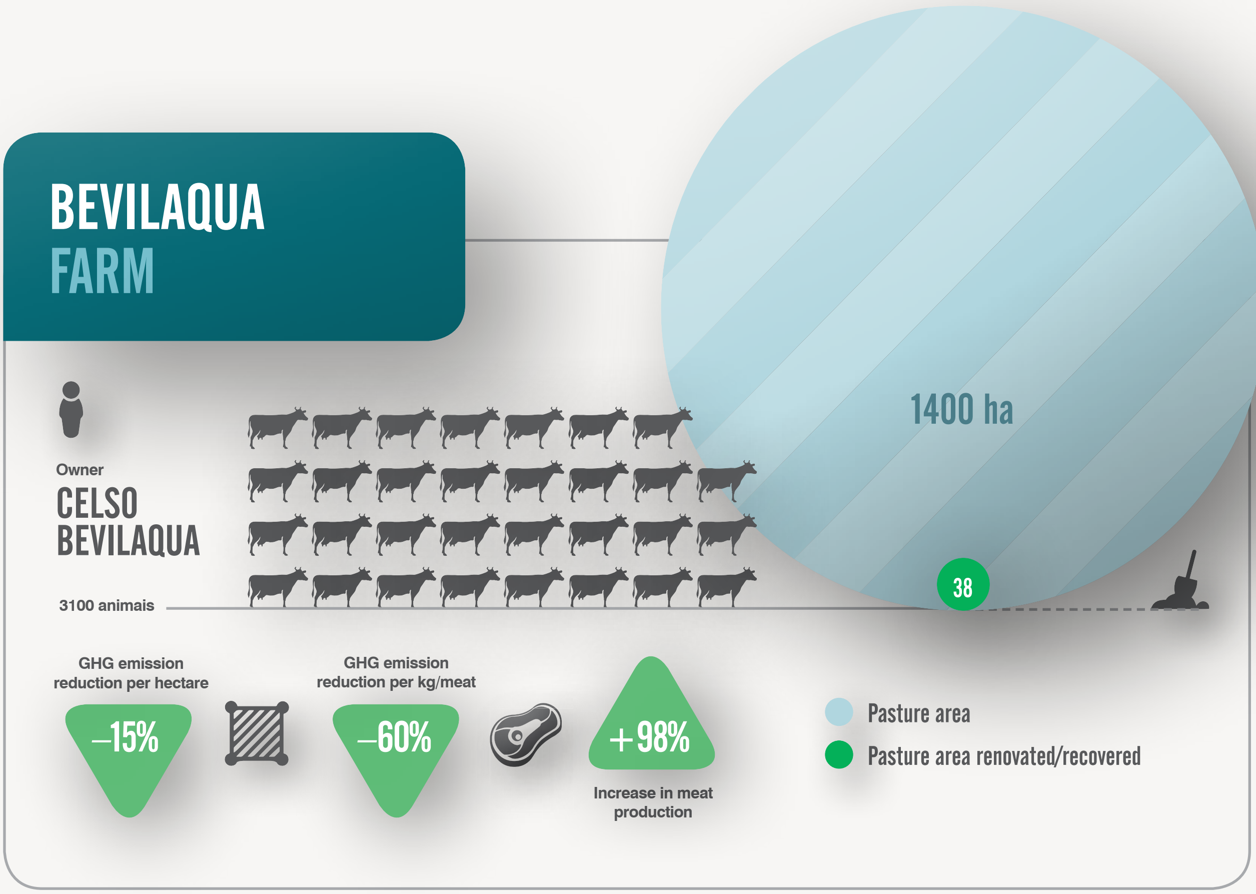
This reduction in GHG emissions resulted from carbon sequestration in soil in the renovated pasture area and from improved herd production efficiency. With food available in sufficient quantity and quality, it was possible to fatten the herd more quickly, reducing emissions from the herd and increasing meat production by 74%, from 50.4 to 87.4 kg of carcass produced per hectare per year (Table 2).

But the 5 Irmãos Farm achieved more than that. In January 2014, also with the assistance from the Novo Campo Program and adopting the practices described in the BPA and GIPS-GTPS manuals, the farm recovered more than 190 hectares of degraded pastures. However, this time this was done by implementing an integrated crop-livestock system (Appendix 2).

