
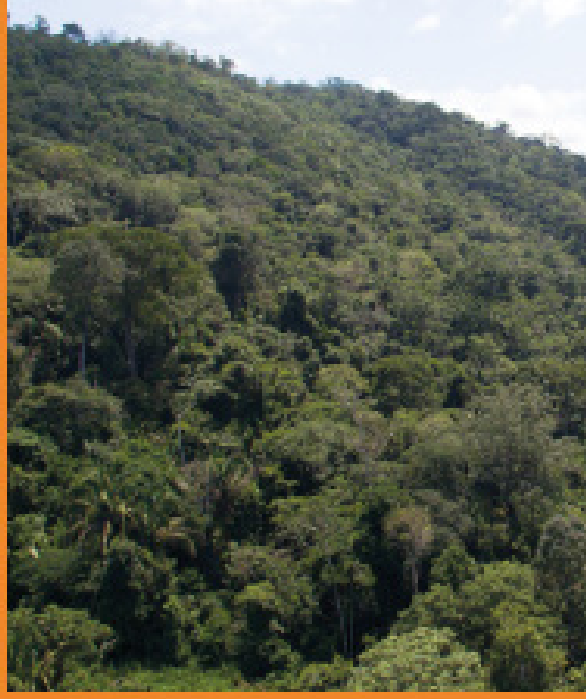

Small scale, great opportunity: towards sustainable young livestock farming in the Amazon and the potential of the Innovation and Learning Hubs (ILHs)

Raquel de Paiva Serôa da Motta, Cintia Munch Cavalcanti, Joyce Brandão, Mariana Pereira, Paulo Lima, Beatriz Domeniconi

Report 1177

WAGENINGEN
UNIVERSITY & RESEARCH

Small scale, great opportunity: towards sustainable young livestock farming in the Amazon and the potential of the Innovation and Learning Hubs (ILHs)

A study to analyse the potential of implantation of Innovation and Learning Hubs (ILHs) for the dissemination of innovative practices in livestock farming for the mitigation of greenhouse gases.

Raquel de Paiva Serôa da Motta[1], Cintia Munch Cavalcanti[2], Joyce Brandão[2], Mariana Pereira[2], Paulo Lima[2], Beatriz Domeniconi[3]

1 Wageningen Livestock Research - WLR

2 Solidaridad Brazil Foundation

3 Brazilian Roundtable on Sustainable Livestock – GTPS

This research was conducted by WLR, Solidaridad Brazil Foundation, Embrapa and GTPS, and commissioned and funded by the Ministry of Agriculture, Nature and Food Quality of the Netherlands (LNV), Project Number BO-43-003.01-012

Wageningen Livestock Research
Wageningen, May 2018

Report 1177

Reino dos Países Baixos

WAGENINGEN UNIVERSITY & RESEARCH

Solidaridad

GTPS Grupo de Trabalho da Pecuária Sustentável

de Paiva Serôa da Motta, R., Munch Cavalcanti, C., Brandão, J., Pereira,M., Lima, P., Domeniconi, B., 2019. *Small scale, great opportunity: towards sustainable young livestock farming in the Amazon; A study to analyse the potential of implantation of Innovation and Learning Hubs (ILHs) for the dissemination of innovative practices in livestock farming for the mitigation of greenhouse gases.* Wageningen Livestock Research, Report 1177.

Collaboration and review:
Vivian Dagnesi Timpani (Embrapa)
Alexandre Berndt (Embrapa)
Rodrigo Castro (Solidaridad)
Gert van der Bijl (Solidaridad)
Daniela Mariuzzo (HDI)

Translation:
Paula Martinelli Vieira da Rosa

Graphic design and layout:
Vínculo Design Estratégico

Photos:
Florence Rodrigues
Diego Rinaldi

Printing: Copies & Printing

This report can be downloaded for free at https://doi.org/10.18174/495347 or at www.wur.nl/livestock-research (under Wageningen Livestock Research publications).

P.O. Box 338, 6700 AH Wageningen, The Netherlands, T +31 (0)317 48 39 53,
E info.livestockresearch@wur.nl, www.wur.nl/livestock-research. Wageningen Livestock Research is part of Wageningen University & Research.

Wageningen Livestock Research is NEN-EN-ISO 9001:2015 certified.
All our research commissions are in line with the Terms and Conditions of the Animal Sciences Group. These are filed with the District Court of Zwolle.

Wageningen Livestock Research Report 1177

Table of contents

List of figures

List of abbreviations

ANDA	National Association for the Diffusion of Fertilizers
APP	Areas of Permanent Protection
ATER	Technical Assistance and Rural Extension
BAU	Business as Usual
BNDS	The Brazilian Development Bank
GAP	Good Agricultural Practices
CAR	Environmental Rural Registry
COP 21	Conference of Parties 21
CEPLAC	Executive Commission on Cacao Farming Planning
CO2	Carbon Dioxide
EMBRAPA	Brazilian Agricultural Research Corporation
GHG	Greenhouse gas
GIPS	Sustainable Livestock Indicators Guide
GTPS	Brazilian Roundtable on Sustainable Livestock
GTA	Animal Transportation Guide
IDH	Sustainable Trade Initiative
ILH	Innovation Learning Hubs
ILPF	Crop-Livestock-Forest Integration
IBAMA	Brazilian Institute of Environment and Renewable Natural Resources
IMAZON	Amazon Institute of People and the Environment
INCRA	National Institute of Colonization and Agrarian Reform
INPE	Brazilian Institute of Space Research
LAR	Rural Activity License
LNV	Ministry of Agriculture, Nature and Food Quality
MAPA	Ministry of Agriculture, Livestock and Supply
MMA	Ministry of the Environment
NDC	Nationally Determined Contribution
SDG	Sustainable Development Goals
NGO	Non-governmental Organizations
PCI	Producing, Conserving and Including
PIN	National Integration Plan
NWFP	Non-Wood Forest Products
PRODES	Project Monitoring the Brazilian Amazon forest by satellite
PRA	Programa de Regularização Ambiental
PES	Payments for Environmental Services
RL	Legal Reserve
SAF	Agroforestry Systems
SMP	Seed Money Project
SEEG	Greenhouse Gas Emissions and Removals Estimates
SEMAS	Secretariat of the Environment and Sustainable Development for the State of Amazonas
SFB	Brazilian Forest Service
SUDAM	Superintendency of Development for the Amazon
TAC	Conduct Adjustment Declaration
TCP	Theory of Planned Behavior
TNC	The Nature Conservancy
AU	Animal Unit
DU	Demonstration Units
VSA	Verified Sourcing Areas
WLR	Wageningen Livestock Research
WUR	Wageningen University and Research

Executive Summary

Livestock farming is considered a key activity for food security, representing 34% of the protein consumed globally and for about 14.5% of global anthropogenic greenhouse gas emissions (GHG), of which 2/3 are attributed to cattle raising.). Brazil, the second largest beef producer and one of the 10 largest GHG emitters in the world, plays a key role in this scenario.

The present study analysed the operational, technical, and institutional feasibilities of scale replication of low-carbon good agricultural practices in the context of family livestock farming with the objective of proposing a scale-up intervention strategy focused on the adoption of such practices and the mitigation of deforestation in the Amazon biome.

The choice of the scope was justified after the understanding that most of the current initiatives are restricted to medium and large properties, many of which are in rural areas consolidated in the Legal Amazon, not reaching the share of small-scale farmers - which have scarce access to resources, technical assistance and technologies -, who are responsible for the least profitable stage within the livestock chain: the production of calves. The Amazon biome was prioritized, since almost a third of the Brazilian cattle herd is located in the Amazon, where the production takes place in extensive systems based on pastures with low use of chemical inputs and little active management practices, resulting in low productivity and, often, in the gradual degradation of the soil. It is also observed that the expansion of livestock farming in the Amazon has been directly associated with deforestation, especially in the international scenario.

The intervention strategy outlined by the study consists of the implementation and replication of the Innovation and Learning Hubs (ILH), based on a model and methodology developed by Solidaridad in Brazil and implemented in the Tuerê settlement in Novo Repartimento / PA. This model is based on three central pillars, namely: implementation of field actions; use of online platforms and applications for family agriculture; and, the establishment of partnerships and the strengthening of local institutional arrangements.

The purpose of replicating the ILHs is to generate an impact on GHG emissions mitigation, to increase the life quality and income of small-scale farmers, and to contribute to the network expansion of new low-carbon businesses. Therefore, the study established targets of emissions reduction in the average productive family unit in the Amazon through a system of GHG emissions measurement based on land use in the region.

Estimates indicated that the implementation of management practices, such as pasture conditions improvement, increase in fertility rate, increase in herd stocking rate, and decrease in deforestation can lead to a reduction in carbon emissions of 75% per kg of weaned calf. According to calculations, livestock farming emissions can be reduced from 4.8 tCO2e / ha / year to 2.7 tCO2e / ha / year, demonstrating, in an unprecedented manner, the potential of family farming to become a GHG sink in the Amazon and to contribute to the national emission reduction targets. We conclude that the ILHs, through a systemic and structured approach to existing knowledge, constitute an accessible intervention strategy for the small-scale livestock farmer in the Amazon region, and are capable of creating a favourable environment for business development and attracting new investments into the territory.

1 Introduction

This study is the result of an exploratory mission by Wageningen Livestock Research (WLR) and Wageningen University and Research (WUR) held in Brazil in March 2018, during which a mapping of stakeholders, organizations and urgent issues related to the livestock sector was developed (de Paiva Seroa da Motta & Hulsman, 2018). At that stage, the relationship with the Dutch Embassy in Brazil, specifically with the Agriculture Division and their attaché was strengthened.

In October of the same year, emerged the opportunity to develop a Seed Money Project (SMP). The Ministry of Agriculture, Nature and Food Quality (*Ministerie van Landbouw, Natuur en Voedselkwalite* - LNV) from the Netherlands requested, through the Dutch Embassy, WLR to address the issue of small-scale livestock farming in the Amazon biome. This issue is an extremely important topic that has, nonetheless, received little attention when compared to the medium and large scale livestock farming.

Thus, in search of institutions with specific and in-depth knowledge about the Brazilian farming sector, WLR joined the Solidaridad Brazil Foundation (*Fundação Solidaridad Brasil*), the Brazilian Roundtable on Sustainable Livestock (*Grupo de Trabalho para Pecuária Sustentável* - GTPS) and the Brazilian Agricultural Research Corporation (Embrapa) to carry out the SMP, which main result is the present study.

Considering the importance of actions and interventions that seek to contain deforestation in the Amazon region, and to promote good agricultural practices (GAP) aiming at the mitigation of the greenhouse gas (GHG) emissions, it is intended to understand if pre-existing models and methodologies of integrated and low-carbon intervention can be configured as an Innovation and Learning Hub (ILH) for the small-scale livestock breeding in the Amazon. The small-scale properties are considered as productive units up to four fiscal modules[1] (to understand the scale of rural properties, see Figure 1). To this end, it is assumed that for its applicability and scalability within this context, it is necessary to identify ongoing innovative experiences and to establish strategic partnerships. This way, recommendations can be made regarding the establishment of financial, productive, and operational arrangements for the near future.

[1] The classification is defined by the law no 8.629 of February 25th, 1993 and it takes into account the fiscal module (and not only in hectares), which varies according to each municipality. Available at: <http://www.incra.gov.br/tamanho-propriedades-rurais>. For more information on the dimensions of the fiscal module by municipality, visit: <http://www.incra.gov.br/sites/default/files/uploads/estrutura-fundiaria/regularizacao-fundiaria/indices-cadastrais/indices_basicos_2013_por_municipio.pdf>.

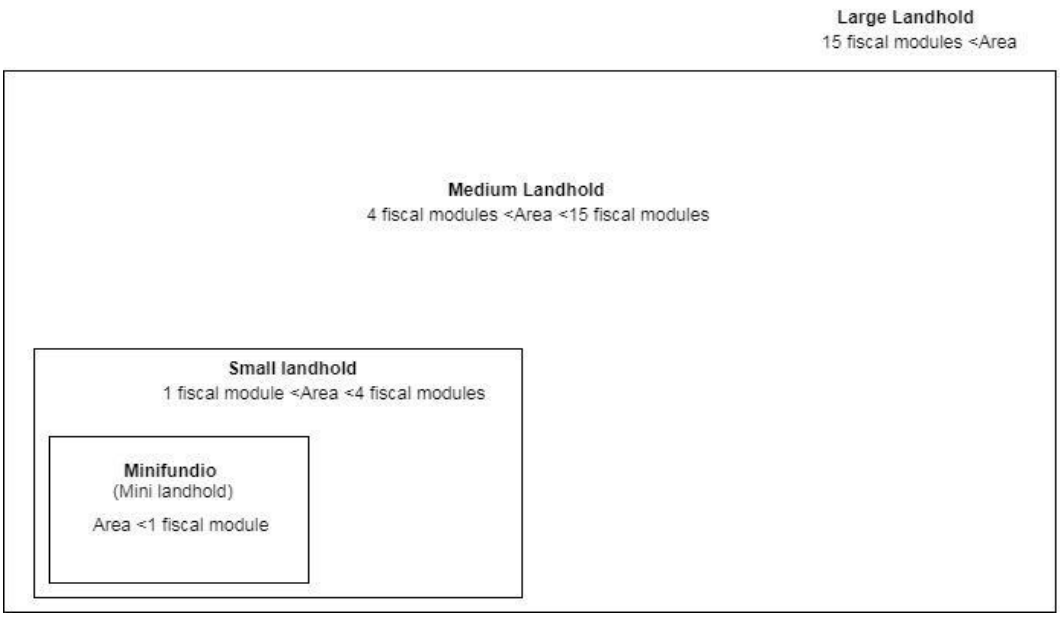

Figure 1 *Scale of the rural properties according to the classification of the National Institute of Colonization and Agrarian Reform (Instituto Nacional de Colonização e Reforma Agrária - INCRA).*

Due to the challenge and complexity of this theme, the number of initiatives to develop sustainable solutions in the Amazon is still small, especially when it comes to small-scale livestock farming. Among some of the initiatives, it is worth noting the intervention model developed by Solidaridad Brazil, which has the objective to improve the carbon balance of productive family units in the Amazon through the integration of three systems: cocoa, livestock, and forest (ILPF).

To implement this model, a methodology of technical assistance and continuous and integrated rural extension has been outlined aimed at productive practices that promote the most efficient use of the soil and contribute to the reduction of deforestation. The methodology is implemented on the field through frequent visits to the productive units, lectures, training, and collective capacitation on good production practices for farmers and extension technicians. Additionally, it includes the implementation of participatory demonstration units – which were installed to test innovative technologies and support the dissemination of good agricultural practices in the region - and the development and use of digital tools. All the activities developed are monitored and evaluated according to their impact in changing practices and their results in production, mitigation of GHG emissions, and an increase in family income. Since 2015, the methodology of Solidaridad Brazil, funded by the Good Energies Foundation and the Dutch Ministry of Agriculture, has been tested and used together with a group of farmers in the Tuerê settlement, in Novo Repartimento / PA, seeking to promote:

- optimization of the use of chemicals;
- improvement in the pasture conditions and herd management;
- recovery of degraded soils;
- genetic improvement of the bovine herd;
- diversification of production;
- improvement of the efficiency in the management of the productive unit;
- the conservation of forests.

In this manner, our study proposes the establishment of ILH based on the model, methodology and field experience developed by Solidaridad Brazil; on its validation for the scientific knowledge and expertise of WLR; on the GAP approach developed by Embrapa; and on the sectorial articulation and network of contacts promoted by GTPS (Brazilian Roundtable on

Sustainable Livestock) for the establishment of partnerships and dissemination of practices and innovative experiences in the context of low-carbon family livestock farming in the Amazon.

1.1 Objectives

The present study proposes to analyse the challenges and the operational, technical, and institutional feasibilities of scale replication of low carbon practices in the family livestock farming sector in the Amazon biome. To that end, the model and methodology implemented in the Tuerê settlement, in Novo Repartimento / PA - through the project Inclusive and Sustainable Territories in the Amazon[2] - were used as references for the establishment of ILH for small-scale livestock breeding in the Amazon. In addition, based on this analysis, it is intended to present a strategy to scale the ILH implementation, taking into account other initiatives (e.g., Strategy for Preservation, Conservation, and Inclusion[3] - PCI; Program for the Sustainable Production of Calves[4], etc.) and the proposal of new partnerships and institutional arrangements.

1.2 Study innovation

Based on the declaration of the new vision of circular agriculture of the LNV[5] from the Netherlands, published in October 2018, this study proposes to unite actors from both countries with the objective of, jointly, increase efforts in the promotion of sustainable livestock farming in the Amazon. As a result, innovation is a key feature that permeates the entire structure of this proposal, from the target audience to which this study is directed, the proposed method and model of intervention, to the strategy for its scaling-up, as we intend to demonstrate .

Currently, in the Amazon region, about one-third of the livestock farmers are considered indirect suppliers in the meat production chain (Hall, 2017). They are responsible for the breeding and rearing phases, for which monitoring and traceability tools are still limited or non-existent. Although it is the basis for sustaining beef cattle, breeding is traditionally considered a marginal activity and with low profitability, being usually destinated to the worst pasture areas, which are located in small farms and rural settlements. It is worth noting that the breeding activity in the Amazon is inserted in a model of land speculation that reproduces a mode of occupation responsible for the perpetuation of a cycle of poverty and deforestation, on which the methodology proposed hereby intends to intervene.

In general, projects and programs to reduce GHG emissions within the livestock sector have focused their attention on large and medium-sized farmers as the target audience for interventions. However, considering that significant amounts of GHG emissions in agriculture come from unsuitable management practices, and that part of the Amazon deforestation also occurs in land parcels of indirect suppliers, many of which are small-scale farmers, it becomes clear there are a necessity and urgency of initiatives that aim at promoting sustainability and at an effective reduction of GHG emissions along all links of the production chain.

In terms of the methodology, the innovation is in the proposal of the ILH which focuses on the small-scale livestock breeding, and it is based on the intervention model developed by Solidaridad Brazil that has been implemented with the small-scale farmers in the Tuerê settlement. It is worth mentioning that ILH aims to foster the adoption of programs of GAP

[2] For more information, visit: https://solidaridadsouthamerica.org/sites/solidaridadsouthamerica.org/files/publications/low_carbon_family_agriculture_in_the_amazon_0.pdf>.
[3] Available at: <http://pci.mt.gov.br/>.
[4] Available at: <https://acrimat.org.br/portal/producao-sustentavel-de-bezerros/>
[5] Available at: www.government.nl/ministries/ministry-of-agriculture-nature-and-food-quality/documents/policy-notes/2018/11/19/vision-ministry-of-agriculture-nature-and-food-quality---english

outlined by Embrapa and it should meet the sustainability criteria established by the GTPS, as well as being integrated into the Sustainable Livestock Initiatives Map[6] developed by GTPS.

In addition, the strategy of scaling-up and making the ILH feasible in the Amazon context based on the articulation of partnerships involving the public, private and third sectors and on the use of existing stakeholders networks, it is also innovative due to its potential to contribute to the strengthening of territorial environmental governance, increasing the visibility of the production chain beyond the level of the direct supplier, and bringing to the legality actors that participate in it.

1.3 Sinergy with local initiatives

The study will identify how collaboration with the institutions and the local government (including facilities / equipment / infrastructure for adult education) can benefit the scaling-up process in the implementation of the ILH in the Amazon biome. The relevance of this theme leads to complementarity and synergy with the interventions carried out by the Sustainable Trade Initiative (*Initiatief Duurzame Handel* - IDH), which develops sustainable livestock farming activities with larger scale farmers in the same territory.

1.4 Priority topics

The study has as a priority to identify existing experiences to provide technical and economically viable alternatives to prevent the extensive livestock breeding to contribute to illegal deforestation in the Amazonian biome. In this context, the themes of public policies related to inclusive agriculture, livestock, and the environment were considered here. Within the scope of the LNV, this SMP is part of the initiative "*Kansen voor Morgen - BO thema internationale voedselsystemen 2018*".

1.5 Next steps

The study intends to also contribute to leverage partnerships between Brazil and the Netherlands, to boost financing for the improvement and establishment of ILH in the Amazon biome, as well as to measure the potential of climate change mitigation and improvement of the beef cattle chain at the breeding phase, reached by the ILH, through scaling-up and on the long-term.

1.6 Study partners funding institutions

The study was requested by the agricultural attaché of the Netherlands in Brazil, funded by LNV and developed in partnership by WLR, Solidaridad Brazil, Embrapa, and GTPS.

WLR has extensive experience on the impacts of animal production systems on the environment. Considering it is a Dutch institution, most of their research is related to the reality of the country, where the production systems are intensive and often confined. Thus, the research and knowledge transfer applied to several productive models focuses on identifying the environmental effects (positive and negative) while understanding the underlying processes of these systems in the soil and atmosphere.

[6] Available at http://gtps.org.br/mapa-de-iniciativas/.

The goal is to promote the environmental sustainability of livestock and agricultural systems. WLR research translates society's demands on livestock production into viable and sustainable solutions for the sector[7]. The international cooperation of WLR has long been established in countries in Asia and Africa, and it is approached as a strategy to strengthen initiatives in Latin America. Therefore, this work is of great importance for WLR and its work in Brazil.

Solidaridad is a civil society organization founded in the Netherlands in 1969 to work with family farmers and fight poverty in the countryside in developing countries. It operates in 35 countries on the development of socially inclusive, environmentally responsible, and economically profitable value chains in agriculture. Solidaridad works in partnership with actors from the different links of the production chains, including companies, governments, nongovernmental organizations, research institutes, farmers' associations, farmers and cattle ranchers. It supports farmers, with an emphasis on smallholder producers to help them produce more and better, promoting the transition to farming production that respects people and the planet, based on good commercial relations which guarantee good life quality for rural communities.