Thus, with 45% of its productive area recovered (218 ha), the balance of GHG emissions from the soil on the 5 Irmãos Farm became negative, i.e. more carbon began to be sequestered in soil than was emitted by degradation. In addition, as a result of the adoption of an integrated crop-livestock system, the farm's capacity to provide quality fodder to the livestock increased, especially during the dry season, and its revenues were supplemented with soybeans and corn grown in the summer.

The farm was thus able to reduce the slaughter time of its herd even more and began to produce 124 kg of carcass per hectare per year, i.e. 150% more than in 2012 (Table 2).

As a result of joining the Novo Campo Program, two years after the adoption of good Livestock Production Practices emissions per hectare from the 5 Irmãos Farm were reduced by 60% (from 5.2 to 2.0 t CO_2e ha^{-1}) and the emission intensity was reduced by almost 85% (from 102.9 to 16.0 t CO_2e per kg of carcass produced) - the greatest reduction in GHG emissions among the first participants in the Novo Campo Program (Table 2).



The Bevilaqua Farm stands out for having the largest pasture area and the largest herd of all the first farms taking part in the Novo Campo Program: 1,400 ha and 3,100 animals on average (Annex 2). Running a full-cycle production system, it produced about 80 kg of carcass per ha^{-1} $year^{-1}$, much more than the national average, estimated at about 50 kg of carcass per ha^{-1} $year^{-1}$ (IBGE, n.d.; Table 3).

However, because it failed to keep itself abreast with the latest pasture and livestock management techniques, the farm could not adopt the most up-to-date farming technologies. This led to early degradation of its areas and prevented its productivity from rising.

Thus, GHG emissions from the Bevilaqua Farm amounted to 5.7 t CO^2e ha^{-1} $year^{-1}$ and cattle were the main source of GHG emissions from the farm (60%) due to their enteric fermentation and waste (Table 3).

With the assistance from the Novo Campo Program, the Bevilaqua Farm initially renovated less than 3% of its pasture area (38 ha) and adopted other production practices described in the BPA and GIPS-GTPS manuals.

TABLE 3: GHG EMISSIONS AND BEEF PRODUCTION BEFORE AND DURING THE NOVO CAMPO PROGRAM

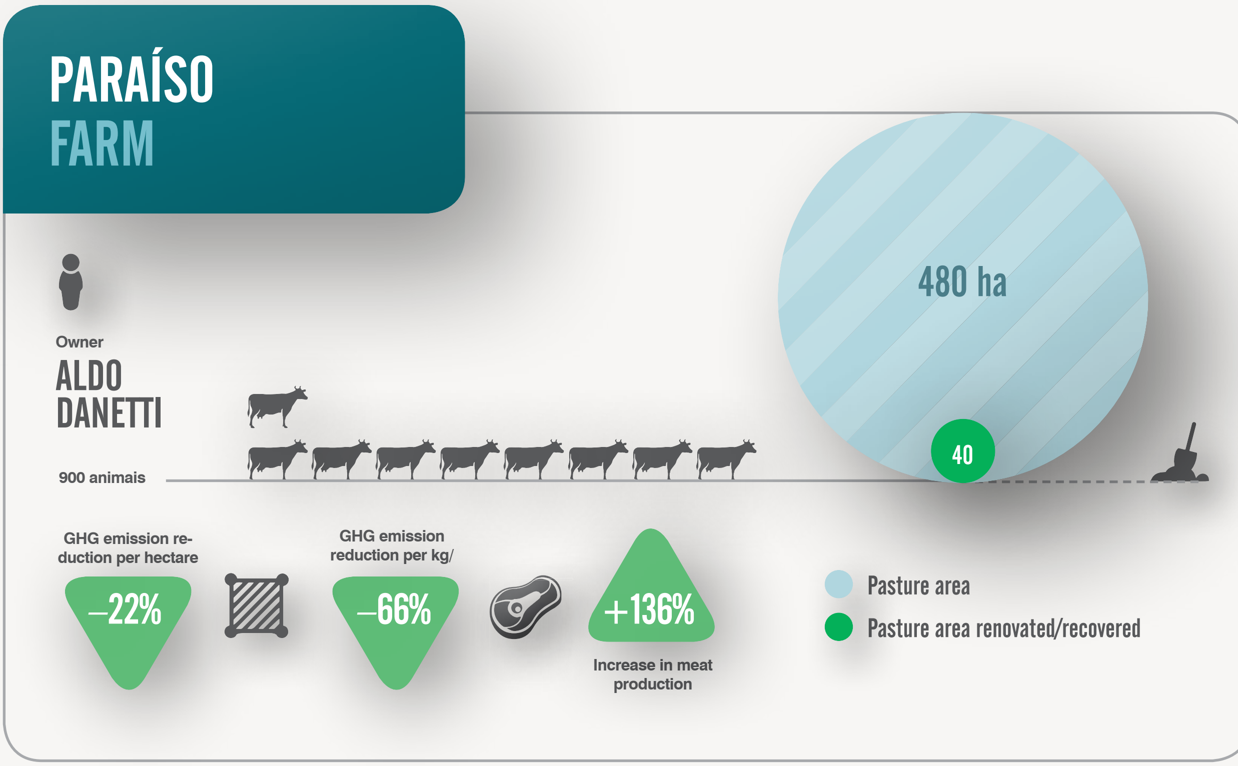
Source	GHG Emissions (t CO_2e / ha)		
	2012	2013	2014
Beef cattle	3.6	3.2	2.8
Enteric fermentation	3.3	3	3
Waste	0.3	0.3	0
Inputs	0.009	0.015	0.015
Urea	0.005	0.011	0.011
Limestone	0.004	0.004	0.004
Diesel oil	0.001	0.001	0.001
Pasture	2	1.9	1.9
Degraded	2	2	2
Reformada	0	-0.1	-0.1
GHG emissions/ha	**5.7**	**5.2**	**4.8**
Meat production*	**79**	**138.2**	**156.7**
Intensity**	**71.8**	**38.2**	**30.5**

* Meat production (kg carcarcarcass ha-1). **Intensity of the emission (kg CO_2e/kg meat).

Two years after the adoption of these good Livestock Production Practices, emissions per hectare of pasture from the Bevilaqua Farm were reduced by approximately 15% (from 5.7 to 4.8 t ha CO_2e^{-1}), even with regular application of urea and use of diesel oil in machinery for maintaining the renovated area (Table 3).

This reduction in GHG emissions resulted mainly from improvements in the herd's production efficiency, as besides having reduced the slaughter time due to the recovery of pastures, it also reduced the herd size by 21% after unproductive animals began to be identified and discarded. These actions made it possible for the farm's meat production to increase by 98%, from 79 to 157 kg of carcass produced per hectare per year (Table 3).

As a result of joining the Novo Campo Program, two years after good agricultural practices were adopted the emission intensity calculated for the Bevilaqua Farm had dropped by 60% (from 72 to 31 tCO_2e per kg of carcass produced) (Table 3; Figure 11)



Among the first farms to take part in the Novo Campo Program, the Paraiso Farm is the one in which the greatest increase in meat production was recorded by renovating only 8% of its pasture area, which was predominantly degraded before.

With 480 ha of pastures and an average herd of 900 animals, running a full-cycle production system the Paraiso Farm produced approximately 52 kg of carcass ha^{-1} $year^{-1}$. Under this scenario, average GHG emissions from the Paraiso Farm amounted to 5.2 t CO_2e ha^{-1} $year^{-1}$ (Annex 2; Table 4)

With the support from the Novo Campo Program, apart from renovating 8% of its pasture area (40 ha) the Paraiso Farm adopted other production practices described in the BPA and GIPS-GTPS manuals, such as supplemental feeding of animals and improvements in the herd's reproductive and health control.