The GTPS is the central meeting of the Brazilian livestock. It originated from a demand from the financial sector in 2007, in order to create tools to reduce the risk of financing activities associated with deforestation. To discuss and formulate proposals for the sustainable development of the national livestock, it is a non-profit association that gathers representatives of all the links in the bovine livestock value chain in Brazil. Rural producers, processing industries, input and service companies, financial institutions, civil society organizations, retailers, and restaurants are all represented. Research and educational institutions also act as collaborators, as well as government representations. GTPS has practical tools to support the continuous improvement of the sector, promotes dialogues around the most sensitive issues for the chain, trying to find a balance between the economic, social, and environmental pillars.

[7] For more information on WLR's work, visit: <www.wur.nl/livestock>.

2 Challenges and Opportunities for the Implementation of Innovative Strategies for Livestock Farming in the Amazon

Livestock farming is a key activity for food security, as animal products provide 34% of the total protein consumed globally and supply many essential micronutrients to humans. The livestock production chain accounts for about 14.5% of GHG emissions, of which 2/3 are attributed to cattle raising. Demand for livestock products is growing rapidly, often referred to as the "livestock revolution," presenting opportunities and threats to humanity.

Brazil, one of the largest emitters of GHG in the world, plays a fundamental role in this scenario. In accordance with the Nationally Determined Contribution (NDC) targets, the country has committed itself to reduce emissions by 37% by 2025 and by 43% until 2030, below 2005 levels (Brazil, 2015). The outlined measures include not only mitigating deforestation and recovering 12 million hectares of native vegetation, but also, as part of the Low Carbon Agriculture Program (ABC), the recovery of 15 million hectares of degraded pasture areas and four million hectares of crop-livestock-forest integration (ILPF) and Agroforestry Systems (SAF) by 2030 (Brazil, 2017).

Nearly a third of the total population of the Brazilian cattle herd is located in the Amazon biome. Beef production in the region is generally characterized by extensive pasture systems with low chemical input, little active management practices, resulting in low productivity and often in gradual soil degradation (zu Ermgassen, 2018). Considering that the current pasture productivity of Brazil is between 32-34% of its potential, an increase in productivity up to 49-52% would meet all demands by 2040 (Latawiec, 2014).

As a result, the expansion of cattle ranching in the Amazonian regions has been associated with the deforestation of this biome. However, as of 2005, the expansion of the cattle herd in the Amazon seems to occur simultaneously to a strong reduction in the deforestation rate, due to a combination of the expansion of the protected areas, market initiatives and economic deceleration (zu Ermgassen, 2018). This development indicates a continuous process of intensification. However, according to Pacheco (2017), it is mostly limited to large-scale rural properties.

An overview of the different recent initiatives that promote sustainable livestock farming in the Brazilian Amazon suggests that there are a variety of technologies that may increase livestock productivity and profitability in this context (see Annex A). Although diverse, such initiatives share many similarities, including the focus on the training of the rural producers, maintenance of agricultural records, improvement of pasture management and, in particular, the implementation of the rotational grazing system and fertilization through chemical inputs or no-tillage (zu Ermgassen et al., 2018).

Thus, in order to understand more deeply the dynamics of small-scale beef cattle livestock farming in the Amazon and, consequently, the determining factors for the implementation of innovative strategies, we will initially present the socio-environmental and political context in which this activity is inserted, through a brief history of the region’s occupation and the land use change in this biome (2.1). Consecutively, we will explore the gaps within the meat production chain in order to demonstrate the urgency of interventions on the breeding stage, as well as the challenges and opportunities for the sector (2.2). Lastly, we will discuss

Solidaridad's experience in the Tuerê settlement as a reference for an existing intervention that presents a potential for scaling-up throughout the future ILH (2.3).

2.1 Socio-environmental and political context of livestock farming in the Amazon

The Amazon biome is the largest continuous remnant of rainforest on Earth, covering 5.3 million km2 (Eva et al., 2005), which accounts for about 40% of the area of tropical rainforest remaining on the globe (Fujisaki et al. , 2015). In Brazil, this biome extends for approximately 4.2 million km2(IBGE, 2004), which means approximately 49% of the country's territory.

In spite of the Amazon's global importance, related to its high biological diversity and to the innumerable ecosystem processes and services related to it - including climate regulation -, the accelerated rate of change in land use, observed especially in the last three decades, has led the Amazon to play a prominent role as one of the largest emitters of carbon dioxide (CO2) in the Land Use Change class (SEEG, 2018). In particular due to the deforestation of areas with the following establishment of large-scale pastures and crops, a tendency which has been attenuated since 2005, when agricultural production in the region increased concomitant to a significant reduction in deforestation (Figure 2).

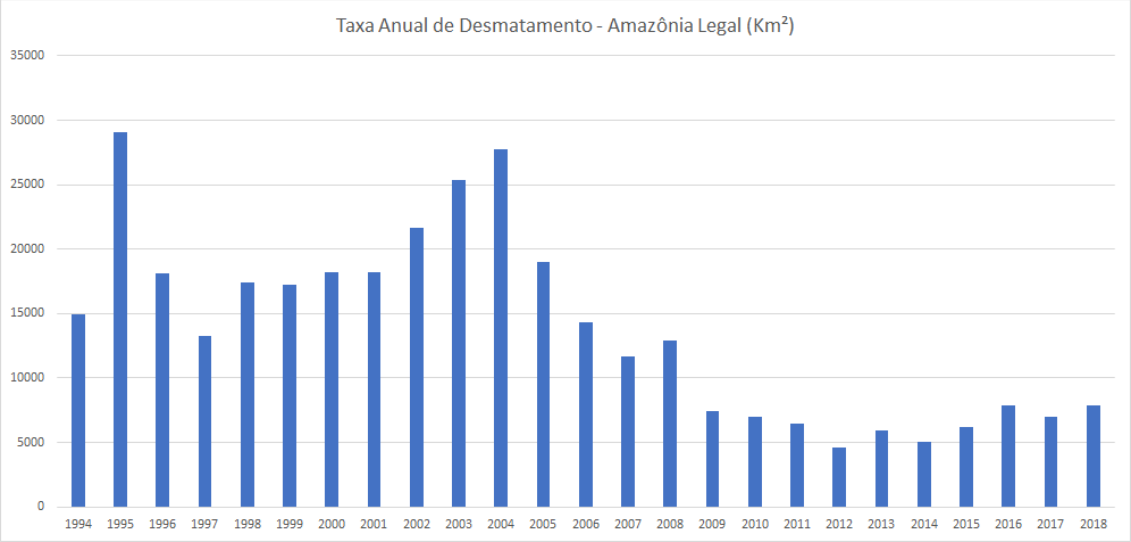

Figure 2 *Annual deforestation rates in the Legal Brazilian Amazon. Source: PRODES/INPE, 2018.*

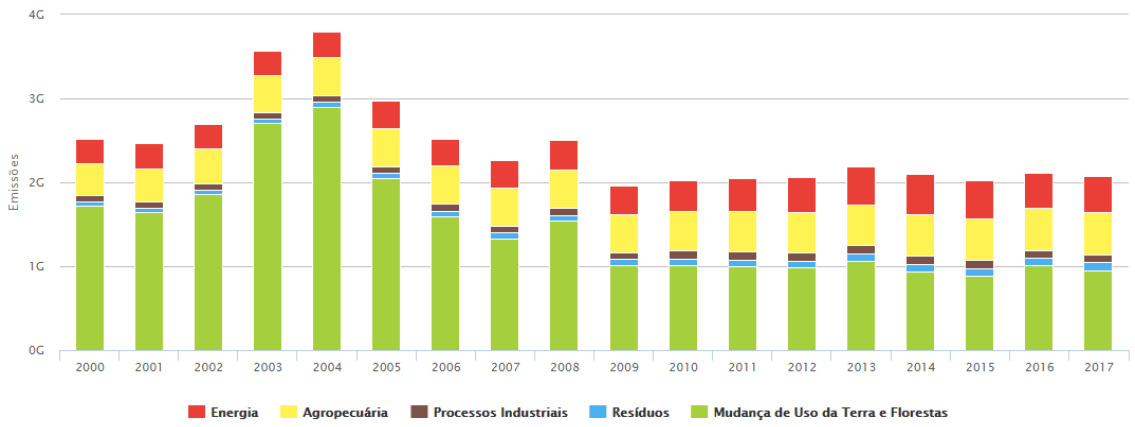

Figure 3 *GHG emissions in Brazil by sectors. Source: SEEG, 2018.*

The process of occupation of the Amazon territory began in the 1960s as a result of a series of state interventions aimed at the exploitation of natural resources, occupation of the region and integration of the North of Brazil in the national socioeconomic context. Among the interventions implemented with these objectives, the creation of the Superintendency of Development for the Amazon (SUDAM), the launch of the National Integration Plan (PIN) and the construction of the Trans-Amazonian Highway represented initial milestones for the establishment of colonization projects in Pará, Rondônia and Mato Grosso, which aimed to promote the occupation of the area, absorbing surplus population of migrants from the Northeast and, thereafter, from other regions of the country.

From the 1980s, this process was intensified, starting to occur pari passu to the rates of deforestation, a fact that is evident when considering that the three states target of the projects of state intervention are part of the region called "arch of deforestation" and currently register the largest deforested areas within the biome.

Data from the Project Monitoring the Brazilian Amazon forest by satellite (PRODES) conducted by the Brazilian Institute of Space Research (INPE) show that after the deforestation rates in the Amazon reached their highest peak in 1995 (29,100 km2), they fluctuated over a decade on average of 19.7 thousand km2 (PRODES / INPE), reaching a new peak in 2004 (27.8 thousand km2). From 2005 to 2012, there was a significant and gradual drop in the rate (4.6 thousand km2) as a result of a convergence of public policies - including the creation of protected areas – and business initiatives policies with the effective use of monitoring systems and credit restriction mechanisms (AGUIAR et al., 2017), the creation of sectoral agreements such as the Soybean Moratorium and the Conduct Adjustment Declaration (TAC) of the Meat in Pará, as well as market factors for that determined period.

In the following years, the rates showed small variations, showing a tendency to increase until 2018, when there was an increase of 13.7% in the deforested area in relation to the previous year, reaching an area of 7.9 thousand km2.

The drastic process of change in cover and land use observed in the Amazon over the aforementioned period was mainly due to the replacement of native vegetation by pastures in medium and large farms, to the establishment of family agriculture centres and settlements of the agrarian reform and, more recently, large-scale agriculture, mainly soybean cultivation - a process observed more intensely in Mato Grosso – which has as main drivers the economic opportunities derived from various regional development programs and the rapid expansion into global markets of agricultural commodities (Ometo, Aguiar & Martinelli, 2011).

In general, the GHG emissions in Brazil (Figure 3) follow the same trend presented in the deforestation rates (Figure 2), a fact that is due to the Land Use Change sector be the one responsible for most of these emissions since 1986, followed by the Agriculture and Livestock sector. When GHG emissions data are grouped according to the economic activity, Agriculture is the primary source, accounting for 74% of the total emissions in 2016, of which almost two thirds are originated from the conversion of forests into pastures and agriculture and the remainder from direct livestock emissions, due to enteric fermentation and soil management (SEEG, 2018).

According to the analysis prepared by the Greenhouse Gas Emissions and Removals Estimates (SEEG)8 in 2018, if the total gross GHG emissions follow the trend observed between 2010 and 2016, Brazil will not be able to meet the target it has established in the Paris Agreement by 2020, when it is estimated to reach 2,395 billion tonnes of CO2e, about 15.9% above the reduction proposal determined by the National Policy on Climate Change (Law 12.187/2009).

[8]The SEEG is an initiative of the Climate Observatory that comprises the production of annual estimates of GHG emissions in Brazil. The Estimates of Greenhouse Gas Emissions and Removals are generated according to the guidelines of the Intergovernmental Panel on Climate Change (IPCC), based on the methodology of the Brazilian Inventories of Anthropogenic Greenhouse Gas Emissions and Removals elaborated by the Ministry of Science, Technology and Innovation (MCTI), and on data obtained from government reports, institutes, research centers, sectorial entities and non-governmental organizations. Further information is available at: http://seeg.eco.br/oque-e-o-seeg/.

The scenario outlined points to the extent of the efforts and challenges to be faced in order for Brazil to be able to fulfil the commitment made in the Paris Climate Agreement, in force since 2016, according to which it should reduce GHG emissions, compared to 2005 levels, by 37% by 2025 and by 43% by 2030. Thus, the elimination of illegal deforestation, especially in the Amazon, the improvement of the farming production systems, including the recovery of degraded pastures and reorganizing the environmental liabilities are, or should be, priority themes of the Brazilian climate agenda in the coming years (Rathmann, 2017).

In line with the efforts to achieve climate goals, the "2030 Agenda for Sustainable Development", established in 2015 by the United Nations General Assembly, proposed a plan of action to achieve 17 sustainable development goals (SDG) by 2030, which, in short, should contribute to global sustainability in its social, environmental and economic axes. In the context of this plan, it is considered that initiatives and actions with the small-scale rural producers aiming at the improvement of their production systems may present significant contributions in the achievement of at least five of the objectives delimited. These include:

- Achieve food security through the promotion of sustainable agriculture (SDG 2);
- Promote inclusive and sustainable economic growth (SDG 8);
- Make human settlements inclusive, safe, resilient and sustainable (SDG 11);
- Ensure sustainable patterns of production and consumption (SDG 12);
- Take urgent action to combat climate change and its impacts (SDG 13);
- Strengthen the means of implementation and revitalize the global partnership for sustainable development (SDG 17).

Contrary to these efforts, the Brazilian political and environmental scenario that was established recently after the 2018 presidential elections, it is marked by changes and fragility in the environmental administrative structure at the federal level caused by the ministerial reform, posing challenges, among them the theme of climate change, which was not included in the attributions of the Ministry of the Environment (MMA), both in terms of conducting national policy and international negotiations, specifically with regard to the Paris Agreement.

The structural weakening of the MMA, the transfer of organs and attributions, such as the Brazilian Forest Service (SFB) and the Rural Environmental Registry (CAR) to the Ministry of Agriculture, Livestock and Supply (MAPA), represents a significant change in environmental governance. On the other hand, the increased representation of the agribusiness sector in the Congress and the Executive, indicate a great opportunity for this sector to play the main role in strengthening the low carbon agenda, maintaining and expanding Brazil's participation in the international meat market in a sustainable manner. Furthermore, they emphasize the importance of establishing and strengthening institutional and multisectoral arrangements so that the benefits may be disseminated throughout the livestock chain and reach the smallholder farmers.

At the international level, the Brazilian farming sector stands out as a major exporter of beef and soy, both commodities historically linked to deforestation in the Amazon. In this context, the adoption of sustainable and low carbon practices is of paramount importance for the sector, which has received intense international pressure due to the risk of exposure to supply areas with deforestation occurrence.
Thus, in view of the importance of relations between producing countries (in this case, Brazil) and consuming (European Union, China, Russia, etc.), initiatives linking Brazilian and international institutions, such as the initiative of this study, are fundamental in order to foster access to technology, to financing, and to the best production and management practices for the sector.

2.2 Livestock breeding: an invisible link in the chain

As we sought to elucidate in the previous topic, the development and expansion on large-scale of the livestock activity in the Amazon region have been at a high environmental cost, especially through deforestation and the subsequent conversion of land use to pasture. Between 2003 and 2013, the cattle herd grew by about 200% in this biome, while in the rest of the country, the observed growth rate was 13% (IBGE, 2014).

Despite the importance of this activity for the international economy and trade – the livestock's increasing GDP presented a contribution of 6.8% to the total GDP and 32% to the Agribusiness GDP in 2017 (IBGE, 2018) - legal compliance has been typically weak in the sector and the efforts to transform land use practices have shown to be ineffective (NWF, 2015). However, in the last decade, awareness campaigns with high reach carried out by non-governmental organizations (NGOs) have exposed the impacts caused by the expansion of cattle breeding in the Amazon, as well as the purchase of agricultural products by multinational corporations from areas with incidence of deforestation. This scenario has led to a combination of interventions in the livestock supply chain, more specifically, the commitment of some slaughterhouses and retailers to zero deforestation, the imposition of criteria to the suppliers and the implementation of government policies (Gibbs et al., 2015; NWF, 2015).

Among the interventions in the meat supply chain in this period, it is worth noting two very similar agreements signed in 2009:

- The agreement called "TAC of meat" through which Conduct Adjustment Terms (TAC) were signed between the Federal Prosecution Service (MPF) and the large producers and retailers who were accused, respectively, of illegal deforestation and purchasing cattle from these areas in Pará. Through these TACs, the slaughterhouses are committed to avoiding buying meat from slaughterhouses connected to illegal deforestation.
- The "Zero Deforestation" or the "G4 Livestock Agreement" is a commitment between the largest Brazilian slaughterhouses (JBS, Marfrig, Minerva and Bertin9) and Greenpeace through which these slaughterhouses have committed to the establishment of monitoring systems to prevent the purchase of animals from farms with deforestation and illegal activities (NWF, 2015).

Both agreements present wide-ranging commitments, since the first one reaches ⅔ of the slaughterhouses inspected by the federal government in the Legal Amazon (Gibbs et al., 2015) and the second comprises about half of the documented slaughters in the region (NWF, 2015). Moreover, the two agreements aim to block purchases from properties with deforestation incidence, or that are not registered in the Environmental Rural Registry (CAR). However, the TAC of meat has an emphasis on avoiding illegal deforestation, in accordance to what it is determined in the Brazilian Forest Code, while the G4 goes beyond the legality, prohibiting any opening of the area even if within the legal limit (NWF, 2015).

Almost ten years after the deforestation agreements, an analysis carried out by Gibbs et al. (2015) of the daily purchases made by slaughterhouses before and after these agreements showed that both had a considerable effect on the meat production chain, consisting of efficient interventions to promote changes in the purchasing criteria and on the purchase blockage in properties that have deforested. However, both agreements currently cover only the properties of the direct suppliers of the slaughterhouses, not disclosing matters of the land properties of the indirect suppliers, which are considered hereby the breeding and rearing stages of the supply chain (for further understanding of the chain, see Figure 4). As the authors of the study point out, although indirect suppliers are mentioned in both agreements, the implementation efforts of this supply chain link have been incipient.

[9] The latter was subsequently purchased by JBS.

In this way, it is observed, nowadays, that the monitoring systems based on the cross-reference of public information - such as the Animal Transportation Guide (GTA)10, the CAR and the list of areas embargoed by the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) - already reach dozens of thousands of properties (NWF, 2015), representing a significant advance for the livestock sector as a whole. Nevertheless, the extension of the coverage of these systems and their extension to the indirect producers, although challenging - in the second case due to the lack of stronger commercial relations between producers responsible for breeding, rearing and fattening - is essential to guarantee cattle production with zero deforestation, since it is precisely at this junction of the supply chain, currently invisible to the monitoring systems, that a large part of the deforestation probably continues to occur (NWF, 2015).

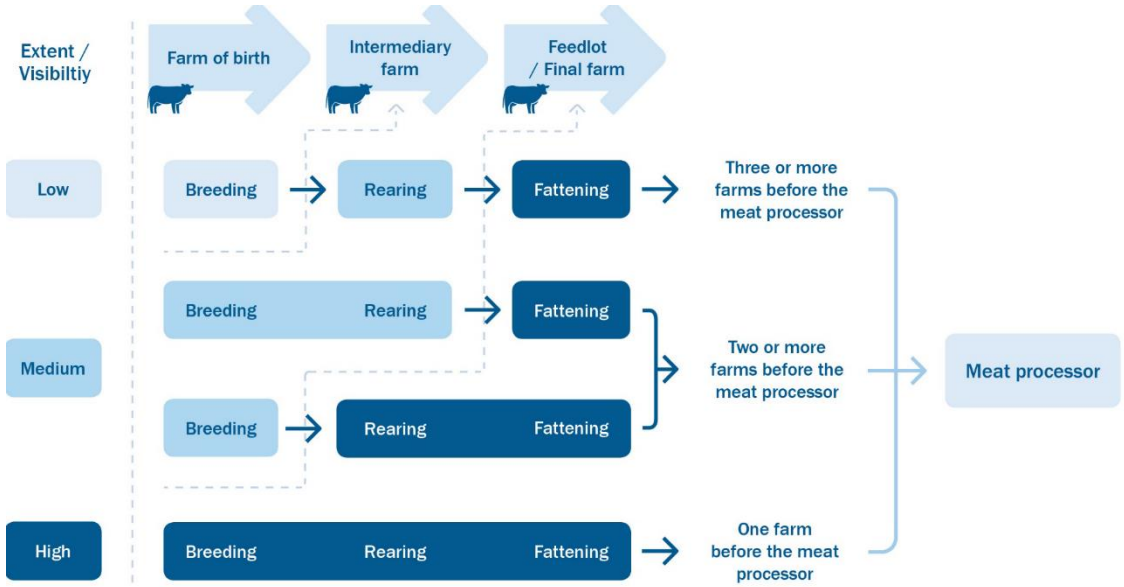

Figure 4 *Flow diagram of the meat production chain and the visibility in its different links. Source: Proforest, 2017.*

In order to promote improvements in the livestock chain for sustainable and low carbon production that reach all its links, in addition to increasing the monitoring and traceability of the proprieties with livestock production, efforts have been made to increase productivity through the transition from an extensive livestock system to a management with more intensified levels and adoption of technologies. However, such initiatives have generally been restricted to large and medium-sized properties, often in rural areas consolidated in the Legal Amazon with a particular focus on the stages of rearing and fattening, and not reaching the small-scale farmers, which have scarce access to resources, technical assistance and technologies and are responsible for the less profitable stage within the beef cattle chain, the breeding, or in other words, the production of calves (Cavalcanti, 2011).

Therefore, with the increasing trend of producers specializing in some of the links of the meat production chain and the intensification of production observed especially in the stages of rearing and fattening (Cavalcanti, 2011), it is possible to infer that the demand for calves should increase in the coming years. Thus, in order for this demand be supplied in a sustainable, efficient and in a deforestation free manner, efforts are essential to use innovative and low-carbon technologies aimed at improving the productivity of livestock breeding, as well as the development of monitoring and control mechanisms for the indirect producers.

[10] Official and mandatory document for animal transportation in Brazil, which contains information on the destination, the sanitary conditions and the purpose of animal transport.

Although projections for meat production in the Legal Amazon region show a strong growth trend, most part of the producers, especially the more traditional ones and with less resources, are carrying out the activity with low technological and managerial level (EMBRAPA, 2018). In order to reverse this scenario, a joint effort and commitment of the whole production chain is necessary in order to allow the techniques of management, production and good practices to reach the small-scale livestock farmers and be effectively incorporated into their production systems.

2.3 The experience in Novo Repartimento-PA: a way to achieve scale impact

The experience of the project "Inclusive and Sustainable Territories in the Amazon" of Solidaridad over the last four years with the farmers of the Tuerê settlement and the technicians from Novo Repartimento, as well as the results achieved so far, such as the improvement of the production and commercial practices related to the cultivation of cocoa and to the livestock in the breeding phase and the articulation for the acceleration of the CAR and the process of environmental regularization, attest to the potentiality and opportunity for scaling-up the scenarios and improvement processes within Tuerê, the neighbouring municipalities and in the future for the entire Amazon biome. This justifies the choice of this experience as a reference of an intervention model for the ILH proposed in this study. In this section, we will firstly present a brief description of the project's operational area (2.3.1) and secondly the intervention model and methodology used, as well as the preliminary results of this project (2.3.2).

2.3.1 Description of the project's operational area

Founded in 1991, Novo Repartimento is a municipality belonging to the south-eastern region of Pará which origin dates back to the settlement of a village created after the construction of the Trans-Amazonian Highway (BR-230), which was later relocated due to the construction of the Tucuruí Hydroelectric Power Plant. Until the 1990s, wood logging and the collection of the Brazil nut were the main drivers of the local economy, while livestock farming had a small contribution, being practiced only in systems with a scale greater than 50 hectares. During this period, there were also incentives from the federal government for the production of crops such as coffee, coconut, cupuaçu and passion fruit, among others, through lines of financing offered to farmers by the Banco da Amazônia (Bank of the Amazon). These incentives did not achieve the expected success due to the lack of well-structured projects, access to the consumer markets, collective organization and qualified monitoring of the technical assistance for crop management.

In the following decade, other governmental incentives for the establishment of settlements in the state, among other factors, generated a considerable increase of the deforestation rates. According to data generated by the Amazon Institute of People and the Environment (IMAZON), between 2000 and 2012 a total of 19.2 thousand km2 were deforested in settlements in the state of Pará, equivalent to 27% of the total deforested in the state for the same period (71 thousand km²). Following this process of land use conversion, the cattle herds increased rapidly in the municipality, from 150,000 heads in 1993 to a population of 900,000 heads in 2017 (IBGE, 2017). Since 2000, cocoa plantations have also begun to expand on the borders of the Trans-Amazon Highway, in Pará, as a result of the implementation of the Executive Commission on Cacao Farming Planning (CEPLAC) in the region. Although it is a relatively recent activity, it currently occupies around 11 thousand hectares in the municipality of Novo Repartimento, generating around R$ 33 million annually for the local economy (IBGE, 2016).

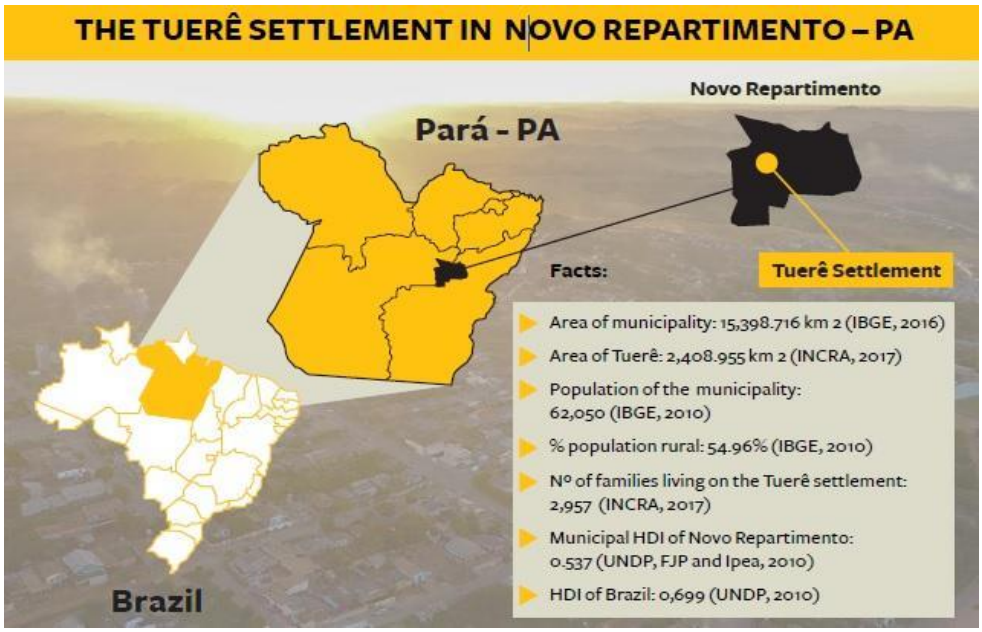

Figure 5 *Map with the location information of the settlement Tuerê and the socioeconomic and demographic data of Novo Repartimento. Source: Solidaridad, 2018.*

In this context, Tuerê, which is among the largest rural settlements in Latin America, was established in an area of approximately 240,000 hectares fully covered by the Amazon biome. In the 2000s, it began to lead the deforestation rates of rural settlements in the Amazon, facing challenges such as illegal logging, inefficiency in landholding regularization and land speculation. The impacts on the forest coverage resulting from the settlement's occupation process, which is known as deforestation in "fishbone", consist of the initial opening of forest areas along the roads, leaving remaining fragments scattered.

Currently, cocoa cultivation and livestock breeding are the main sources of income for farmers in the settlement (Solidaridad Brasil, 2015). Even though the livestock production is generally destined to the larger parcels of the productive family units, due to the characteristics of the management used, the activity has a good liquidity, but inferior when compared to the activity of the cocoa, for example.

In general, the family farmers of Tuerê employ multiple combinations of land use practices and production systems, which include cocoa cropping systems (full-sun and shaded, along with variations in shade-providing tress and cocoa densities), livestock systems (mainly for breeding, rearing, but also for milk production and fattening), native forest (degraded and non-degraded) and annual crops such as açaí and cassava.

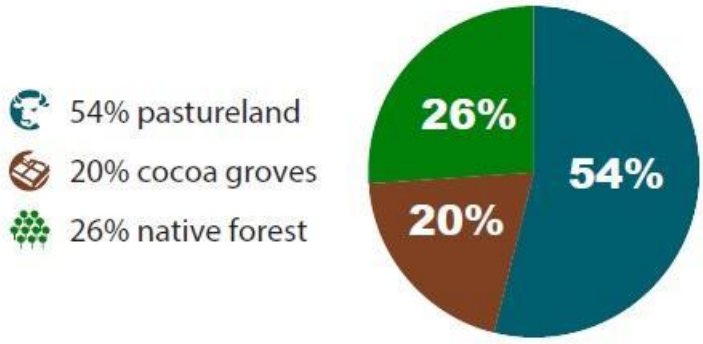

Figure 6 *Example of land use on an average plot (50 ha) on the Tuerê settlement. Source: Solidaridad Brazil, 2018.*

The livestock production system is characterized by the absence of the use of inputs - limestone and fertilizers -, an average occupancy rate of 0.86 head/hectare and a 75% female fertility rate. The cultivation of cocoa, since it is a native species of the Amazon with increasing demand for the domestic and foreign markets, is considered a priority as an economic activity of the state strategic planning, "Pará 2030". In addition to its economic potential, it is a key activity to increase forest coverage from agroforestry systems, reduce soil degradation, promote soil recovery and generate income for family farmers. Therefore, it is an agricultural crop with high potential for social inclusion and provision of ecosystem services.

The size of the forest remnants varies from plot to plot11 according to the strategies adopted by the farmers in the conversion of the forest to pasture and /or crops and, although they do not currently represent a direct source of income for the productive family units, they are important regulators of ecosystems services.

In order to understand the dynamics of deforestation, an analysis of the change in land use was carried out for the period from 2008 to 2016, which allowed the quantification of the environmental liabilities of the settlement and smallholder plots. According to the results obtained, the environmental liability of Tuerê accounts for 13,464 hectares, which corresponds to 18% of the plot of the settlement analysed.
Although considerable, the liability presents a strategic opportunity for the settlement given the possibility of using agroforestry systems of cocoa for compensation in the region, which allows to add value to the product, contributes to the increase of cocoa production and to the strengthening of the national industry and, at the same time, generates income for the farmers since the first year of the system's implementation. Additionally, cocoa cultivation in SAF brings diversification to the productive unit, improves livelihoods and represents an alternative to deforestation, including the smallholder farmers in the process of environmental regularization.

2.3.2 The potential of the project "Inclusive and sustainable territories in the Amazon" and its importance for ILH

Since 2015, the Tuerê settlement is the focus of Solidaridad's intervention, aiming to promote a low-carbon sustainable farming in the context of family agriculture in the region of the Trans-Amazonian Highway in the State of Pará. For this purpose, the goals of the initiative are:

- Encourage efficient land use that promotes the mitigation of GHG emissions and climate adaptation in an inclusive perspective;
- Implement low carbon practices aimed at increasing production and productivity;
- Strengthen environmental governance in order to enable the territory to receive public and private development programs, in a promising and trustworthy environment.

The methodology used as the basis for the interventions in this territory aiming at its future scaling-up includes:

- Training and collective capacitation;
- Individual integrated technical assistance;
- Installation of Demonstration Units;
- Improvement of the commercialization channels;
- Economic education and financial management of production;
- Articulation with public and private actors;
- Support the environmental regularization of the region;
- Digital solutions and inclusion;

[11] It should be noted that the Brazilian Forest Code (Law 12.651 / 2012) determines the allocation of 80% of the area of rural properties within the Amazon biome, where the native vegetation must be maintained for the formation of the Legal Reserve. However, since the determination of the Economic Ecological Zoning (Law 7.398 / 2010), this area can be reduced to 50% of the rural property in some regions, such as in Tuerê. In the case of deforestation in an area greater than that established after July 2008, forest restoration or compensation is necessary. In the case of small-scale productive units (less than 4 fiscal modules), if deforestation occurred before 2008, the deforested area is considered consolidated, and there is no requirement to implement activities of forest restoration and/or mitigation, and new conversions for alternative soil use is prohibited.

From 2015 to the present, 150 family farmers have benefited from the program of continuous technical assistance and collective training of Solidaridad Brazil. During these years, these farmers received individual technical visits in their productive units, as well as participated in courses of collective training in various topics related to their productive activities, with a main focus on livestock farming and cocoa production.

During this period, demonstration units (DU) were installed to test cocoa and livestock management practices and forest restoration techniques. The UDs aim to validate the management model proposed by the Solidaridad Brazil, to substantiate the model of economic viability of these activities and to become a space for learning and dissemination of good practices for the farmers.

It is also part of the actions with the farmers the articulation with the main buyers of the cocoa chain and enabling access to new markets. Among the specific actions related to the market, we can mention the advances of the local cooperative in the commercialization of cocoa beans directly with the industry, via articulation carried out by Solidaridad, and the access of some farmers to the market of fine cocoa, in which one pays better price for the cocoa's almond.

In the context of environmental governance, some of the results obtained were the engagement with public agencies and private companies to accelerate the CAR, its validation with the environmental agency, and a pilot in 50 plots of the Environmental Regularization Program (PRA), as well as an analysis of the gaps and opportunities linked to environmental compliance in the context of rural settlements. In addition, in order to understand and scale-up the intervention, land use mapping, environmental assets and liabilities and ecological connectivity were also carried out.

More specifically, in relation to the commitment to the climate agenda, in order to understand the dynamics of the emissions and to assess the potential contribution of family agriculture in the Amazon to mitigating GHG emissions, Solidaridad developed the study "Carbon Balance in family agricultural production in the Amazon: scenarios and opportunities"12. The study created a specific calculation methodology for the diversified systems of the region through which it was possible to estimate the carbon balance of the family unit in different conditions.

For the calculation of the carbon balance, the key variables were considered in terms of emissions from the productive arrangements, such as: land use change, herd stocking rate, pasture condition and diversity of the cocoa systems. The results show the estimates for the emission balances of the baseline and of the "business as usual" scenarios and with the improvements implemented, making evident the large impact that changes in some practices can generate in terms of emissions mitigation in the small-scale agriculture.

For the baseline, which considers to be no deforestation, there is an emission of 1.76 tCO2e / year and in one of the improvement scenarios the sequestration potential is of 113.7 tCO2e / year. In this study, Solidaridad defined a desirable future scenario in which the adoption of low carbon practices, zero deforestation, changes in land use, and the recovery of degraded pastures through agroforestry systems of cocoa could be the drivers for change in the region. For this future scenario, technical indicators were established to improve livestock practices based on recommendations from Embrapa and scientific research.

In 2018, Solidaridad intensified the interventions related to livestock farming, which are based on the following practices:

[12]The study is available at: https://www.solidaridadsouthamerica.org/sites/solidaridadsouthamerica.org/files/publications/low_carbon_family_agriculture_in_the_amazon_0.pdf

• Management of soil fertility and conservation practices aiming at the recovery of degraded pastures;
• Development of a feasible intensification model for the livestock breeding family-based aiming at increasing the stocking rate in pastures;
• Genetic improvement of the cattle herds in order to improve the fertility of females and increase the profitability of the livestock breeding.

With the adoption of these practices, it is expected to increase the stocking rate up to a maximum that is still favourable in terms of emissions and livestock productivity, both in terms of animal weight gain and the fertility rate and, consequently, an increase in the number of calves produced.

At the end of 2018 a demonstration unit was installed in a plot of the Tuerê settlement. After the baseline study, in which the management practices of the cattle herd and the pastures adopted by the farmers were identified, a rotational grazing area of 7.26 ha was implemented, where good livestock management practices are applied with the goal of sustainable intensification of production on the family property. The farmer and his family received technical training and, with the support of Solidaridad technicians, the following practices were implemented: animal watering system; rotational grazing; registration of information and improvement in the management process; genetic improvement and management of soil fertility.

The implementation of the demonstration units is part of the ATER strategy of Solidaridad, which objective is to complement the individual technical visits and the collective training, as shown in the diagram below:

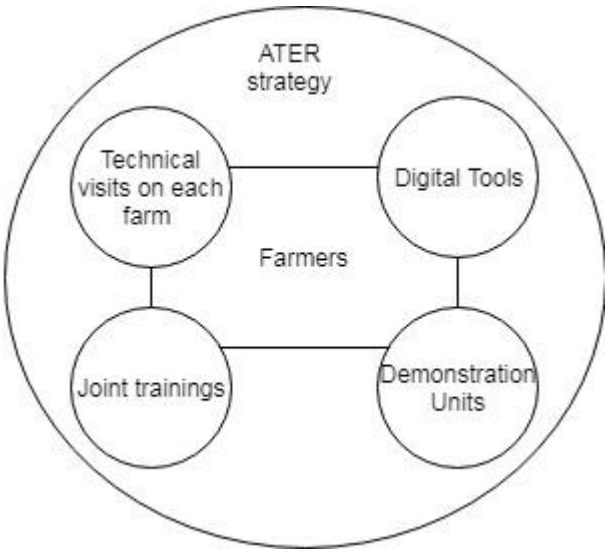

Figure 7 *Diagram of the integrated ATER strategy of the project Inclusive and Sustainable Territories in the Amazon. Source: Solidaridad, 2018.*

In general, the historic, socio-cultural, environmental and land ownership of Tuerê configures this settlement as a suitable place to implement strategies and interventions that aim to reconcile the intensification of production systems - through the efficient use of soil and the adoption of low carbon practices focused on increasing the productivity of farming systems - mitigating GHG emissions and strengthening environmental governance.

3 ILH: the solution in scaling-up

The model proposed by this study is configured as Innovation Learning Hubs (ILH) that make use of existing tools and knowledge and offer innovative solutions to the tripod *production, conservation, and social inclusion* in order to describe the process of learning and the change of practices in small-scale livestock farming in the Amazon.

The central objective of the establishment of the ILH is to generate impact in this activity through models that mitigate GHG emissions, increase the quality of life and the income of the farmers and contribute to the expansion of the network of new businesses. It is, thus, a set of efforts to facilitate a learning environment built on partnerships and institutional arrangements possible for the Amazon region.

The intervention strategy of the NIAs is based on three central pillars:

1. Field Actions: local interventions carried out directly with farmers, agricultural technicians, farmers associations, local governments, and others. The interventions are based on a methodology of integrated ATER, already implemented successfully in the project in Novo Repartimento, which will be presented later. The scope of action of ILH includes agricultural technical knowledge and priorities that are defined according to the potential demands and context of each region.
2. *Online* Platform [13]*:* a digital environment for the training of local technicians and farmers, responsible for providing technical information, room for the resolution of questions, as well as connect initiatives in progress.
3. Partnerships and strengthening local institutional arrangements: responsible to technically and economically enable the ILH, making it possible to leverage sector actions and commitments.

This strategy is part of the consideration that digital solutions and face-to-face actions are complementary actions in the pursuit of overcoming the major difficulties encountered in the sector. In order to achieve both actions, the identification of local demands and partnerships with institutions that leverage the initiative – bringing to the farmers access to tools - and establish the commitment with the other partner institutions.

Following, we will present the conceptual design of the ILH (3.1), the methods and tools to be implemented within this strategy (3.2), and the importance of institutional arrangements and intersectoral partnerships (3.3) in order to achieve impact on small-scale livestock breeding.

3.1 The ILH outline

As presented in the previous chapter, the small-scale livestock farming in the Amazon is extremely relevant to the sector due to its considerable participation in the production of calves in the region. In 2017, of the 11 million animals that trod in Pará, approximately 7 million were originated in productive units focused on breeding (Adepará, 2017). In spite of its importance, the livestock breeding faces several technical challenges, of economic feasibility and that involves also a cultural change, since over the years of occupation of the Amazon, it was established an exploratory model based on change of land use and coverage, which has been reproduced by small ranchers responsible for the production of calves, showing low productivity and, consequently, low economic return in comparison to intensified farming systems.

[13] In order to demonstrate the purpose of this component, we have created a pilot platform that will be supplied hereafter with a description of technical information and new contents. Available at: https://pecuariadecriasustentavel.wordpress.com

In the face of this scenario, Solidaridad Brazil is developing a pilot project in Novo Repartimento, which is responsible for validating the steps necessary for the establishment of the model of the ILH. The project is being implemented in the rural settlement of Tuerê, and it has the central objective to promote profitable and inclusive low carbon farming in the small productive units in the Amazon.

Based on the implemented model, the first step to define a methodology for the study was identifying the soil use pattern in the settlement and the main productive chains already established in the region. Sequentially, the Project invested in activities that would improve practices of cocoa plantation, breeding and forest restoration and conservation, by means of a local strategy of intervention in the productive units. From the definition of the main objective and its regional action scope, based on the described experience, we designed the methodology (Figure 8) that contributes to the intervention strategy of ILH based on field actions, digital solutions and establishment of partnerships and intersectoral commitments to leverage the adoption of efficient and low carbon practices for small-scale livestock farming.

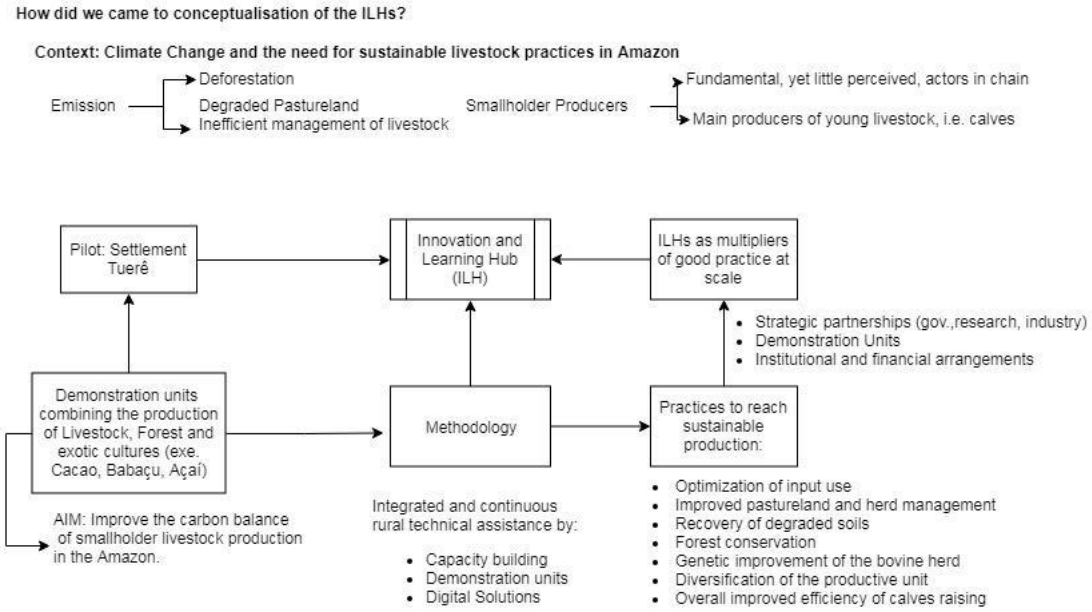

Figure 8 *Flowchart of the conceptual design of the ILH. Source: WLR, Solidaridad, Embrapa, and GTPS, 2018.*

The evaluation of the results obtained in the pilot intervention in Tuerê showed that, as the farmer advances with the adoption of the practices applied, he also becomes able to monitor the improvements and thus interact more actively with the digital tools and with other individuals in his social life, such as other farmers in the surroundings of his productive unit. With the advancement of the knowledge of the farmer on his production practices and opportunities for improvement, the usage of digital tools is emerging as an important support tool. In this regard, Solidaridad developed the *farming solution*[14], a mobile application for the assessment and monitoring of the farmer's practices. Through this application, the farmer can make his plan of action, trade experiences with neighbors and colleagues, and monitor the improvements he makes on the property.