TABLE 4: GHG EMISSIONS AND BEEF PRODUCTION BEFORE AND DURING THE NOVO CAMPO PROGRAM

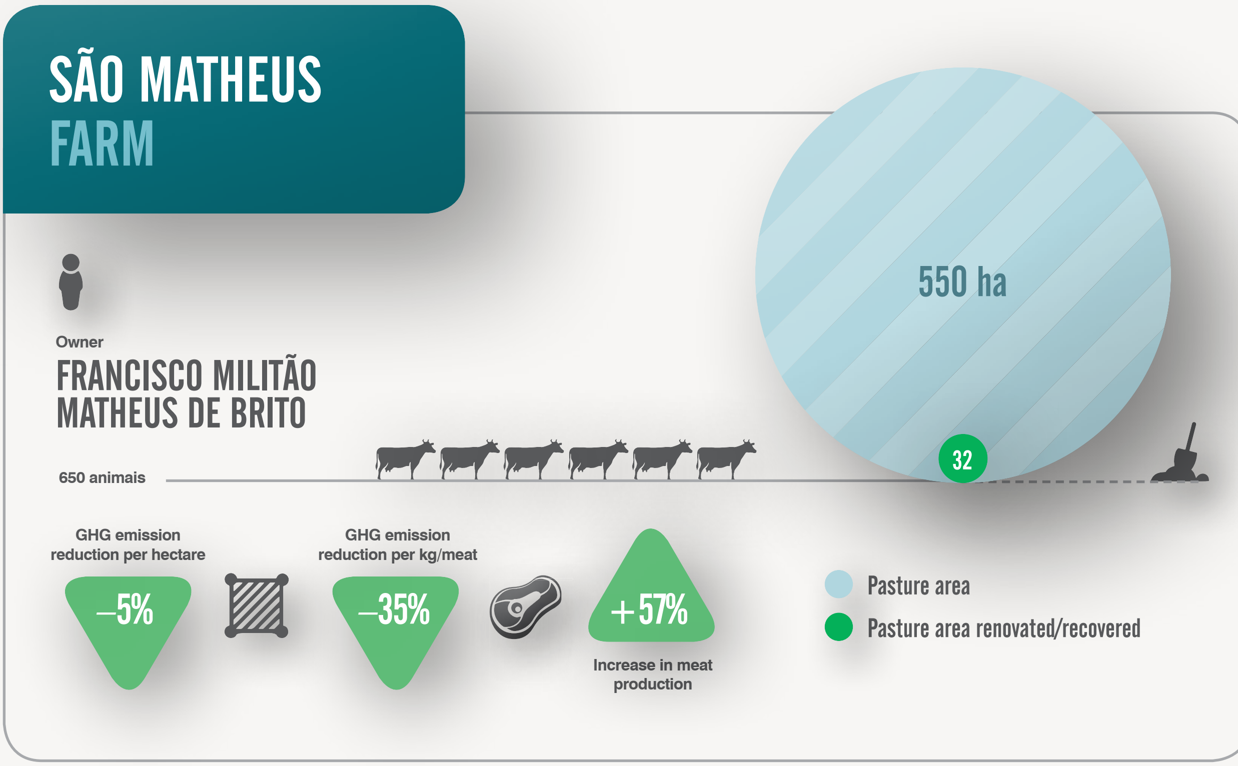
Source	GHG Emissions (t CO_2e / ha)		
	2012	2013	2014
Beef cattle	3.1	3	2.4
Enteric fermentation	2.9	2.8	2
Waste	0.2	0.2	0
Inputs	0.028	0.045	0.045
Urea	0.017	0.033	0.033
Limestone	0.012	0.012	0.012
Diesel oil	0.002	0.002	0.002
Pasture	2	1.7	1.7
Degraded	2	1.9	1.9
Reformada	0	-0.2	-0.2
GHG emissions/ha	**5.2**	**4.7**	**4.1**
Meat production*	**52.1**	**91.2**	**123.2**
Intensity**	**99.5**	**52.5**	**34.1**

* Meat production (kg carcarcarcass ha-1). **Intensity of the emission (kg CO_2e/kg meat).

Two years after adopting these good Livestock Production Practices, the Paraiso Farm was able to reduce its emissions per hectare of pasture by approximately 20% (from 5.2 to 4.1 t CO_2e ha^{-1}), even with regular application of urea and use of diesel oil in machinery (Table 4).

This reduction in GHG emissions resulted mainly from improvements in the production efficiency of the herd, which after being given access to food of a higher quality due to the renovation of pastures and disposal of unproductive animals, began to produce nearly 140% more meat, with an increase from 52 to 123 kg of carcass per hectare per year (Table 4).

As a result of joining the Novo Campo Program, two years after the Paraiso Farm adopted good Livestock Production Practices its emission intensity decreased by 66% (from 100 to 34 t CO_2 per kg of carcass produced).