The model incorporates the best practices recommended by the GAP program guide of Embrapa, as well as environmental components included in the project aimed at forest conservation and restoration. For all the learning process to become a permanent cycle in the

[14] Available at: <https://play.google.com/store/apps/details?id=org.solidaridadnetwork.farmingsolution&hl=pt_BR>

regions, strategic partnerships and public and private co-financing are fundamental to the existence of ILHs.

The multiplication and adoption of GAP depend on the access to technology and services to farmers. To that end, partnerships can be set in several ways, including arrangements with other people in the following links of the chain, such as buyers - mainly large producers responsible for the purchase of calves -, the processing industry, and end-consumers. In addition to the typical and possible arrangements within the chain, through this pilot it was identified that partnerships which involve companies that support the access to technologies, inputs, and services in areas that are difficult to reach in the Amazon are essential, because, without these, the changes in the practices by the small-scale farmer is unlikely to be scalable. Thus, in view of the challenges within the scope of the small-scale livestock breeding and the opportunities available for this link of the production chain, it is suggested the implementation of the ILHs.

3.2 Tools and methods to implement the ILH

Until the present day, a series of online and offline strategies were developed aiming to achieve scale impact in the initiatives and interventions with the purpose to improve the agriculture practices in a determined territory (appendix A). To determine these strategies, a selection of approaches and tools considered more appropriate to outline the ILH strategy was done regarding its scaling-up potential. In the following items, we will explore the methods, tools, and their contribution to the intervention strategy that we propose.

3.2.1 *In situ* Methods

- **Continued and integrated technical assistance**
  Through ATER, a cycle of visits starts in the productive units, which begins with a monthly visit in the first year, being reduced gradually in the following years according to the success of the farmer and the improvements on the property. The visits are guided by the success indicators related to the production practices, which are registered and monitored. This monitoring is carried out by means of a digital system, the *extension solution*[15], a mobile application developed by Solidaridad for the extension technicians to support the rural technical assistance. With the *farming solution* application, which is part of the digital farming tools of Solidaridad, it becomes possible to have remote interaction between farmers and technicians, as well as enables the performance analysis on sustainability of the productive units and the organization of a work plan aimed at continuous improvement of the productive model.

- **Collective training and qualifying courses**
  The collective training for farmers and technicians occurs monthly. Although conceptually, the training has been designed to contribute to the farmers' qualification, through the ILHs, there are also opportunities for the training of regional technicians and for bringing them up-to-date. Furthermore, the exchange of experiences among them favors solutions and partnerships.

- **Demonstration Units**
  An important component in the methodology is the collective identification of the problem to be solved and the experiment for resolutions with support of the qualified technician, who is prepared to adapt the technologies to the local situation. To facilitate and encourage this process, the establishment of demonstration units (DU) is a fundamental tool, resulting in this interactive learning and empirical environment. Additionally to the educational role of the UDs, they also present an experimental character, since, through them, it is demonstrated the usage of technology. In the context of ILHs, the UDs combine

[15] Available at: <https://play.google.com/store/apps/details?id=org.solidaridadnetwork.extensionsolution>

technological solutions to the study of economic feasibility of the adoption of the technologies.

We emphasize that, especially in the case of small-scale livestock farming, field demonstration of economic feasibility and logistics of adoption of new technologies is crucial. To this end, the participation of the private sector is essential, because in many situations a lack of access to services and supplies is the major obstacle for the continued adoption of best practices by the ATER.

3.2.2 Digital solutions for online impact

Together with the set of *in situ* actions, digital solutions are an essential part of giving efficiency and scale-up the process of changes in the field. Digital access is still a limiting factor in many regions of the Amazon, it is important, therefore, that applications, such as those developed by Solidaridad, also work so *offline* and synchronize the data when necessary.

- **A pilot platform for the ILHs: Sustainable Livestock Breeding**
  The platform of "sustainable livestock breeding" was created by WLR as a product of this study with the goal to connect the actors of the production value chain of livestock breeding, as well as share the contents and information regarding sustainable production practices. The platform was inspired by the "*Knowledges Banks*"[16] of the Plantwise Project, and its development is still in the pilot phase. Various initiatives that provide content and manuals of good practices for livestock farming are online, such as the portal of Embrapa [17] and GTPS [18] which already exist, but none of them have specific focus on livestock breeding, justifying, therefore, the additional value of this platform on channeling information resources in a single portal aiming at the engagement and improvement of this sector.

- **Applications for family agriculture**
  The application "farming solution"[19] was developed by Solidaridad to increase farmers' access to information about the best practices, complementing the technical assistance, boosting the farmer's autonomy to identify and plan improvements, and to monitor the progress in their productive units over time. The tool promotes a continuous learning process in which farmers have the autonomy to build their path to more efficient production, with access to information to support their decision-making.

  With the application, the farmers can identify the challenges for the production through self-assessment, organize their improvement plan, learn how to implement best practices, and monitor the progress of their areas of production. The accessible content was developed based on scientific research and the experience of Solidaridad and its partners. This knowledge is then applied to the local reality of each agricultural activity. The application used by farmers enables the creation of a huge database that supports the development of strategies for improvement of the production chains.

  The *"extension solution"* application was also developed by Solidaridad Brazil to make the technical assistance more efficient and effective. The goal is to assist in the daily work of the field technicians, allowing them to organize their tasks, record the interactions, and collect data from the field. Through the application, the project coordination can follow all field activities, with data provided in real time from a custom made a ILH dashboard with the necessary indicators for decision making, providing support for the farmer.

- **Guide of Indicators for Sustainable Livestock**

[16] Available at: <https://www.plantwise.org/KnowledgeBank/home.aspx>.
[17] Available at: <https://www.embrapa.br/pecuaria-sudeste>.
[18] Available at: <http://gtps.org.br/>.
[19] For more information, visit: <https://solidaridadfarmingsolution.org/farming-solution>.

The GTPS has developed the Sustainable Livestock Indicators Guide (GIPS) with the participation of all the actors from the links in the production chain, in a transparent and collaborative process. The tool establishes the principles and criteria defining sustainable practices of production, processing, throughand marketing of the livestock products in Brazil, enabling the diagnosis and definition of goals for development in each area. The indicators have two to five levels of service, and the user of the tool can see the "next steps" to be taken.

There are specific indicators for each link of the chain, and it is possible to use an online self-declaring tool, where you can access a series of reference materials for each principle of GIPS, including the Manual of Practices for Sustainable Livestock. That way, the search tool leverages continuous improvements through the diagnosis, stating "what must be done", and also providing options of "how it's done".

GIPS is also an interesting tool for disseminating the concept of sustainability for livestock activity. It can also assist in the process of professional training for the technicians who work with ATER in the field as multipliers of good production practices.

- **Map of initiatives of Sustainable Livestock**
  The Map of Sustainable livestock Initiatives[20] is the result of the project between the GTPS and the Gordon and Betty Moore Foundation, and it aims to highlight the sustainable initiatives in progress in the country. Through the map, it is possible to access the location, the project's executors and partners, the total area covered, the size of the herd, the investment, and general information about the initiative.

3.2.3 The benefits of ILHs to every link of the livestock value chain

Concerning the design of ILHs, the Sustainable Livestock Working Group has identified the potential benefits of its existence for each link in the livestock chain:

Productive sector

- Improvement in production quality
- Improvement in management
- Increase in profitability
- Ensure the continuity of the production system

Industries

- Improvement in the quality of the raw material offered (flow, standardization, and quality)
- Lower risk of losses (disposal because of waste / abscesses / bruising)
- Lower risks concerning the legality of the origin of the raw material
- Lower risks associated with environmental and labour issues

Supplies and Services

- Increase and durability of the consumer market

Financial Institutions

- Higher guarantees of debt payments (good production/financial management capacity = security to the financer)
- Lower risks associated with environmental and labour issues

Civil society

- Endorsement of socioeconomic development and environmental conservation

Retail and Restaurants

[20] Available at:< http://gtps.org.br/mapa-de-iniciativas/>.

- Improvement of the quality of the products offered to consumers
- Lower risk concerning the legality of the origin of the raw material
- Lower risk associated with environmental and labour issues

3.3 Institutional arrangements for the effectiveness of ILHs

According to the field experiments aimed at the application of good low carbon agricultural practices and the inter-sectoral commitment, it is observed that the creation of regional ILHs depends on partnerships that complement each other, as well as on potentializing actions that are already underway.
The model proposed by this study was designed to involve the demands of the private sector, government, civil society, and research institutions, so that the establishment of commitments and partnerships among organizations of all spheres make possible the increase in productivity in the field, mitigation of deforestation and environmental regulation of the farmers, and the provision of risk-free products.

In this context, we highlight the importance of the involvement of the private sector in these partnerships, so that commitments in the value chain can reach the objectives and are effectively implemented, reducing the risks in the supply areas. In addition, the involvement and articulation of research institutions such as Embrapa, universities, and technical institutes are part of the consolidation and expansion of the ILHs. Civil society organizations can contribute to leverage and structure the partnerships, playing an important role in the search for models to promote the improvement of environmental, social, and economic conditions in the field. They also play an important role in developing innovative local solutions, building more sustainable, and inclusive public policies and raising funds.

Following, we will address the importance of interinstitutional agreements and partnerships in strategies for sustainable development, as well as in complementing innovation and lifelong learning processes (3.3.1), and, sequentially, we will present some ongoing sector initiatives in the territory (3.3.2), justifying the choice of the intervention model of the present study.

3.3.1 Importance of partnerships for sustainable development

Sustainable development is a common challenge that permeates different sectors and demands changes and adaptations of production systems and consumption habits from all of society. As sustainable development is a collective challenge, strongly influenced by regional, natural and cultural characteristics, there is no single way to achieve it, which means that the solutions presented must respond to very specific contexts.

When we approach sustainability in livestock farming, we must bear in mind, primarily, the size and the diversity encompassed by this sector. Even when we take into account a small aspect of the production process, such as region, a producer's profile or even a single stage of the production process, we must consider that the activity alone has many factors of variation and that its success depends on the mutual relationship between the actors responsible for each stage of the process along the value chain.

In the context of the production phase — that is, activities inside the farm -, the importance of partnerships stands out by two main factors: the viability and the example.

To make a determined process viable is something that the farmer does not always have the skill or ability to perform alone. Although economic feasibility, investments, and access to credit are often appointed as barriers by the smallholder farmers, the lack of continued technical assistance to ensure a consistent adaptation process and subsequent improvement of the productive system, is often shown as a limiting factor. In other cases, access to different inputs

is also a crucial issue. Factors such as distribution logistics and product volume demand may prevent the adoption of specific production practice.

The lack of documentation and settlement of rural buildings is also an impediment to efforts aimed at improvements in productive units, especially when these include infrastructure investments and betterment, since which farmer would risk investing in a property over which he has no guarantees of ownership? Which financial institution would grant credit to farmers under these conditions?

In these situations, in which only the acceptance or commitment of the farmer to evolve are not enough for the process to develop, partnerships between institutions of different sectors play a fundamental role. In this sense, ATER institutions can contribute; the official bodies and their autarchies - through public policies and more certain services - and the private sector - making responsible production valuable. In order for the chain to move in a more sustainable direction, the involvement of all actors and sectors of livestock is necessary and leveraging, providing more equitable gains along with its links.

The establishment of partnerships is not a simple process, neither fast. Even after the partnership is established, goals and activities do not always move at speed necessary to meet all expectations. Often, this inconsistency results in a lack of engagement or even disruption of the process. In this sense, the cooperation between the different links in the value chain has proved to be an important catalyst for sustainable development, either in specific chains or in entire regions.

The public-private, institutional, and multi-stakeholder arrangements allow the dialogue and the sharing of responsibilities, as well as harness each party's expertise. Fortunately, currently, Brazilian livestock farming has some different examples of such initiatives, some of which will be presented in the next subsection.

There is no sustainable production if good management practices are not adopted on the farm, if the inputs used are also not produced responsibly, if the industry does not take care of its raw materials, processes and workers, if there are no accessible and adequate credit options to the production systems or if retailers offer the products with or without responsible origin with no distinction to the final consumer. The common challenge of sustainable development is a task that will be only fulfilled with the effort and cooperation of different actors.

3.3.2 Distinctive Initiatives

Considering the importance of establishing inter-institutional partnerships and collaboration among existing initiatives to scale-up changes in practices in small-scale livestock farming in the Amazon, we will present a summary of some distinctive initiatives in this context, which show potential to contribute to the establishment of ILHs, namely:

- **Strategy: Producing, Conserving and Including (PCI**
  In December 2015, at the Climate Convention (COP 21) held in Paris, the State of Mato Grosso launched the "Strategy: Producing, Conserving and Including", also known as PCI. The goal of the strategy is to reduce carbon sequestration and emissions of 6 *GTon* CO2 by controlling deforestation and developing a low carbon economy.

  The PCI came from a collective and participatory arrangement involving different state secretariats, representatives of nongovernmental organizations, private companies and representative entities of sectors of the economy of the State. This arrangement was based on the assumption that the State could obtain better results from its performance with the establishment of a partnership between the public sector, the private sector and the third sector, seeking to meet the social interest. Thus, PCI has as its strategy to raise funds for the State of Mato Grosso aiming at:
  1. Expansion and increase of the efficiency of agricultural and forestry production;

2. Conservation of remnants of native vegetation, reorganization of environmental liabilities;
3. Socioeconomic inclusion of family agriculture.

The strategy is a set of goals to help it achieve its objectives. All goals and their specific objectives can be found on the PCI online portal [21]. However, some goals are of great relevance to the sustainability of livestock farming in the Amazon region and are highlighted in our study:

- Producing: Expansion and increase of the efficiency of agricultural, cattle and forestry production
  - Bovine livestock:
    - Recover 2.5 million hectares of pasture areas with low productivity up to 2030
    - Increase productivity from 50 to 95 kgcw / ha / year up to 2030
- Conserve: Conservation of native vegetation and reorganization of liabilities
  - Deforestation:
    - Reduce by 90% deforestation using as baseline: 2001-2010 (PRODES) of 5,714 km², reaching 571km² / year by 2030.
- Include: Socioeconomic inclusion of family agriculture and traditional populations
  - Production and Market Inclusion:
    - Increase the assistance of the Technical Assistance and Rural Extension (ATER) of family agriculture from 30% to 100% of families by 2030
    - Increase family agriculture's share of the domestic market from 20% to 70% by 2030
    - Enlarge participation in the institutional markets from 15% to 30% by 2030

- **Sustainable Calves Production Program**

  The initiative was implemented by the Sustainable Trade Initiative (IDH) in the state of Mato Grosso, aiming to respond to the challenges of the indirect suppliers - responsible for 31% of the state's herd (HDI, 2018) - in the Brazilian meat sector. The Program is carried out together with companies, farmers, communities, governments, and civil society to build governance models – recognized as Verified Sourcing Areas (VSAs) - with the goal to attract new sources of funding. The VSAs are a mechanism to accelerate commodity production and absorption globally, whereby areas with clear governance can be directly linked to the market demands and sustainability criteria (IDH, 2018).

  The program uses a three-axis approach based on the establishment of regional pacts to create areas where agriculture and forestry and food products are grown sustainably (sustainable production), natural resources are protected (protection and restoration), and farmers and communities thrive (Inclusion) (HDI, 2018). In the field, the strategy is implemented through agreements, and it is part of a coalition of actors from the public and private sectors in the landscape driven by the PCI strategy presented earlier.

  The objectives of this program are:
  1. to reduce the risks of chains connected to illegal deforestation, achieving adequacy, transparency, and traceability
  2. to build transformational solutions for the market;
  3. to increase the income and quality of life of small-scale farmers and the entire region through improved management practices, increased productivity, and access to the market and financing.

  Currently, as part of the initiative are three co-financing projects which focus on technical assistance for smallholder farmers in important cattle production regions in the state of MT, bringing together key players in the value chain, covering a total of 15 municipalities, and benefiting directly more than 500 small calf producers.

[21] http://pci.mt.gov.br/ accessed on April 4th 2019.

These projects aim, overall, to support the PCI State Strategy in the intensification and restoration goals of the meat sector in the region, endorsing the responsible intensification of livestock farming, the restoration of areas of low productivity, and a traceable and deforestation-free production of calves.

Besides the initiatives described, we carried out a survey on other interventions that aim at the same target in the Amazon, which can be seen in the "Matrix of public, private, financial and non-profit initiatives for small-scale livestock farmers in the Amazon from the year 2000 onwards" (Annex A).

4 Expanding GHG Emission Mitigation with Livestock Farming Innovation

In this chapter, we will address the potential for GHG emissions mitigation if low-carbon stock breeding strategies and practices gain scale among family farmers in the Amazon. With this purpose, we will present the results of a study on the estimation of the carbon balance of productive units of the settlement Tuerê, in Novo Repartimento, obtained through a customized calculation for diverse systems (cocoa, livestock, and forest) developed by Solidaridad and Imaflora (4.1). Following, the levels of adoption of practices and their potential for expansion in the biome through ILHs are indicated, as well as the variables that can be used in a future calculation of the GHG emissions reduction potential by the sector (4.2). Lastly, we will go into the specificities of the low carbon farming practices proposed by our model (4.3) and the challenges for its implementation in the Amazon context (4.4).

4.1 Starting point: carbon mitigation practices and their potential in productive units in the Amazon - livestock, cocoa, and forest.

The study "Carbon Balance in family agricultural production in the Amazon: scenarios and opportunities"[22] developed by Solidaridad Brazil, in a technical partnership with the Institute of Agricultural and Forest Management and Certification (Imaflora), was strategically chosen as the starting point for a better understanding of how the mitigation of small-scale livestock farming GHG emissions can expand. The study developed a framework for measuring GHG emissions and analyzed the soil use and productive practices of Amazonian family farmers to estimate the emission balance in the productive units and to understand the dynamics and the potential of mitigation of emissions in future scenarios, taking into account improved scenarios and business as usual scenarios - when improvement interventions are not established.

The insufficiency of data on GHG emissions and removals in small productive units has been a limiting factor in the characterization of their emissions, constituting, therefore, a knowledge gap on the effect of the practices adopted and the measures necessary to promote changes. The lack of this information, access to adapted technologies, public incentives and clarity about potential economic benefits, will reduce the capacity of family farmers in Brazil to make a transition to low-carbon rural territorial development, to access targeted public policies, to ensure opportunities to attract inclusive investment funds to mitigate carbon emissions, and to demonstrate their role in global supply chains that are committed to the climate agenda.

Generally, in Brazil, the production systems used by family farmers are diversified, being composed of both agricultural and livestock production systems within the same property. Given the complexity of the interactions between such systems, identifying appropriate and expeditious indicators and methods to analyze the GHG emissions balance, on this scale, is essential to establish a baseline that captures all relevant information and indicates significant monitoring and evaluation systems to address climate mitigation and adaptation options for this context (FAO, 2012; Rosenstock et al., 2013, Colomb et al., 2013).

[22] The study is available at: <http://www.solidaridadsouthamerica.org/sites/solidaridadsouthamerica.org/files/publications/low_carbon_family_agriculture_in_the_amazon_0.pdf>.

Considering the limitations presented by the GHG calculation tools most commonly used, and the possible biases associated with their use, it was necessary to develop specific strategies that combine and adapt existing calculator components to the elaboration and application of new models based on the scientific literature and the IPCC guidelines (IPCC, 2006).

4.1.1 The design of a customized calculator for the context of farming diversification in the Amazon

In general, family farmers deal with multiple combinations of land use and production systems. The Tuerê family farmers have arrangements that include cocoa cultivation systems (shaded and full-sun, different shade-providing trees and cocoa densities), livestock systems (for milk production and beef cattle: breading, rearing, and fattening), native forest (degraded and not degraded) and annual subsistence crops, such as cassava.

This land-use characteristic imposes a special situation for GHG calculators, which are generally constructed to be used for a single crop. Faced with this challenge, we sought alternatives to carry out this measurement based on the existing calculators, methods, and guidelines for calculating the GHG balance in different land use and production systems.

Tools used to calculate the GHG balance

Based on a compilation of available scientific papers to estimate emissions and GHG removals from the farming and land use sectors, the Intergovernmental Panel on Climate Change (IPCC) developed a protocol for the accounting of GHG at the national level (IPCC, 2006). Through the protocol, new tools were developed to support the more precise quantification of GHG emissions (Colomb et al., 2013, Denef et al., 2012). However, due to the variety of land uses and management practices in the context of family farming, these tools do not consider the primary sources and sinks of GHG present in this type of productive system.

Therefore, after a preliminary study of the most widely used calculators globally, significant limitations were found, leading to the need for customizing a tool to measure the GHG balance of productive family units.

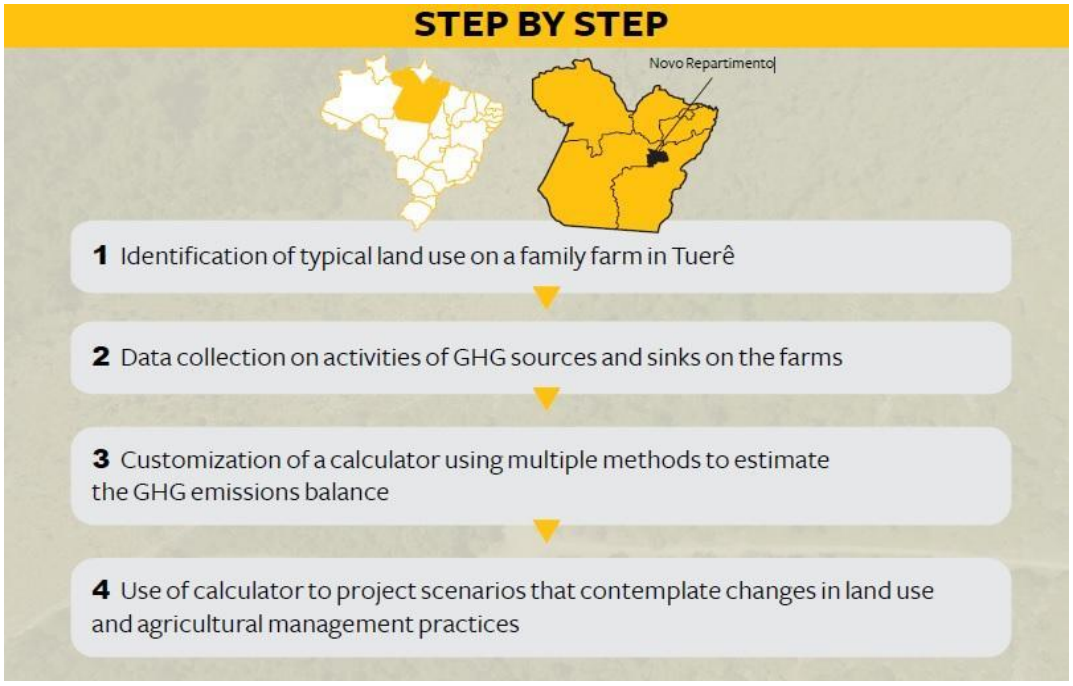

Figure 9 *Step-by-step construction of the calculation structure until the creation of scenarios relating it to the practices and the estimates of emissions balance. Source: Solidaridad, 2018.*

Method for calculating the GHG balance in the systems: cocoa; livestock and forest

- GHG balance in cocoa systems
  For the balance of GHG emissions in cocoa production systems, the accounted variables with regard to the system adopted (shaded or full-sun) were: biomass production, the residue of cocoa pruning (IPCC, 2006 and Guerrero, Chalapud, 2006), the use of soil inputs, and the soil management practices adopted (CFT, WRI, 2014). In the full-sun systems, to calculate the above-ground biomass of Cocoa trees, the allometric equation proposed by Ortiz Guerrero and Riascos Chalapud (2006) was used. In the case of shaded systems, above-ground biomass was estimated by the multispecies allometric equation proposed by Brown (1997).

- GHG balance in livestock systems
  The variables considered were the number of animals per hectare and their age (WRI, 2014), the number of inputs used in the soil, management practices (CFT, WRI, 2014), and soil condition in productive units (WRI, 2014). For the calculation of GHG emissions by the cattle herd, the emission factors used varied according to the sex and age of the individuals. In the case of GHG emissions due to inputs use and practices of soil management, the variables considered were the application of limestone and nitrogen-based fertilizers, the use of fossil fuels, and the use of burning practices. Finally, to calculate the GHG emissions according to the soil conditions in the productive unit, emissions factors were used according to three categories: degraded, nominal, and improved.

- GHG balance in forest areas
  The total estimates of carbon stock in the forest areas of the productive units of Tuerê were performed using data from Brown (1997) for above-ground stocks, and Mokany et al. (2006) for below-ground stocks. In the scenario modelling, carbon stocks above and below ground were accounted for the carbon emissions derived from deforestation. The calculation of GHG emission due to deforestation of tropical forests by cutting and burning practices was done using the EX-ACT tool, which estimates CO2, CH4 and N2O emissions (Bernoux et al., 2010).

4.1.2 Projected scenarios for the average family unit in Tuerê

Considering the variables used in the GHG balance of an average productive family unit in Tuerê in the 2016 baseline scenario, five future scenarios for GHG emissions and removals were projected in accordance with changes in land use (deforestation, conversion to other productive systems, and forest restoration), in the management practices of the livestock and cacao production systems, in the productivity, and in the condition of soils with pasture (Figure 10 and 11). The Business as Usual (BAU) scenarios represent the absence of adoption of good agricultural practices (low carbon agriculture), and consequently, the lack of programs to improve and support the family farmer. On the other hand, the "Improved" scenarios reflect the expected impact of the interventions of good practices of low-carbon emissions [23] proposed to the program's participants.

The scenarios were constructed through interviews with local and regional actors, such as family farmers, private technical assistance companies, members of the Executive Commission on Cacao Farming Planning (CEPLAC), agents of local commercialization of the livestock and

[23] The activities considered as improvements in the production practices of livestock breeding and rearing, and in the cacao management, are the ones that allow carbon storage and increase of productivity without associated deforestation - through the conversion of degraded pasture to forest restoration associated with the cultivation of cocoa. These include:
1) Livestock systems: implementation of improvement in animal husbandry (reproductive, sanitary and raising), rotational grazing, nitrogen fertilization, liming in pasture areas (10 kg of urea / ha / year and 1,5 t of limestone every five years), and ceasing burning practices. In addition, it considers the use of 10 liters of diesel / ha / year.
2) Cacao cultivation: use of fertilizers, pruning and increasing the number of shade trees in the systems.
GHG emissions caused by deforestation were proportionally allocated to areas that eventually became pasture (90%) and cocoa cropping systems (10%).

cocoa chain; trends in land use change in recent years; and technical experience of Imaflora and Solidaridad.

Scenarios	BAU 1 Deforestation and Reduced Productivity	BAU 2 Reduced Productivity	BAU 3 Deforestation and Improved Management	Baseline – 2016 Scenario	Improved 1 – Improved Management	Improved 2 – Improved Management and Restoration
Deforestation rate	5% of forested areas	Zero	5% of forested areas	Zero	Zero	Zero
Changes in land use	90% of the area recently deforested is converted into pasture land and 10% into cocoa grove		90% of the area recently deforested is converted into pasture land and 10% into cocoa groves			Reduction of pasture land by 1 hectare to be used for cocoa farming
Livestock farming changes	Cattle: 0.43 heads/ha Fertility rate: from 75% to 70%	Cattle: 0.43 heads/ha Fertility rate: from 75% to 70%	Cattle: 1.38 heads/ha Fertility rate: from 75% to 80%	Cattle: 0.86 heads/ha Fertility rate: from 75%	Cattle: 1.728 heads/ha Fertility rate: from 75% to 80%	Cattle: 1.72 heads/ha Fertility rate: from 75% to 80%
Soil condition of pastureland	Degraded	Degraded	Improved*	Degraded	Improved*	Improved*
Cocoa farming	Stable productivity at 720 kg/ha 60% shaded	Stable productivity at 720 kg/ha 60% shaded	Productivity increased to 1,200 kg/ha 60% of the cocoa trees are combined with shade trees Fertilizers use**	Stable productivity at 700 kg/ha 60% shaded	Productivity increased to 1,200 kg/ha 100% of the cocoa trees are combined with shade trees Fertilizers uses**	Productivity increased to 1,200 kg/hectare 100% of the cocoa trees are combined with shade trees Fertilizers use**

Figure 10 *Variables considered for the baseline and projected scenarios for an average productive unit in the Tuerê settlement. Source: Solidaridad; Imaflora, 2018.*

Activity	BAU 1	BAU 2	BAU 3	2016 Scenario	Improved 1	Improved 2
Pasture (ha)	27,6	27,6	27,6	27,0	27,0	26,0
Cocoa (ha)	10,1	10,0	10,1	10	10,0	11,0
Forest (ha)	12,4	13,0	12,4	13	13,0	13,0
Total (ha)	50	51	50	50	50	50

Figure 11 *Land use in the family farms unit in the 2016 baseline and projected scenarios. Source: Solidaridad, 2018.*

Balance of GHG emissions in the Baseline scenario 2016

Through the identification of the land use and the practices implemented in an average family unit, it was possible to calculate the GHG emissions balance of 1.76 tCO2e / year (50 ha), or

0.04 tCO2e / ha / year for the 2016 baseline. The characteristics and results of the calculation of the GHG balance of the livestock and cocoa production systems and in the native forest areas that integrate the productive family unit in the baseline scenario are described below.

- Characteristics and balance of GHG emissions from the livestock system (2016)

  In the Tuerê settlement, pasture areas are predominantly degraded (moderate level), often divided into three plots, managed with a simple rotating system, the use of inputs (limestone and fertilizers) is practically nonexistent, and the burning practices usually occur every two years, to control the vegetation regeneration that happens during this period. The average size of the herd per productive unit is 44 heads (25 cows, 18 calves, and one ox). Depending on the burning regime adopted, it was assumed a biomass amount accumulated in the secondary vegetation in degraded pastures of 5.0 t / ha / year (Uhl, 1988). The results indicated that a livestock system of a typical productive family unit in the Tuerê settlement emits 4.8 tCO2e / ha / year, or 128.8 tCO2e / year per unit of pasture area (27 ha).

  About 47% of these emissions come from the herd (enteric fermentation and manure), 43% from pasture degradation and 10% from pasture burning. Although the literature on the evaluation of GHG emissions balance in breeding and rearing systems is limited, an emission of similar magnitude was also estimated for livestock systems with the predominance of degraded soils in the Amazon region (Imaflora, 2016). Therefore, the results suggest that the livestock systems in degraded pastures can present similar emission profiles as a consequence of the lack of grazing and animal management.

  The main product of livestock in Tuerê are the calves, which are sold after weaning (8-10 months), weighing about 185 kg. Considering that this system contains 0.9 cows per hectare and produces about 0.7 calves (or 119.3 kg) per hectare annually, a typical productive unit of the Tuerê settlement emits 40 kg of CO2e per kg of calf produced. The values are consistent with those found in the literature (Bencoña et al., 2014; Beauchemin et al., 2006; Pelletier et al., 2010).

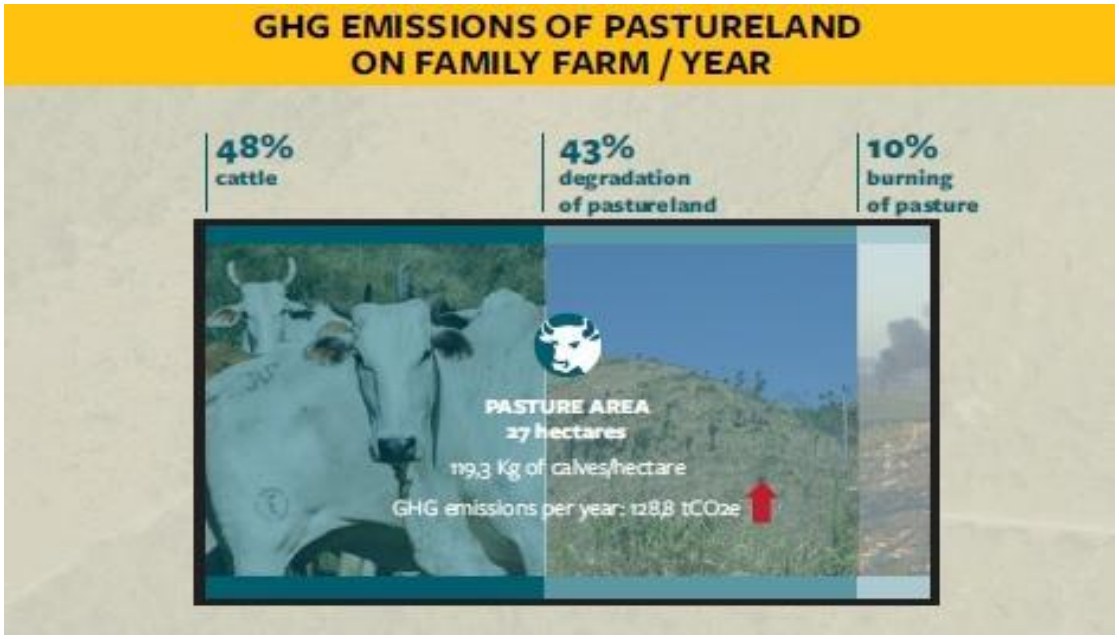

Figure 12 *Infographic of GHG emissions from the livestock area in the productive family unit/year. Source: Solidaridad, 2018.*

- Characteristics and balance of GHG emissions from the cocoa system (2016)

According to the data collected, there are no sources of GHG emission in cocoa systems established in a characteristic productive unit of Tuerê. Although N2O emission has been identified due to the cocoa's shell decomposition after the harvest season, the cacao tree and its shading are natural CO2 sinks.

The GHG emission balance was evaluated in 26 cocoa production systems, which showed variations according to the age of the cultivations and the shading models in 14 units. The evaluated production systems also showed a great variation in the number of shade trees per area with an average density of 58 trees per hectare.

The results indicate that the shaded cacao system, with native trees, tends to stock and sequester more carbon than the system in plain sunlight. Over a period of 18 years, the shaded systems stored an average of 300 tCO2e / ha, while full-sun systems stored about 100 tCO2e / ha. With regard to carbon sequestration, the cocoa production systems present rates ranging from 16.6 CO 2 e t / ha / year in shaded systems to 5.4 CO 2 e/ ha / year for full-sun systems - which is consistent with rates found in literature, ranging from 10 to 40.7 tCO2e / ha / year.

The average carbon balance in cocoa systems for the most common situation found in a Tuerê unit is -120.6 tCO2e / year or -12.1tCO2e / ha / year. The balance per ton of almonds produced is -16.7 tCO2e.

- Characteristics and balance of GHG emissions in forest areas (2016)

Areas occupied by native forest are natural carbon sinks. It is estimated that tropical forests stock 648 tCO2e per hectare and sequestrate an additional 0.5 tCO2e per year to maintain their structure as a function of their growth (Bernoux et al., 2010). Thus, the results indicate that the average productive family unit in Tuerê stores around 8,424 tCO2 in remnants of native forests (13 hectares) and sequestrates additional 6.5 tCO2e annually with its maintenance.

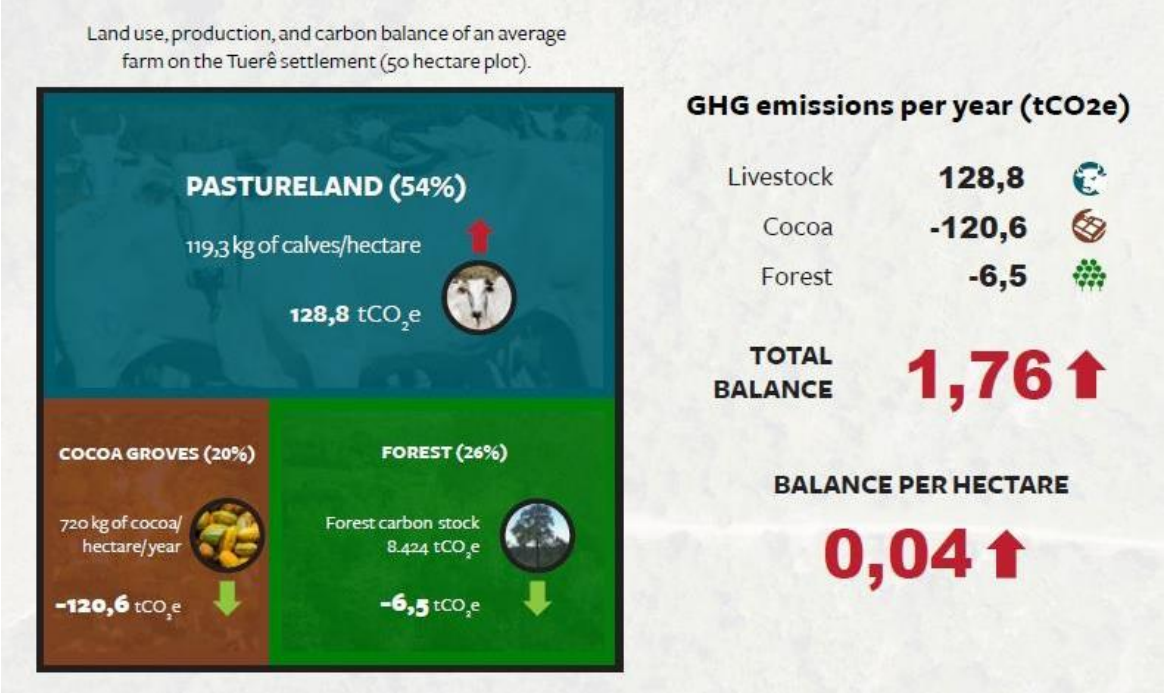

Figure 13 *Infographic of the land use, production, and carbon balance of an average productive unit of the Tuerê settlement (Portrait 2016). Source: Solidaridad, 2018.*

GHG emissions in the projected scenarios

After determining the results of the calculation of the GHG balance of the production systems and forest areas at the baseline, some scenarios were created with pre-defined practices. The developed projected scenarios involve the business as usual scenarios and the scenarios for the improvement of practices and land use.

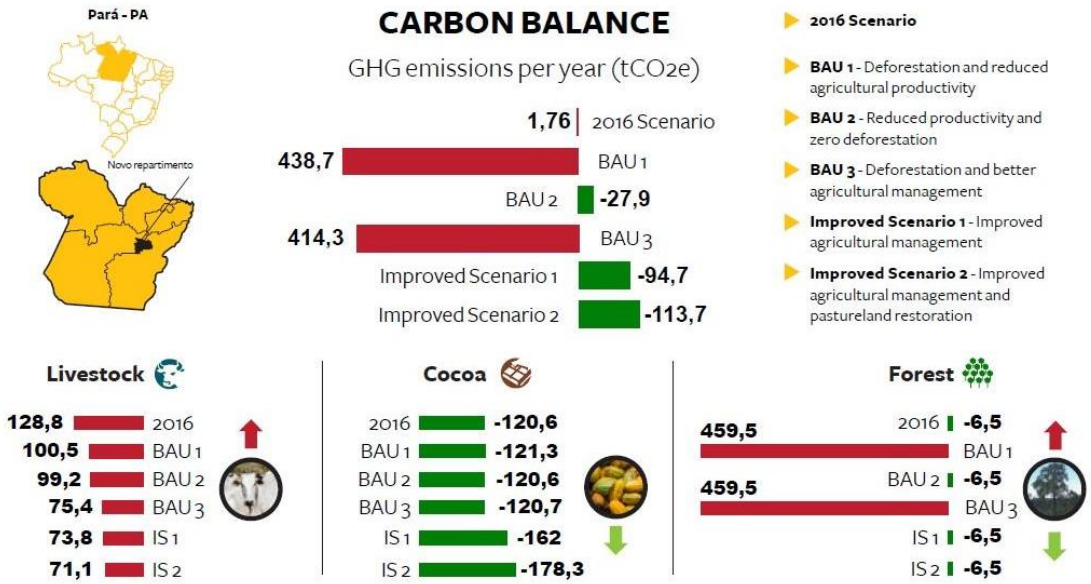

Figure 14 *Infographic analysis of the carbon balance by the cocoa, livestock and forest systems for the 2016 baseline and for the different projected scenarios. Source: Solidaridad, 2018.*

- BAU scenario 1 - Deforestation and reduced productivity

  In this scenario, it was considered a deforestation rate of 5 % and a reduction in productivity of the livestock system, with a reduction of 50% in the herd stocking rate and 5% of its fertility rate in relation to the 2016 baseline. The GHG emission balance estimated for a productive family unit was 8.8 tCO2e / ha / year, which represents an increase of emissions of over 220 times in the scenario observed in 2016.

  Therefore, the large increase in emissions in the BAU scenario 1 (+ 220%) has as a main consequence the loss of forest through cutting and burning. Moreover, when allocating 90% of the deforested area for pasture and 10% for cocoa cultivation, the intensity of products emissions increased by 8.5 times, 746% per kg of weaned calf and 62% per ton of almond of cocoa produced.

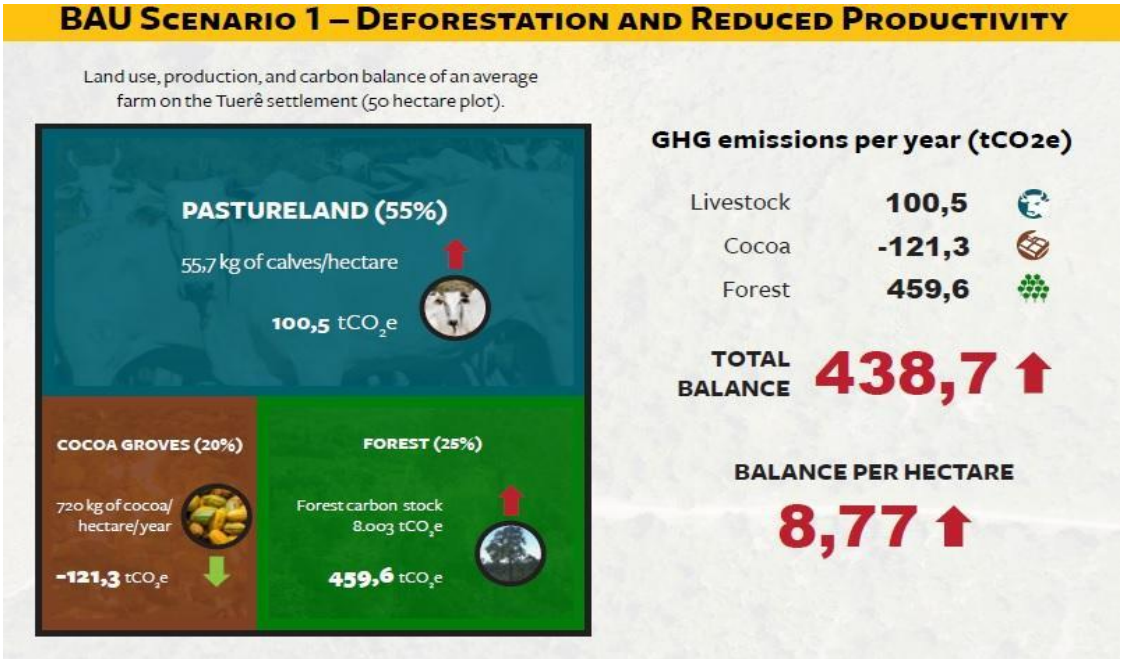

Figure 15 *Infographic of the soil use, production, and carbon balance in the average productive unit of the Tuerê settlement in the BAU 1 scenario (Deforestation and reduced productivity). Source: Solidaridad, 2018.*

- BAU scenario 2 - Reduced productivity

  In this scenario, there is a reduction of livestock productivity, as in BAU 1; however, with a zero rate of deforestation. The GHG balance of the family unit was estimated at -0.56 tCO2e / ha / year. Therefore, in this case, there is GHG removal, which suggests that under zero deforestation, a large part of the GHG emissions in the unit would be avoided.