The São Matheus Farm provides an interesting scenario in relation to GHG emissions and meat production under its management system. Working with breeding and fattening, the emissions from that farm were the lowest among the first participants in the Novo Campo Program: 3,6 t CO_2e ha^{-1} $year^{-1}$ (Table 5).

This was due to its low stocking rates in its grazing area, less than 1.2 animals per hectare, the main source of GHG emissions from its production system. However, with pastures under degradation, production on the São Matheus Farm amounted to less than 75 kg of carcass ha^{-1} $year^{-1}$ (Table 5).

During its participation in the Novo Campo Program, the farm renovated only 6% of its 550 ha of pastures under degradation and preserved the same herd profile: about 650 animals aged less than 24 months on average (Annex 2). This means that this farm did not have to discard less efficient animals like the other farms did. However, the adoption of good practices improved the efficiency of its system, which began to produce nearly 60% more meat, with an increase from 72 to 113 kg of carcass produced per hectare per year (Table 5).

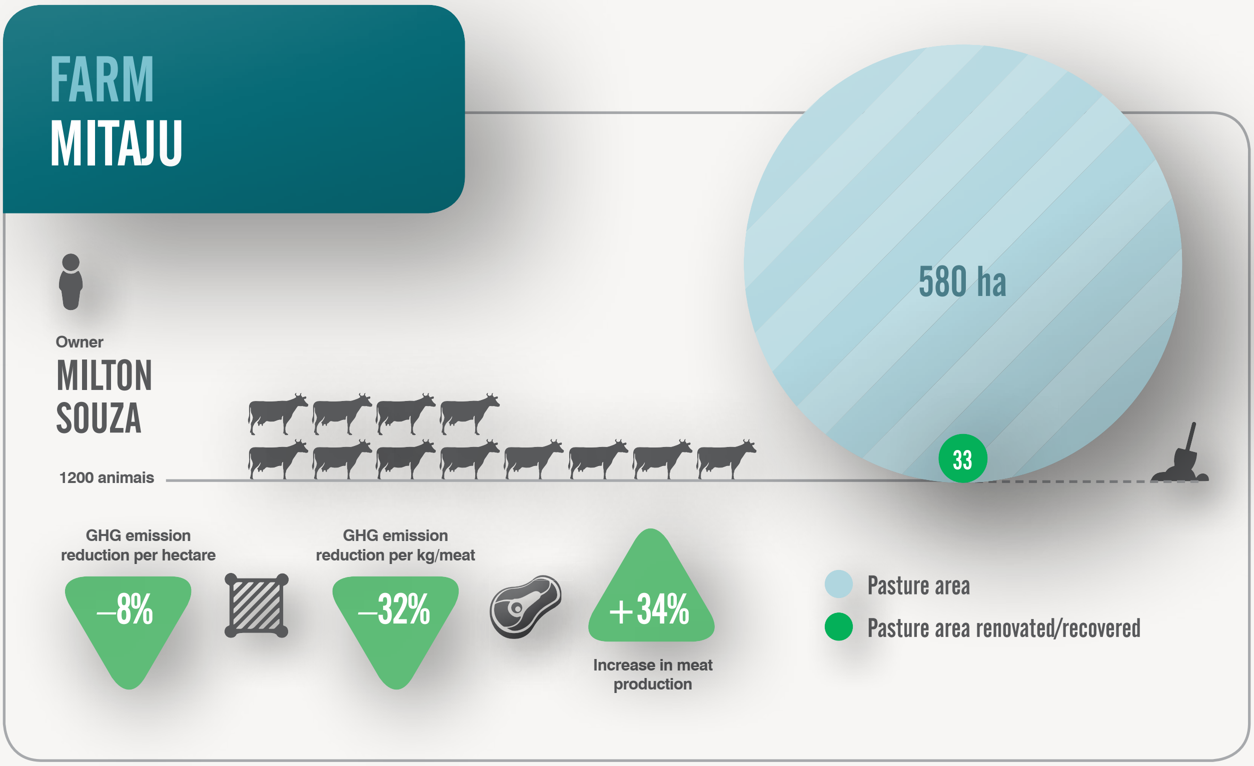
TABLE 5: GHG EMISSIONS AND BEEF PRODUCTION BEFORE AND DURING THE NOVO CAMPO PROGRAM