  Although BAU 2 presents lower GHG emission than in the Scenario 2016 (0.04 tCO2e / ha / year), the increasing pasture degradation significantly reduces the pasture production capacity in each productive unit. With the reduction of the stocking rate by 50% and the production of weaned calves by 55%, in this scenario, the associated emissions per kg of weaned calf produced increased by 65%.

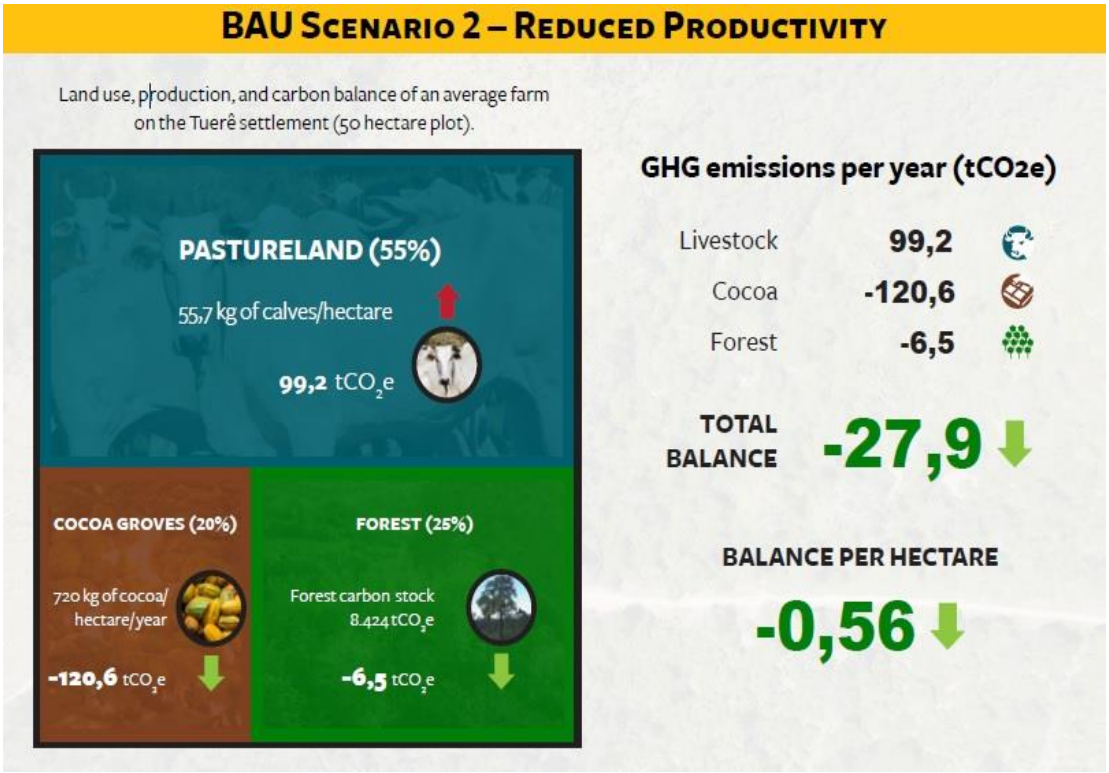

Figure 16 *Infographic of the soil use, production, and carbon balance in the average productive unit of the Tuerê settlement in the BAU 2 scenario (Productivity reduced). Source: Solidaridad, 2018.*

- BAU scenario 3 - Deforestation and improved management

  In the BAU scenario 3, new forest areas are converted to increase production areas (90% of the deforested area for pasture and 10% for cocoa) in the family unit, similarly to BAU 1. However, there is an improvement in management practices in the production systems of cocoa and livestock. The GHG balance of the productive family unit was estimated at 8.29 tCO2e / ha / year, which represents an increase in GHG emissions, in comparison with the 2016 scenario, by the family unit of about 207 times and 76%kg of weaned calves, whereas for each ton of cocoa almond produced, a 65% reduction in emissions was observed.

  Even though under this scenario, there is an improvement in livestock management in the productive family unit in Tuerê, with a doubling of the stocking rate and an increase in cow-calf production efficiency (115% more calves per hectare), such practices would not compensate emissions from deforestation associated with this production system.

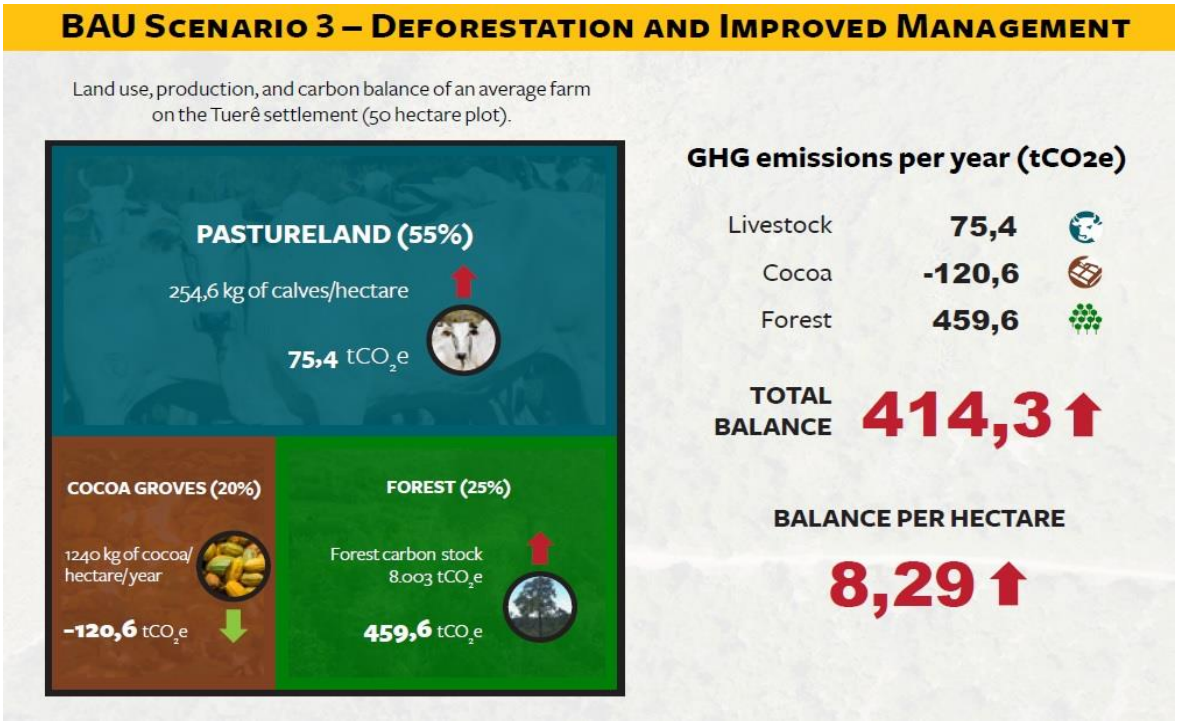

Figure 17 *Infographic of the soil use, production, and carbon balance in the average productive unit of the Tuerê settlement in the BAU 3 scenario (Deforestation and improved management). Source: Solidaridad, 2018.*

- Improved Scenario 1 - Improved Management

  In Improved scenario 1, there is an increase in the production of the productive family unit without deforestation, as a result of the intensification of agriculture and livestock. The GHG balance of the family unit was estimated at -1.89tCO2e / ha / year. By restoring pastures and improving cocoa management, GHG emissions would be reduced by 55 times compared to the 2016 scenario (from 0.04 to -1.89 tCO2e / ha / year). Thus, in this scenario, there is an increase in both climatic performance and productivity, which makes the productive family unit a GHG sink.

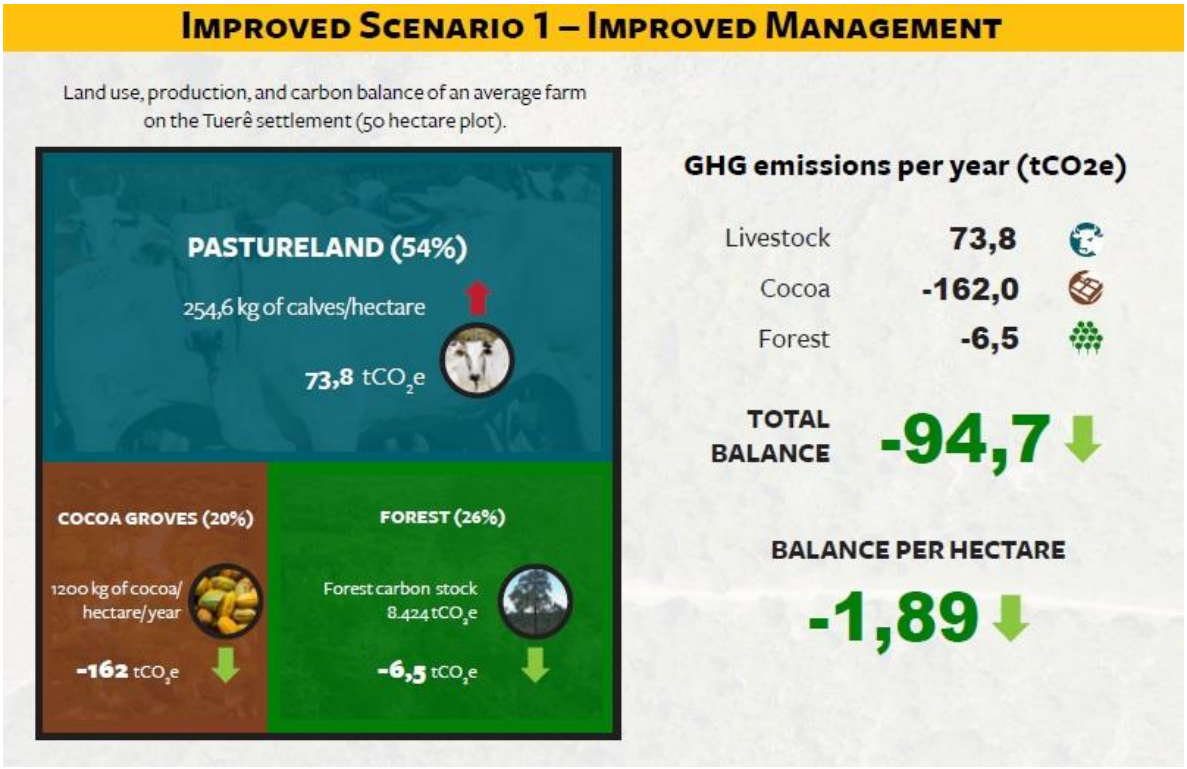

Figure 18 *Infographic of the soil use, production, and carbon balance in the average productive unit of the settlement Tuerê in the improved scenario 1 (Improved management). Source: Solidaridad, 2018.*

- Improved Scenario 2 - Improved management and restoration

  In Improved scenario 2, with improved management practices and the conversion of 1 hectare of pasture into cocoa cultivation, GHG emissions are reduced by 65 times compared to baseline. The GHG balance in the family unit was estimated at -2.27 tCO2e / ha / year. It should be noted that, for both improvement scenarios, the GHG emission would be reduced by 75% per kg of weaned calf and 20% per ton of cocoa almond produced.

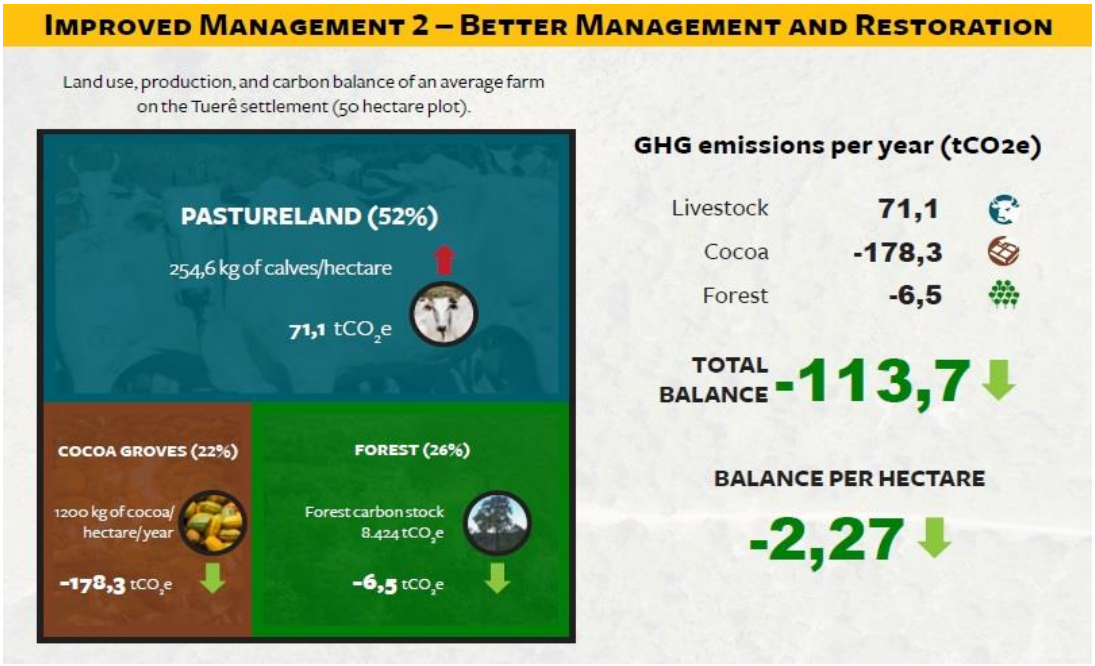

Figure 19 *Infographic of the soil use, production, and carbon balance in the average productive unit of the settlement Tuerê in the improved scenario 2 (Improved management and restoration). Source: Solidaridad, 2018.*

The variables considered in the projected scenarios involve changes in soil use and management of the livestock and cocoa systems. In order to assess only the impact of technology adoption, disregarding land use changes, the best analysis to be done is to compare the BAU 2 and Improved 1 scenario, where there is the potential to reduce emissions of 1.33 tCO2e / ha / year.

4.1.3 Conclusions

The information related to land use and agricultural management in family farms in Brazil and its effect on the GHG emissions balance is scarce. In this regard, this study contributed to the advancement of this topic by subsidizing the discussion with local information and data that provide support for the elaboration of public policies and private programs aimed at the development of low-carbon family agriculture in the Amazon.

In an unprecedented way, the study analyzed the role of family agriculture in reducing emissions and their potential as a carbon sink in the Amazon. The study can also establish a framework to monitor and evaluate emissions in different scenarios and generate information to improve current and future GHG calculators to obtain more comprehensive emissions assessments in small-scale agriculture. We conclude that, in order to favor carbon balance in the productive family units, avoiding deforestation is crucial. At the same time, technologies of herd and pasture management should be adopted, burning practices combated, agroforestry systems implemented and improved, and production systems diversified.

4.2 Scaling-up the reduction of GHG emissions from the sector

The motivation to devise a GHG emissions mitigation strategy for the livestock sector derives from the need to understand (1) the extent of the sector's emissions, (2) the potential for improvement, (3) the sector's challenges (e.g. farmer's engagement, understanding of the production chain, economic and cultural nuances), operational (e.g. implementation of the management practices), and institutional (e.g. financial arrangements and partnerships) in order to reach impact at scale. In addition, the intention was to understand how this proposal can be adapted to other biomes in which cattle breeding activity is also representative, as in the Cerrado.

Considering the potential contribution of the implementation of GAPs related to the improvement of pasture management and herd betterment for the reduction of GHG emissions originated from small-scale livestock breeding in the Amazon, the following questions were asked:

1. *What would be the impact of the mitigation of GHG emissions if the improved practices of small-scale livestock breeding expanded within the Amazon biome?*
2. *How important is this production sector to the national commitment to global climate change agreements?*
3. *What strategies are needed to ensure that the improved scenarios of the low-carbon livestock breeding production go from a micro scale (of productive unit) to a (biome and sectoral) macro scale?*

In the context of Tuerê, estimates of improved projected scenarios indicate that the implementation of some management practices in relation to the current scenario can generate a reduction of carbon emissions of 75% per kg of weaned calf. According to Solidaridad (2018), livestock emissions can be reduced from 4.8 tCO2e / ha / year to 2.7 tCO2e / ha / year. These results show, unprecedentedly, the potential of family agriculture to become a GHG sink in the Amazon and to contribute to national emission reduction targets. Therefore, if models similar to those proposed in Tuerê replicate at the local, regional and biome levels, the GHG emissions profile from small-scale livestock breeding can be improved and collaborate in the achievement of lower GHG emissions rates nationally. For the understanding of the levels for which the adoption of the practices can expand, the figure below was elaborated, in which each sphere represents a layer of the process of scaling-up.

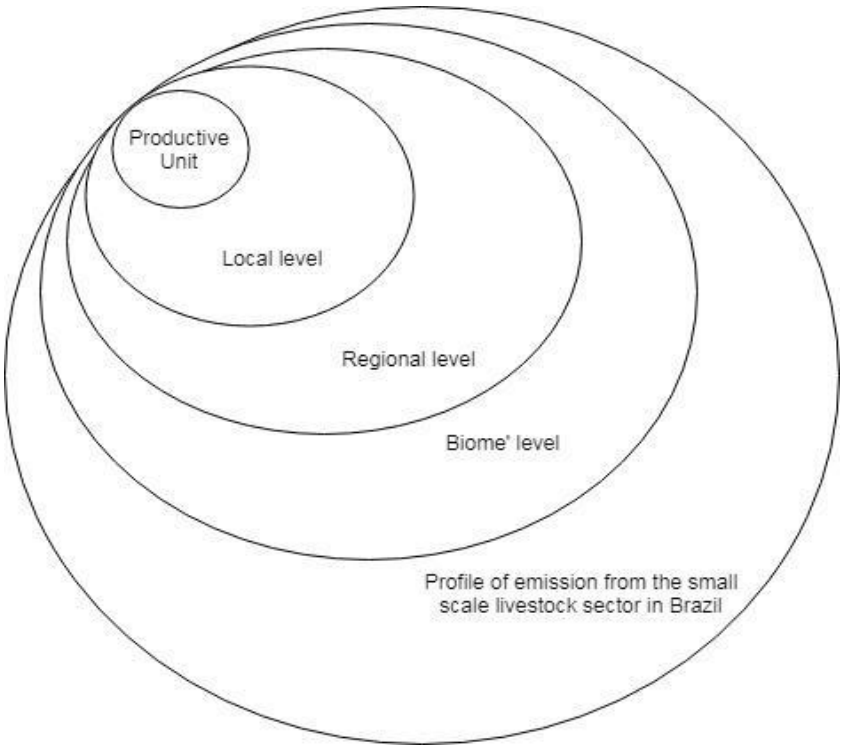

Figure 20 *Levels of adoption of practices aimed at mitigating GHG emissions in small-scale livestock breeding. Source: Authors.*

4.2.1 Possible strategy: from Tuerê to the Amazon biome

Although we consider that an effective strategy for scaling-up the adoption of GAP programs to reduce GHG emissions by small-scale livestock breeding presents specific variables for each case, we did a survey of possible variables from which, in the future, it will be possible to calculate the potential of emissions reduction of this sector. For this purpose, we take as a starting point the scenarios outlined by the study carried out at the settlement of Tuerê (Solidaridad, 2018) to design the improved scenarios of GHG emissions if the practices are scaled-up to the scope of the Amazon Biome. The following table (Figure 21) presents the variables identified and the data sources that can contribute to the elaboration of this calculation at a later stage of the study.

Table 1 *Possible variables and data sources for the calculation of GHG emissions projections in improved scenarios for the implementation of low carbon GAPs at different scales[24].*

Scale	Parameter	Source
Productive unit level	Pasture areas, and degraded pasture area (hectare). Forest area (hectare).	MapBiomas. (http://mapbiomas.org/)
Local level	Herd of the municipality (Number of heads related to cattle breeding).	IBGE: Census of Livestock in the Amazon
Regional level	Productivity of the state where the productive unit is located (kg of calves/hectare). * * Assuming that the herds do not move beyond the territories of the UDs. Data from IBGE, MAPA and studies of the production chain.	Data from IBGE, MAPA and studies of the production chain.
Biome level	Pasture area and degraded pasture area (hectare). Forest area (hectare). Deforested area (hectare) Numbers of livestock establishments smaller than four fiscal modules located within the geographical limits of the biome.	MapBiomas. (http://mapbiomas.org/) Data from IBGE Data from INPE - PRODES
Nacional level	Data on national GHG emissions. Data on national GHG emissions from livestock farming.	National GHG inventory, Ministry of the Environment, Embrapa and MAPA.

Source: Authors.

4.3 Practices for low-carbon livestock farming

GHG emissions from livestock are linked to the characteristics, conditions, and management practices of the herd and pasture. According to reports from the ABC Observatory (ABC Plan Observatory, 2017c), in order to increase the Brazilian herd with a low-carbon perspective, it is fundamental to seek greater efficiency in the final balance of GHG.