Source	GHG Emissions (t CO_2e / ha)		
	2012	2013	2014
Beef cattle	1.6	1.6	1.6
Enteric fermentation	1.5	1.5	2
Waste	0.1	0.1	0
Inputs	0.000	0.025	0.032
Urea	0.000	0.018	0.023
Limestone	0.000	0.007	0.008
Diesel oil	0.000	0.001	0.002
Pasture	2	1.9	1.8
Degraded	2	2	1.9
Reformada	0	-0.1	-0.1
GHG emissions/ha	**3.6**	**3.5**	**3.4**
Meat production*	**72.4**	**84.2**	**113.4**
Intensity**	**50.1**	**42**	**32.6**

* Meat production (kg carcarcarcass ha-1). **Intensity of the emission (kg CO_2e/kg meat).

Two years after adopting these good Livestock Production Practices, the São Matheus Farm managed to reduce emissions per hectare of pasture by approximately 5% (from 3.6 to 3.4 t CO_2e ha^{-1}), even with regular application of urea and use of diesel oil (Table 5).

As a result of joining the Novo Campo Program, two years after adopting good Livestock Production Practices the São Matheus Farm reduced its emission intensity by 33% (from 50 to 33 t CO_2 per kg of carcass produced) (Table 5).



Over the years, the Mitaju Farm has been working with a breeding-and-fattening production system. With a stocking rate of 2.1 animals per hectare and a meat production of about 70 kg of carcass ha^{-1} $year^{-1}$, the GHG emissions from the Mitaju Farm before it joined the Novo Campo Program amounted to 5.2 t CO_2e ha^{-1} $year^{-1}$ (Table 6).

After the farm joined the Novo Campo Program, almost 6% of its 580 ha of pasture area under degradation were renovated. However, after it adopted the production practices described in the BPA and GIPS-GTPS manuals and by sequestering carbon in soil in the renovated area, the Mitaju Farm managed to reduce its emissions per hectare of pasture by approximately 8% (from 5.2 to 4.8 t CO_2e ha^{-1}), even with application of urea and use of diesel oil (Table 6).

TABLE 6 : GHG EMISSIONS AND BEEF PRODUCTION BEFORE AND DURING THE NOVO CAMPO PROGRAM

Source	Emissão		
	2012	2013	2014
Beef cattle	3.2	2.9	3
Enteric fermentation	2.9	2.6	3
Waste	0.3	0.2	0
Inputs	0.000	0.006	0.031
Urea	0.000	0.004	0.023
Limestone	0.000	0.002	0.008
Diesel oil	0.000	0.000	0.002
Pasture	2	2	1.8
Degraded	2	2	1.9
Reformada	0	0	-0.1
GHG emissions/ha	**5.2**	**4.9**	**4.8**
Meat production*	**73.2**	**78.9**	**98.2**
Intensity**	**71.4**	**62.8**	**48.9**

* Meat production (kg carcarcarcass ha-1). **Intensity of the emission (kg CO_2e/kg meat).

Even though this reduction in GHG emissions is not as significant as those recorded in farms participating in the program running full-cycle production systems, the adoption of good practices improved the efficiency of the system to such a point that it began to produce almost 35% more meat, with an increase from 73 to 98 kg of carcass produced per hectare per year (Table 6).

As a result of joining the Novo Campo Program, two years after adopting good Livestock Production Practices the Mitaju Farm reduced its emission intensity by 32% (from 71 to 49 t CO_2 per kg of carcass produced) (Table 6).

Annex 2. Average annual data used to calculate the GHG emission balance, using the GHG Protocol Agricultural Tool, of five farms participating in the Novo Campo Program.