The livestock farming currently practiced in Brazil occurs extensively and with low adoption of technologies, which, in many cases, leads to inefficient systems that favor pasture degradation and late animal slaughter (about 4 years). Similarly, as the pasture productivity decreases, there is a stimulus to deforestation to open new areas in search of more fertile soils, which are capable of supporting the herd and its growth (SEEG, 2017).

Faced with a more demanding consumer market and the need to keep the forest "standing up", the coexistence of the Amazon forest with livestock activity is directly linked to the awareness of the farmers on preservation and adoption of modern and rational technologies of livestock production, turning, in this manner, the properties more productive in a smaller area (Marcuzzo, 2015).

Therefore, given the context of extensive livestock farming in the Amazon, the model intervention for improving the system should aim to improve the soil conditions of the pastures, increase the rate of stocking per area and increase the fertility rate of the flock. In this regard, the model to be replicated through ILHs, based on the project implemented in Novo Repartimento, proposes the improvement and/or implementation of practices concerning each of the aforementioned factors and that will be presented in the next subsections of this chapter.

4.3.1 Improvement of soil conditions in degraded pasture

In order to implement improved soil conditions, pastures should the pastures be considered as crops, so that their correct management ensures the productivity of the livestock system and

[24] It is worth mentioning that the table may be extended as the calculations and projections become more sophisticated.

high-performance indexes of animals. A well-managed pasture contributes to the conservation of the natural resources of the property (water, soil, etc.) minimizing the impacts of erosion, soil compaction, and water infiltration.

Soil fertility and fertilization

The level of productivity of pasture and the performance of the animals are directly related to the fertility of the soil and the level of fertilization adopted in the maintenance of this pasture, which in turn, provides a potential response from the forage (Ruggieri, 2018). In the case of tropical pastures, productivity is strongly related to soil management based on practices that maximize the recycling of nutrients, minimize their losses and prioritize their entry into the system (Dias-Filho, 2011).

In this context, fertility management, specifically through constant fertilization, is a technique that provides soil fertility. In more intensive systems of pasture use, phosphate (phosphorus) and nitrogen fertilizers are generally required. In the Brazilian Amazon, due to the type of predominant soil, forages present a higher response to phosphate fertilization than nitrogen (Dias-Filho, 2011). The temperature and the luminosity of the region also contribute to a favorable response from tropical forages.

Phosphorus, when in inadequate levels, is directly related to the decrease of fodder production and consequent grazing degradation. This nutrient is considered the most limiting for the implementation and maintenance of a pasture with high productivity. In acid soils, liming can increase the efficiency of phosphate fertilization (Dias-Filho, 2011). Phosphate fertilization must be done in conjunction with the addition of other minerals, such as nitrogen (Corrêa, 2000).

Nitrogen is an important nutrient for maintaining the productivity of the pasture, especially in intensified cattle production systems. It should also be used in pastures where the soil has a tendency to flood and little drainage. Nitrogen losses in pasture usually occur through volatilization (from the urine of the animals), leaching, and water erosion (Dias-Filho, 2011). Hence, nitrogen fertilization should be done by hedging soon after the exit of the animals from the paddock (Corrêa, 2000).

When it comes to acid soils - common in the North region of Brazil - liming (calcium, potassium, and magnesium) is an important management practice. Although there are controversies about its effect on the productivity of tropical grasses, experiments carried out on farms with intensive livestock raising show a positive result. It should be the first pasture fertilization procedure, because it reduces acidity, improves the incorporation of other nutrients, provides calcium and magnesium to the soil, and increases the efficiency of cation exchange. In the formation of the pastures, it should be done 30 to 90 days before planting, at the time of plowing the soil. The maintenance of liming should be done periodically after the rainy season, which in the case of northern Brazil occurs between December and April (Corrêa, 2000).

Choice of fodder

Another important aspect of obtaining quality in the pasture is the choice of fodder that will be used. In Brazilian livestock farming, it is very common to substitute nutrient demanding forages for less demanding ones, due to the drop in quality and soil fertility over time and consequent reduction in pasture productivity. In these cases, the lack of maintenance and use of correct management techniques ends up leading to its degradation (Ruggieri, 2018), as it is the case for large pasture areas in Brazil. However, it should be emphasized that each area or region has different soil and climatic characteristics, more adapted forages, different production systems, and soil fertility, meaning that the definition of the pasture management style should be adapted according to these features.

In the choice of forage, besides soil fertility, another factor to be taken into consideration is its adaptation to excessive soil moisture conditions (Ruggieri, 2018) and high solar incidence, especially when it comes to the North region of Brazil, where the rainfall index is very high, and the lands are subject to flooding at certain times of the year.

Type of animal grazing

Regarding grazing management, it is necessary to take into consideration the grazing form of the animals. There are two basic grazing systems and derivations from these. In continuous grazing, the animals have unlimited and uninterrupted access to the entire pasture or paddocks for a longer period. This type of grazing is justified in extensive livestock raising systems and in contexts where there is no way to implement the rotational system (Corrêa, 2000).

In rotational grazing, it is used the concept of the period of occupation, which corresponds to the time the animals graze on the paddock (Ruggieri, 2018). In this system, the total pasture is divided into smaller paddocks, according to the size of the herd and the occupation period, where, depending on the number of paddocks adopted, the animals are rotated in predetermined periods, from paddock to paddock, allowing the ideal recovery of forage in the paddock already used, guaranteeing its good quality and quantity. Thus, the duration of the animals in the paddock must be compatible with the supply of forage therein, and the animals must be removed when the minimum plant height is reached to enable plant recovery. It should be noted that the paddocks do not need to be all the same size, but it is recommended that they are square or rectangular with a width of one-third of their length (Ruggieri, 2018).

4.3.2 Increasing the stocking rate

When we discuss animal performance, there are two basic components to be considered: the genetic potential of the animal itself and the potential for dry matter production by the forage (Corrêa, 2000). In the second case, we refer more specifically to its carrying capacity, that is, the maximum stocking rate that the pasture holds, without compromising the performance of the animals and the foragers of the area.

In this regard, a basic principle to maintain the pasture adequate for longer periods is to maintain the balance between animal stocking rate and forage mass rate, both in quality and quantity, of the pasture (CEPLAC, 2018). The stocking rate corresponds to the number of heads or animal units (animals weighing 450kg of live weight) divided by the grazed area. It varies in the system depending on several factors, such as, season, which determines the supply and quality of grass fodder; rainfall, temperature, soil fertility, among others (CEPLAC, 2018). Therefore, it is important that the rate is defined according to forage growth, so that there is no excessive consumption of the plant by the animals - which can prevent its regeneration - nor excessive trampling by the animals. On the other hand, one should also seek a stocking rate that does not leave the pasture idle due to the use of a few animals.

In Brazil, in general, it is common the use of an inadequate stocking rate, above or below the pasture carrying capacity in overgrazing and undergrazing systems, respectively (Garcia, 2017). In overgrazing, the stocking rate is far higher than the carrying capacity of the pasture, compromising animal performance due to an inferior consumption to the one desired, which is caused by a competition between the animals for the areas with better forage quantity and quality (Garcia, 2017). On the other hand, in undergrazing, the stocking rate is below the pasture carrying capacity. The lower number of animals per area leads to a forage waste, leaving the pasture idle. However, in this case, since there is no competition among the animals for better forage, it results in greater individual performance (Garcia, 2017).

Considering the aforementioned aspects, it is necessary caution when planning an increase in the stocking rate. The rate should be calculated based mainly on the carrying capacity of the pasture.

Pasture management is an indispensable practice for increasing stocking. With correct management techniques, which often do not imply a cost increase, it is possible to increase the stocking rate in tropical pasture areas with considerable gains in performance (Machado and Kichel, 2004).

Finally, it should be noted that each pasture area has specific characteristics that must be evaluated and considered for its correct management. Certainly, pastures in more fertile soils

and, primarily, with constant maintenance through fertilization, can be used more intensely and for much longer without degradation (Machado and Kichel, 2004).

4.3.3 Increase in fertility rate

Reproductive efficiency is the most important factor in the profitability of livestock, with a direct impact on the productivity levels of the herd and, consequently, on the economic return of the activity. The fertility rate is an index of the reproductive performance related to female's fertility, on which farmers and technicians focus their attention to increase the performance of the animals through specific management techniques (Gottschall et al., 2013).

In this context, the following are used as indicators: pregnancy rate, which represents the number of pregnant cows in relation to the total number of cows that could be pregnant within the herd; and the delivery interval, which ideally should be between 12 and 13 months, and assists in the evaluation of nutrition and the sanity of the cows (SAC / CPAMT, 2018).

Reproductive efficiency is physiologically complex in cattle because it is dependent on a number of factors, such as nutrition, reproductive management, animal welfare, diseases, among others. One of the most important factors for the good reproductive performance of the herd is nutrition, since the levels of nutrients available for the cows must satisfy its needs in the various stages of gestation (Do Valle et al., 2000). Inadequate feeding may lead to non-onset of estrus within 45 days postpartum and impair the development of the fetus. Another factor of impact on the reproductive performance of the matrices is the temperature, especially in countries of tropical climate and in areas like the North region, where the state of Pará is located, as this affects the quality of the semen and embryos, influencing the pregnancy results of these animals (SAC / CPAMT, 2018).

Parallel to the well-conducted nutrition of the matrices, adequate reproduction management techniques must be implemented and conducted (Melo Filho and Queiroz,2011). One of the techniques used in the reproduction management of beef cattle is the establishment of a breeding season. The advantage of this type of management is that the period of the great supply of forages in the pastures, both in quality and quantity, coincides with the lactation stage of the cow, in which the animal presents a higher nutritional requirement (Melo Filho and Queiroz, 2011).

Another technique is related to the management of heifers (young cows up to 27 months of age that have not yet had their first offspring). In this technique, nutritional strategies are implemented in the farm so that these females reach, as soon as possible, in relation to the animal's age, the minimum recommended weight for the first mating of the zebu cattle. As a parameter, in these breeds, it is considered ideal when the heifer reaches the corresponding 60-65% of its adult live weight. Early heifers show higher reproductive efficiency and have longer lives in the herd (Gottschall et al, 2013).

The detection of the heat of the cows, either by observation and/or bulls (vasectomized or surgically altered), is another important point in reproduction management, since it determines the correct moment of insemination, when it is used, and it avoids open cows (not pregnant) for a long time, which can negatively impact the costs and performance of the farm drastically (SAC / CPAMT, 2018). However, the extensive system used in beef cattle in Brazil makes it difficult to adopt this type of management. In this case, the introduction of bulls with improved genetics is a good alternative for the improvement of the herd.

Finally, we emphasize that another aspect of management that should receive attention for a good herd reproduction performance is the sanitary state. For good sanitary conditions, a rigid schedule of vaccination, which takes into account diseases that mainly affect reproduction, such as Leptospirosis and Brucellosis, must be implanted and rigorously followed in the farm (SAC / CPAMT, 2018). These diseases are a major cause of death of newborn calves on farms where there is no vaccination. The deworming is another practice that must be adopted in conjunction

with the reproductive management, because in the face of a high infestation, it can cause a high mortality rate in the herd (Do Valle et al, 2000).

4.4 Technical Challenges for scaling-up low-carbon livestock farming

Although projects to mitigate climate change involving smallholder farmers may offer solutions to reduce the contribution of farming to GHG emissions, there are innumerable gaps and challenges to overcome in order to scale-up the projects and make them relevant in the global context.

From the point of view of pasture management, the challenges encountered for the adoption of good practices in the Amazon biome are many, and they begin in the absence of a consolidated ATER network. It is evident the need for an extension technician to make the technological diffusion efficient and to provide safety for the farmers when adopting new practices. In this way, the first step towards a real change is by structuring the ATER network and training the local technicians.

Access to inputs such as limestone and fertilizers is also a major obstacle. According to data from the National Association for the Diffusion of Fertilizers (ANDA), the states of the North represent together less than 3% of the national fertilizer consumption, with consumption in the state of Pará corresponding to 1.3% of that amount. The difficulty of access to these inputs is due not only to poor road infrastructure conditions, but also to the absence of a marketing network in the more distant localities. In addition, the absence of accredited laboratories, where it is possible to carry out soil analyzes that can guide the recommendation of the use of fertilizers and countermeasures to the pastures, also represents an obstacle to the implementation of the correct management.

The problems arising from the precarious logistic infrastructure and lack of commercialization network also directly affect the access of farmers from several regions of the North of Brazil to quality seeds. Often, family farmers, with little bargaining power over large suppliers, do not have many alternatives of forage species to form their pastures.

The implementation of good practices for bovine production that contribute to the reduction of GHG emissions is also challenging. Many of these practices require the development of adaptations that fit the characteristics of the Amazon region and the reality of the family ranchers. To this end, it is evident the need to strengthen the scientific research network aimed at the development of these practices in this context, as well as the expansion of the existing technological diffusion network. From the perspective of the bovine herd management and the development of techniques accessible to the family-based livestock farmer in the Amazon, the challenges must be addressed by the following practices:

1. Best feeding practices
   Gas emissions can be reduced through the feed by increasing the proportion of concentrates in the diet. The success of this practice depends on the number of animals in production per area and the age of animal slaughter. Another practice that can reduce gas emissions is the addition of oils and oilseeds in the diet, which improves its quality by promoting the improvement of animal productivity, reducing the percentage of energy lost in the form of methane, optimizing protein consumption, and reducing nitrogen excretion (Prada et al, 2013);
2. Use of food additives
   Examples of food additives to reduce gas emissions by ruminants include: Ionophores, such as monensin; halogenated compounds that inhibit methanogenic bacteria; nitrate, which exerts deleterious action on probiotic bacteria and protozoa; and, biotechnological products, with emphasis on supplementation with fibrinolytic enzymes composed of celluloses and

hemicelluloses. These enzymes are extracted from fungi or bacteria, and they are precursors of propionate, such as fumarate or malate.

3. Changes in farm production management
   Increased productivity through management, breeding, and sanity practices, and better property management can improve the efficiency of the beef cattle, which reach slaughter weight at a younger age, with reduced emissions during their lifetime.
4. Biological processes of nutrient recycling:
   An alternative to minimize the impacts caused by the large generation of manure in cattle production is the biological processes of nutrient recycling. These processes use the waste derived from animal husbandry as raw material for the generation of by-products of added value. Anaerobic bio-digestion is one of the main processes of nutrient recycling, in which a complex interaction of microorganisms occurs that degrade the various organic components of bovine manure to form biogas and biofertilizer. Both can be used on the farmer's own property, as an energy source and in pasture fertilization.

5 Opportunities for the implementation of practices and the diversification of production

This chapter is devoted primarily to examine the economic feasibility of practices (technological processes) for low-carbon livestock for family farmers in the Amazon context in terms of the impact on production efficiency. Those are described by the Manual of Practices for Sustainable Livestock prepared by GTPS (5.1). In a complementary manner, we discuss the importance of diversification of production in small-scale productive units and present a brief indication for opportunities in this sense (5.2).

5.1 Profile of the small-scale farmer vis a vis to the implementation of practices

Given the target audience of the ILHs, this section is dedicated to identifying which improvement practices fit the financial realities of smallholder farmers in the Amazon. To this end, the Manual of Practices for Sustainable Livestock (GTPS, 2016) was used as a starting point to identify which low-cost investment practices result in major impacts on productivity. The Manual of Practices for Sustainable Livestock has been developed in collaboration with industry experts in fields of activity which are fundamental to efficient animal production and management:

1. Management
2. Nutrition
3. Pasture usage
4. Reproduction and genetic improvement
5. Sanity
6. Animal welfare

Since the goal of the ILH is to empower smallholder farmers and technicians and facilitate the achievement of technological improvements through the continued access to information, learning and innovation, a series of technological processes were listed for each specialty aiming at the improvement of the livestock activity, which were analysed according to five criteria:

A. Cost of implementation: Low, Medium or High
B. Payback time: Quick <1 year < Medium< 5 years< High
C. Impact on productivity: Low, Medium or High
D. Implementation time: Short< 1 year; Long 2> years
E. Technological Complexity: Low, Medium or High

It was concluded that the ILHs would already assist farmers with criteria (B), (D) and (E), being considered together as the most relevant criteria to identify the technological processes of greatest applicability in the context of smallholder farmers in the Amazon, the cost of Implementation (A) and the impact on productivity (C).

Thus, understanding that smallholder farmers in the Amazon have low income and need a considerable increase in the production efficiency of their systems, we carried out an analysis of the 118 technological processes proposed by the Manual of Practices for Sustainable Livestock

and selected all the solutions that feature high impact on productivity with the need for low-cost implementation. Figure 21 presents the different classifications of the 5 criteria proposed by the manual, where the scope of our analysis is shown in yellow.

Criteria		Level	
Cost of implementation	Low	Medium	High
Payback time	Quick <1 year	1 year < Medium< 5 years	5 years< High
Impact on productivity	Low	Medium	High
Implementation time	Short< 1 year	Long 2> years	
Technological complexity	Low	Medium	High

Figure 21 *Criteria of the Manual of Practices for Sustainable Livestock selected for facilitating the choice of the technological processes to be implemented through the ILHs. Source: Adapted from Technical Committee of the GTPS, 2018.*

Of all the 118 options of technological processes suggested in the manual, those which presented low investment cost and high impact on productivity were: 9 Management solutions, 7 Nutrition solutions, 4 solutions in Pasture Usage, 6 solutions in Reproduction and genetic improvement, 12 solutions in Sanity, 9 solutions in Animal Welfare.

There was a selection of a total of 47 technological processes of effective improvements for smallholder farmers, which represents 40 % of the total options indicated in the manual. These results highlight the importance of ILHs as an instrument of access to innovation and learning. Through the ILHs, smallholder farmers will have access to the aforementioned technological processes, will understand their added value, and will be able to apply them. Finally, it is understood that the improvement of the productivity of the sector, in most cases (40%), can be achieved with small investments. In this context, we emphasize as well the importance of financial agencies, credit lines, and the third sector so that such investments occur in productive family units.

A table showing the results of the selection per field of action is presented below (figure 23). For more technical information about each of the technological processes, please see the Manual for Sustainable Livestock Practices [25] in full (GTPS, 2016).

Table 2 *Low-cost investment practices and high productivity impact for sustainable small-scale livestock farming.*

Technological process	Investment costs	Impact on productivity
MANAGEMENT		
Diagnose of management model	Low	High
Market analysis	Low	High
Liabilities analysis	Low	High
Budget planning	Low	High
SWOT Analysis	Low	High
Field and technical data collection	Low	High
Financial data collection	Low	High
Administrative data collection	Low	High
Traceability monitoring	Low	High
NUTRITION		
Checklist	Low	High
Training and sizing labour force	Low	High
Zootechnical and economic performance indicators	Low	High
Analysis and control of water quality	Low	High
Sizing of water demand, storage and distribution (plumbing, animal watering system)	Low	High
Carcass quality (objective)	Low	High
Manger	Low	High

[25] Available at < http://gtps.org.br/manual/>.

Technological process	Investment costs	Impact on productivity
PASTURE USAGE		
Forage inventory	Low	High
Pasture division	Low	High
Ambience	Low	High
Mechanization	Low	High
REPRODUCTION AND GENETIC IMPROVEMENT		
Selection/discard criteria	Low	High
Environment adaptability	Low	High
Diagnosis	Low	High
Breeding season	Low	High
Identification	Low	High
Training of employees	Low	High
SANITY		
Training of employees	Low	High
Vaccination against foot-and-mouth diseases	Low	High
Vaccination against brucellosis	Low	High
Diagnosis of tuberculosis	Low	High
Clostridiosis vaccination	Low	High
Vaccination against rabies	Low	High
Control of endoparasites	Low	High
Control of ectoparasites	Low	High
Treatment of parasitic sadness	Low	High
Treatment of neonatal problems	Low	High
Treatments of reproductive problems	Low	High
Mastitis treatment (cattle milk)	Low	High
ANIMAL WELFARE		
Access and distance to water	Low	High
Transport	Low	High
Sizing/location positioning	Low	High
Training	Low	High
Reduction of injuries	Low	High
Formation of the lot	Low	High
Sodomy	Low	High
Pre-Boarding fasting	Low	High
Check List	Low	High

Source: GTPS and Solidaridad (2016) *Manual of Practices for Sustainable Livestock*. São Paulo.

5.2 Beyond livestock farming: diversification in the productive family unit

The development of a model of sustainable livestock production in the Amazon in the context of family agriculture should involve strategies for the entire productive unit. To execute the farming activities, the small-scale requires the efficient use of soil and the optimization of all resources available. In this regard, the diversification of production systems is key to the economic prosperity of the family unit, promoting social and environmental benefits.

Diversification brings economic resilience to the productive unit as it enables access to different markets, widens the sources of income and reduces the dependence on sectorial price fluctuations. Besides expanding market opportunities, diversification also ensures the subsistence of the family farmers. In the area of the Trans-Amazonian Highway, where the main economic activity is livestock farming, there is a great opportunity for diversification in production, taking into account the demand of moderate labor for herd and pasture management.

In the Tuerê settlement, where the Solidaridad acts, production diversification is a reality. The land use of the lots involves 3 main components: livestock breeding, agroforestry systems of cocoa, and forests. In this arrangement, where traditional cattle activity was complemented with cocoa crops, and in conjunction with the maintenance of forests, it was established a profitable and low-carbon production system.

There are several alternatives to the diversification of production that complement the livestock farming in the Amazon, being the cocoa SAFs one of the most interesting because they add several benefits. The cocoa SAFs combine income generation and the restoration of the landscape, also promoting the inclusion of family agriculture in the process of environmental regularization.

The choice of cocoa for the leading role of the SAF is justified not only by its attractive commercial value but also for the ecosystem services provided by this production system. Since it is a native species of the Amazon, it is more productive and more resistant to pests and diseases in this biome in comparison to the cocoa produced in the South of Bahia. It also is more profitable than the traditional regional activity, the livestock breeding and rearing. In addition, the cocoa plantation offers the possibility of exploitation of other crops such as cassava, pumpkin, and banana, in the first years of the systems' implementation. It also represents an alternative for income generation, and it ensures food safety to the families.