TABLE 7: DATA FROM EMISSIONS CALCULATION OF GHG USING THE GHG-PROTOCOL

	5 Irmãos Farm			Bevilaqua Farm			Paraíso Farm			S. Matheus Farm			Mitaju Farm		
	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
Herd (heads)															
Between 6 e 12 months															
Male	124	88	80	500	501	353	222	199	101	112	35	133	229	156	288
Female	136	141	117	222	237	160	155	182	156	112	35	133	235	197	231
Between 12 e 24 months															
Male	27	22	46	301	257	270	142	161	164	109	191	167	18	5	70
Female	145	157	349	520	517	384	192	164	77	109	197	203	100	116	32
Above 24 months															
Male	90	24	11	346	352	358	66	42	15	163	114	15	51	56	36
Female	511	430	229	1558	1320	1209	285	290	298	48	37	32	636	602	581
Total	**1033**	**862**	**833**	**2447**	**3185**	**2733**	**1062**	**1038**	**811**	**653**	**608**	**682**	**1269**	**1132**	**1239**
Aplication/use of Inputs															
Urea (t)*	0,3*	3,5	22,5	0,3*	3,8	3,8	0,3*	4,0	4,0	0,3*	3,2	3,2	0	10,0*	3,3
Limestone (t)	1,8*	52,4	337,4	1,9*	56,6	56,6	2,0*	59,4	59,4	1,6*	48,2	48,2	0	148*	49,5
Diesel oil maq. (l)	58,3*	349,5	2250	62,8*	377	377	66*	396	396	53,5*	321	321	0	82,5*	330
Meat production															
Kg carcass ha^{-1}	50,0	87,4	124,4	79,0	138,2	156,7	52,1	91,2	123,2	72,4	84,2	113,4	73,2	78,9	98,2
Pasture area															
Degraded	500	465	275	1400	1362	1362	480	440,4	440,4	550	518	518	580	547	547
Well handled	0	35	35	0	37,7	37,7	0	39,6	39,6	0	32,1	32,1	0	33	33
Integration	0	0	190	0	0	0	0	0	0	0	0	0	0	0	0

* Annual values were relativized by the number of months in which the reform of pasture occurred (between November and December 2012 - except for Mitaju Farm that occurred between October and November 2013), since before this reform there was no use of these Inputs in the Pastures; Additionally it was considered that there was no application of urea in the first month of the reforestation of the area, but from the second month, in cover after sowing of the pasture.

TABLE 8: BLANCE OF GHG EMISSIONS BETWEEN THE PARTICIPATING FARMS

	5 Irmãos Farm			Bevilaqua Farm			Paraíso Farm			S. Matheus Farm			Mitaju Farm		
	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014	2012	2013	2014
GHG Emissions (t CO_2e ha^{-1})															
Herd	3,1	2,6	2,3	3,6	3,2	2,8	3,1	3,0	2,4	1,6	1,6	1,6	3,2	2,9	3,0
Enteric ferment.	2,9	2,4	2,1	3,3	3,0	2,6	2,9	2,8	2,2	1,5	1,5	1,5	2,9	2,6	2,7
Waste	0,3	0,2	0,2	0,3	0,3	0,2	0,2	0,2	0,2	0,1	0,1	0,1	0,3	0,2	0,2
Inputs	0,024	0,038	0,217	0,009	0,015	0,015	0,028	0,045	0,045	0,000	0,025	0,032	0,000	0,006	0,031
Urea	0,014	0,028	0,208	0,005	0,011	0,011	0,017	0,033	0,033	0,000	0,018	0,023	0,000	0,004	0,023
Limestone	0,010	0,010	0,009	0,004	0,004	0,004	0,012	0,012	0,012	0,000	0,007	0,008	0,000	0,002	0,008
Diesel oil	0,002	0,002	0,011	0,001	0,001	0,001	0,002	0,002	0,02	0,000	0,001	0,002	0,000	0,000	0,002
Área Pasture	2,0	1,7	-0,6	2,0	1,9	1,9	2,0	1,7	1,7	2,0	1,9	1,8	2,0	2,0	1,8
Degraded	2,0	1,9	1,7	2,0	2,0	2,0	2,0	1,9	1,9	2,0	2,0	1,9	2,0	2,0	1,9
Handled	0,0	-0,2	-2,3	0,0	-0,1	-0,1	0,0	-0,2	-0,2	0,0	-0,1	-0,1	0,0	0,0	-0,1
Balance of GHG emissions (kg CO_2e)															
GHG/ha	5,2	4,3	1,9	5,7	5,2	4,8	5,2	4,7	4,1	3,6	3,5	3,4	5,2	4,9	4,8
Variation		-60%			-15%			-22%			-5%			-8%	
GHG/kg meat	103,9	50,7	16,0	71,8	38,2	30,5	99,5	52,5	34,1	50,1	42,0	32,6	71,4	62,8	48,9
Variation		-85%			-60%			-66%			-35%			-32%	

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BPA Brazilian GAP

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