Besides diversification through the Agroforestry Systems, livestock breeding in the Amazon can be complemented with various activities, such as: dairy farming, fish farming, pig farming, fruit growing and exploitation of Non-Wood Forest Products (NWFP).
Lastly, the expansion of markets and the generation of income in household production can also be boosted by agricultural industrialization. The establishment of small units for product processing such as fruit pulp, vegetable oils, and dairy products, can bring high added value for the family business.

6 Small-scale farmers as multipliers for the ILH

As we have shown in the previous chapters, because we understand that the experience with smallholder farmers in the Tuerê settlement constitutes a model of intervention capable of leveraging the adoption of new farming and environmental practices in the Amazon context, we conducted a survey on the social acceptance of the sustainable production strategies and innovative technologies through interviews with their beneficiaries - Tuerê family farmers and local agricultural technicians - with the goal of evaluating the potential for establishing an ILH in this region.

In this chapter, we will first discuss the determinant factors in the acceptance of strategies of sustainable production by small-scale farmers according to the scientific literature (6.1), and secondly, we will present the views on the interventions carried out by the project, its benefits, and the needs perceived to boost scaled-up initiative (6.2).

6.1 Determining factors in the acceptance of sustainable production strategies by small-scale farmers

The introduction of low carbon sustainable farming practices[26] and technological innovation in rural areas has been considered an important and advantageous strategy, especially for developing countries since they present the potential to increase agricultural productivity, food security and economic growth, and simultaneously, contribute to the mitigation of GHG emissions and climate change, and to the improvement of environmental aspects within productive rural units.

Although the use of these practices and improved technologies by rural producers have been successful in increasing productivity on the farming sector and food security in Asian, African and Latin American countries (FAO, 2014), their adoption has been going slow, remaining below expectations (Zeweld, et al., 2017). In the last decades, a growing number of studies (Naspetti et al., 2017; van Dijk et al., 2016) has sought to understand the behaviour of rural producers towards the adoption of sustainable practices, as well as the determining factors of acceptance of sustainable production strategies[27] and of motivation to participate in projects and/or programs that promote these strategies from a cognitive and psychosocial perspective.

In the context of the specific determinants factors of acceptance of unsubsidized sustainable production strategies, the main contribution made in psychosocial studies has been the Theory of Planned Behavior (TCP) (Ajzen, 1991). According to this theory, the concretization of a certain behaviour is directly dependent on the intention that the individual has to carry the behaviour out. This, in turn, would be directly related to three factors: (i) the attitude towards the presented theme; (ii) social pressure from other significant individuals to perform a particular behaviour; and (iii) the perceived behavioural control, namely, the perceived ability to perform the attitude. In addition to these factors, the self-identification of the individual with the practice has recently been added to models as one of the most prominent indicators of TCP

[26] Among other aspects, sustainable farming practices include creating and maintaining a healthy and fertile soil, efficient water resource management, minimizing water and air pollution, reducing GHG emissions and fostering the maintenance of biodiversity and the resilience of the agroecosystems (Zeweld et al., 2017; Kassie et al., 2013).
[27] Sustainable production strategies, according to Naspetti et al. (2017) can be defined as long-term, comprehensive action plans that provide a guide to achieving farmers' goals in terms of sustainable farming practices.

(van Dijk et al., 2016; Burton and Paragahawewa, 2011). As we shall see next, these factors, in turn, are influenced by the perception of some empirical aspects of the presented practices.

It has been observed that a positive attitude towards a new farming-environmental practice is of fundamental importance for its adoption and it is strongly related to its perceived utility and ease of implementation by the targeted rural producers (Naspetti et al., 2017). Thus, factors such as increased productivity, reduced working time, and improved soil quality were identified as motivating factors for the adoption of practices by a study in Mozambique (Lalani et al., 2016).

Moreover, observation and proactivity are highlighted as motivational aspects by farmers with a high intention of using sustainable production practices, indicating that they are likely to have observed the results obtained by other farmers who have adopted the practices, or they have observed results in experimental areas in their productive units, developing the perception that the practice can be successfully performed (van Dijk et al., 2016).

Social pressure, on the other hand, is the influence that the norms from the group in which the individual belongs have on his perception. Therefore, if on the one hand, the intention to adopt certain practices is related to the understanding of the practices' usefulness, such an understanding is strongly influenced by the opinion of "relevant or significant others" (Naspetti et al., 2017). It may be assumed that social pressure and self-identification are directly related, since when identifying themselves as belonging to a certain group, the other group members may become social pressure factors on their intention to perform a certain practice. From this perspective, the organization of farmers in regional cooperatives may contribute to the adoption of sustainable and innovative practices, by being able to create new social representations as well as new identities (McGuire, Morton & Cast, 2013).

Within the collective, the exchange of knowledge and skills was also pointed out by farmers in some studies (Franks and McGloin, 2007; Mills et al., 2011) as a facilitator for the implementation of farming-environmental practices, contributing to the creation of cultural capital (knowledge, capacity and aptitude) and social (access to networks and their resources) (van Dijk et al., 2016, Burton and Paragahawewa, 2011). In these systems or mechanisms of social learning, participation is related to a greater intention to adopt good agricultural practices due to the perception of its benefits, but also due to influential social norms, since the participants have a greater motivation to implement the practices of the group, perceiving them as easier to use (Lalani et al., 2016).

Finally, perceived behavioural control refers to the self-perception of the individual as apt and able to perform a given practice according to its knowledge and its availability of time and resources. In this context, a study on opportunities for intensification of sustainable production identified significant knowledge gaps among the poorer farmers, suggesting the introduction of basic agronomic practices for a substantial increase in productivity before suggesting the use of costly inputs such as fertilizers and herbicides, since the return on investment of applying inputs is higher for medium and high-performance farmers (Roxburgh & Rodriguez, 2016). Furthermore, from the economic point of view, it is suggested that the choice for adopting a given technique, innovation or technology depends on the maximization of the expected utility, being subject to prices, policies, personal characteristics and natural resource assets (Caswell et al. 2001).

6.2 The views, benefits, and needs of local social actors in Novo Repartimento

From the exposition of the determining factors for acceptance of strategies for low carbon sustainable production and innovative practices, we present a qualitative analysis of the perceptions and perspectives of the social actors involved in the project Inclusive and

Sustainable Territories in the Amazon[28] on the sociocultural and economic importance of the livestock, the status of this activity in small-scale productive units in Tuerê and the activities implemented under the scope of this project (6.2.1). Following (6.2.2), we present an analysis of the social acceptance of low carbon production strategies used by the project, with an emphasis on the importance of the support instruments and the perspectives for mitigation of deforestation and environmental suitability of the productive units (plots). Finally, we intend to highlight the opportunities for the establishment of an ILH in the Novo Repartimento region (6.2.3), based on the experience of the Tuerê settlement.

6.2.1 Small-scale livestock breeding in Novo Repartimento: between tradition and an ideal

Within the sociocultural and historical context of the Trans-Amazonian region, where the municipality of Novo Repartimento is located, livestock farming expanded through the opening of forest areas, between 1975 and 1979, becoming, two decades later, the activity with the highest economic importance of this municipality. Initially, it was carried out by medium and large farmers, gradually being incorporated by small-scale farmers, predominantly from the agrarian reform from other states and that sought to improve their living conditions on the agricultural frontier being established.
Many reasons may be considered for the establishment of extensive livestock farming as a standard rural activity among small-scale farmers of Novo Repartimento. Among them, it is worth noting that the very dynamics of occupation and land use change in the Amazon context favoured livestock farming to the detriment of other agricultural activities, as much as because of the lack of structuring of other production chains, as for the ease of the pastures' implementation. In addition, many of the family farmers already had the activity as a traditional practice in their home state, either for subsistence purposes or as an ideal to be reached in a new context.

> "When people came to occupy the Amazon, they already had a mentality for extensive cattle farming, with a reference from some other state and came here to realize their dreams, to work with livestock, to become a farmer, to become a cattle rancher. Naturally, by using the logic of settlements, I tell the farmer that he cannot be a farmer by doing extensive livestock farming. It is not fit for them. We say that (in this extensive system) if we add up, they have losses." (Pedro Santos, Solidaridad's technician in Pará)

Currently, in general, the largest area proportion of the plots within Tuerê is destined to livestock breeding, whose expansion over the years has been directly related to the progress of deforestation. The cocoa crop began to be disseminated almost a decade after the establishment of the settlement, starting in 1998, through CEPLAC, as a crop with the potential to generate income and contribute to the subsistence of local farmers. Regardless of the success of the implantation of cocoa crops, their economic return, and complementarity in relation to livestock farming in Novo Repartimento, and in Tuerê itself, it was possible to verify the increasing importance of livestock farming in the social representations of small-scale farmers, who referred to the activity as "main", "flagship", "the one that moves the region", and it was supported with unanimity by the speeches of the interviewed technicians.

According to the interviewees, the animal and pasture management within the breeding systems of Tuerê is carried out in a so-called "traditional" or "rustic" manner, without the application of fertilizers and with the common use of fires to reduce the number of invasive plants and/or nutrient availability. The open areas are generally subdivided into large pastures with areas ranging from ten to fifteen hectares, where the livestock herd remains for a period of

[28] As mentioned earlier, the data was collected through interviews conducted between November 10th and 14th 2018, with the family farmers of the Tuerê settlement who were beneficiaries of the initiative, the farming technicians from the project in Novo Repartimento and the farming technicians from Unitec Farming Projects, the responsible company for elaborating the CAR of the plots of this settlement.

time, and it is rotated between the subdivisions in order to regenerate the pasture. Although it is an extensive system, with a low stocking rate of around 0.82 animal unit (AU) per hectare, it can be observed, among the technicians, a perception that the stocking rate, even though it is very low, it is generally exceeded by farmers due to poor pasture conditions and low efficiency in herd maintenance, as it can be recognized in the following statements:

> "The livestock farming in the region is traditional. The farmer opened the area - I'll talk here in terms of four bushels of pastures. In this area, he only makes three divisions and exceeds the amount of animal per area. Then, because it exceeds it, the soil starts to become degraded. The cattle trample much of the area and the pasture that was supposed to last longer doesn't. Then, the cattle take turns between these three areas. Often he takes the cattle out of the area after the time to do so has passed, and this hampers the forage regrowth." (Daniel Costa, Solidarity technician)

Considering that more intensified livestock systems can sustain a much larger number of livestock units per area (3 to 4 AU/ha) than the average used in the settlement (0.82 AU / ha), such perception may derive from the observation of the pastures' degradation caused by the lack of subdivisions in smaller paddocks and by the prolonged period of areas occupied, leading to the overgrazing and grass trampling by the cattle. In this sense, many farmers and technicians highlighted having the perception of the need to modify the management, by increasing the number of paddocks per area in order to establish a more efficient rotational grazing, as it can be noticed in the following speech:

> "To make the pasture last longer, I had to build more paddocks. To improve conditions, make more divisions. Because then, it will take longer to use the whole pasture, for the animal to walk around the entire pasture. He'll stay in a small place and make better use of the pasture." (BNL, farmer of Novo Repartimento / PA)

On the other hand, despite the existence of areas used for pasture for more than two decades, many of which are under the regimen of burning practices, among the farmers prevails the perception that the soil of their productive units is not degraded, which leads to the perception that the replacement of nutrients through fertilization is not necessary.

In general, the livestock farming model practiced currently in Tuerê is observed as an economically unfeasible activity by all the interviewed technicians, who have called attention to the urgency of adapting it to a more intensified, productive and profitable model.

> "The way it has been carried out (the livestock farming), the farmer has losses. I do not think he can sustain himself only with the 50 hectares for cattle ranching in the way he has been working on it, extensive. If he changes to the other model, the one we are building now, it is another reality: he can produce more, earn more, and have more cattle in a smaller area; increasing quality by bringing technology. " (Pedro Santos, Solidaridad's technician)

6.2.2 The social acceptance of strategies for sustainable production in Tuerê

The process of engaging farmers to adopt the new practices proposed for the management of livestock production usually follows a script, which begins with evidence of the productive and economic efficiency of the new practices proposed within the scope of the demonstration units. Simultaneously to the execution of the activities within the demonstration units, the farmers carry out the collective technical training which complements the recommendations from the individual technical visits. Due to the recent initiation of interventions focused on livestock farming (January 2018) and the need for financial and labour investments by farmers, few changes have been effectively implemented in the animal husbandry and pasture management systems within the beneficiaries' productive units. In this context, the project's local technicians

highlighted the importance of working together with the farmers on the medium- and long-term and the need to demonstrate empirical results in order to increase participation in the promoted practices.

> "There is still little change. Some (farmers) already talk about pasture reform - doing an analysis, adding limestone, fertilizing - but they are still very few, because this means investing in that area. When it comes to the costs, some are afraid to sell what they already have (cattle) in order to know if it will generate a benefit. But there are many farmers who want to invest in having a larger herd within their property." (Pedro Santos, Solidaridad's technician).

On the other hand, due to the training and capacity building already carried out, some changes in the usual practices have already been observed, for example, some of the beneficiaries are reducing or forsaking the practice of burning pastures. Moreover, it has been noticed a positive attitude on the part of the farmers towards the management practices and techniques encouraged by the project and, in some cases, the intention and, even, the projection of change in the pasture and animal management systems in order to increase the profitability of the activity, as the farmer from JSR explains:

> "So far, cattle management has not changed, but I already see some changes. Ideas that have already been proposed to us, which I find interesting and I'm sure they will be used! It is necessary to work on the further improvement of the management and paddocks systems. This is the main focus, the first step. I'll even do it on my own." (JSR, farmer)

As pointed out by the research done by Naspetti et al. (2017) and Lalani, Dorward, Holloway and Wauters (2016), the perceived utility of the practices stimulated by the project, more specifically due to a possible increase in productivity, acts as a motivating aspect that promotes a positive and receptive attitude by the farmers. Furthermore, other practices described by the farmers as potentially applicable and beneficial to the productive system were the improvement of the pasture conditions and the herd's genetics, changing the choice of the forage grass species and the forest-livestock integration.

The Importance of Supporting Instruments

Among the benefits associated with the project, interviewees highlighted the creation of cultural capital through continuous training, capacitation, continuous technical assistance, and agricultural extension. From the farmers' perspective, the great contribution of their direct participation in the project is related to the acquired knowledge, which has made possible new choices, especially concerning the cocoa production system, whose activities in the field have been executed by the project since 2016.

> "The project is helping with everything! Even with the fine cocoa that I produced, they (project technicians) were the ones who helped me. They are there for about two, almost three years. All this is happening because of them, and no one could have seen it. I took the chocolate to Paris, I already went to São Paulo, I could not have imagined it. I already have a new goal! I'm also curious, so I dive into it, right?! That's what they want."(JSR, farmer).

In addition to the aforementioned methods, the project implemented a demonstration unit in a lot of Tuerê in September of 2018 to demonstrate the practices promoted by the project. This unit is used as a training space for technicians and farmers. Although the results have not yet been consolidated, the method presents great potential to leverage the intention and, consequently, the adoption of new practices by the cattle ranchers, since the observation *in locu* allows them to verify the utility - in this case, more specifically, the increase of productivity - as well as the ease of applying the practices, as highlighted in section 4.1. The method of intervention is being perceived very positively by the farmers, who emphasized that the

observation of the management system implementation and the practices is a key motivating factor in the intention of adopting them.

> "Only when we see it happening that we will be able to develop, because people, nowadays, are very sceptical. Sometimes they implement it (the intensive livestock system) in one place, but we will only really believe in it when we see the results. They are already implementing it (a demonstration unit) there. Next year we will start seeing how much it increases income, the number of animals that live in that piece of ground. Only then people will want to be part of it". (BNL, farmer).

From the technicians' point of view, besides the potential to leverage the adoption of good agricultural practices among the beneficiaries of the project, the method may also contribute to its dissemination among the other farmers of the settlement, even being evaluated as the most effective method for the project's target audience.

> "We have large experience in the field, and what the farmer does not see, he does not believe in it. We took the farmers from Novo Repartimento to visit farmers in another state, so they could see what we were talking about in the lectures. When they heard a farmer's testimony about how much he was earning in a small area, many returned with a dream (purpose?) in their heads:
> I'll do it on my property!" Many did and it worked. So, while the farmer does not see that what we are talking about is working in practice, he will not do it. "(Pedro Santos, Solidarity coach)

The use of digital technologies is part of the project's strategy to increase the scope of the implementation of good practices and scale-up technical assistance. To that end, Solidaridad developed two applications - "farming solution" and "extension solution" - already available to use and which shall be distributed among the Tuerê technicians and farmers in the coming months. Regarding these tools, although some of the farmers are not yet familiar with their usage, a positive attitude towards them has been observed, as demonstrated by the following quote:

> "I do not understand well the cell phone, no. I hardly use it, but my wife knows how to. I would use it. Because this way, with the new cattle registration that people are talking about, those who do not know how to do it will have to ask for help and then, with time, the person will learn. Having someone at home who knows it, it helps." (AJF, farmer)

From the technicians' perspectives, the tools are seen as facilitators for contacting the farmers, contributing simultaneously to the organization of ATER's work and to the monitoring of the adoption of the practices.

Perspectives for deforestation reduction and environmental adequacy of the productive units

In general, the interviewees perceive the increase in efficiency of the production system as a crucial motivating factor for the reduction of deforestation with a view to the opening of new pasture areas. However, the importance of the parallel work on awareness of the process of environmental adequacy of the productive units in order to achieve more effective and lasting results was highlighted as fundamental by the project's technicians.

> "The areas are continuously being opened to place cattle. The farmers always complain: - How am I going to do it, where will I put my cattle? There is no more pasture here! In this case, with the adoption of these good practices, we know - through several studies that show evidence of it in different regions -

> that they could survive in small areas and make a bigger profit." (Fagner, Unitec technician)

> "I believe this goes a long way toward environmental awareness as well because if farmers implement the rotational management for 35 or 40 heads of cattle and it works well, I believe they may want another area just like that one to put more cattle. That is why it is important to work with awareness, talk about deforestation and environmental regulation." (Daniel Costa, Solidarity technician)

In this context, an emerging aspect from the Unitec (local ATER company) technicians' perspective was the recognition of the project's contribution in supporting the compliance of the productive units with the environmental legislation.

> "Here in Pará, Tuerê is an area that has a high incidence of deforestation. With the practices that Solidaridad has promoted, especially that of environmental regularization, to comply with the Forest Code of 2012, this is very interesting for both the farmer and the State, it is a general improvement." (Tiago, Unitec's technician)

The support offered by the project for the process of formal environmental regularization of the lots, as well as the activities already carried out as trainings, capacitation and ATER, have shown to have stimulated the interest and the perception of the need to acquire greater knowledge about environmental legislation, the possibilities related to the sustainable management of species within the areas of permanent protection (APP) and Legal Reserve (LR), access to credit and financing programs, as well as possibilities related to payments for environmental services (PES). In addition, there was a strong expectation that the environmental regularization of the lots would be done via PES, since the settlers who deforested areas within their lots after July 2008 should restore the vegetation to be in conformity with the legislation and, this way, be able to access credits for investment and regularize their production activities.

> "The environment is the main thing, because if you act in the right way, then it will expand, for sure! Some compensation will come to us so we don't have to deforest. The settler only deforests because he has to. It is missing knowledge in the whole of Pará and I believe it is right. People deforest! If I have a good salary, why would I deforest? But, if it's not going well, I'm going to take it (forest) down and I don't even care if I will get a fine. The forest doesn't give me anything, no. The fertile land only produces if we work on it ." (JSR, farmer)

The environmental issue is highlighted as the greatest challenge in the different angles and perspectives of the local actors, especially curbing deforestation according to the technicians' perspective, and being compulsory the restoration of vegetation , in the view of the farmers, as it can be evidenced in the following statements:

> "Our greatest challenge is to curb deforestation and creating awareness. Putting inside the farmer's head that he does not have to deforest. To demonstrate the importance of having a standing forest. In his view, he gets nothing out of it, but in our view, we have to demonstrate that there are a series of values added to the forest within a global context." (Pedro Santos, Solidaridad's technician)

> "I think a challenge is the financial condition on this side of reforestation. You may even have someone who has a reforestation plan for what was deforested, but the (economic) condition will not help." (AJF, farmer)

If in the farmers' view, environmental compliance is treated as an impediment to the production activity and the access to credits from government programs, it becomes a sensitive issue for the technicians, making it difficult for them to approach the farmers and it generates mistrust on the part of the latter, requiring time, ability and different strategies than those aimed at improving the efficiency of the production system.

> "If when we arrived, in 2016, you said to the farmer that one of the goals of the project was to stop deforestation, 90% of the people would say they did not want to participate. So, first, we did our job by trying to meet the needs of the productive unit and then, afterwards, try to educate the farmer further. Creating awareness is, for us technicians, what weighs the most. It's the hardest work of all!" (Pedro Santos, Solidarity coach)

In one hand, it was observed an expectation from the farmers that the environmental regularization of the lots will fully occur through subsidies from external initiatives, as exemplified by the following statement from a farmer:

> "I needed a little reinforcement (subsidies)... In many cases, it would even help. Because even with (financial) help, it would still be difficult to do it in the right way. A technician would have to be there together with the farmer at the moment he would reforest it, because if ten or twenty thousand (Brazilian reais) appear in the hands of the farmer, he might end up not even doing what he's supposed to. This is how it goes!" (AJF, farmer)

On the other hand, the demand of the CAR, of joining the PRA and the Rural Activity License (LAR), in the case of Pará, as requirements for gaining access to government programs and to credits that finance investments to improve the production systems - such as irrigation projects for the cultivation of cocoa and the implementation of rotational grazing to intensify livestock production- end up being factors of social pressure for its implementation.

> "The first difficulty is financial, because in this case, if these farmers have to pay for it, I assure you with certainty that no one would pay from 2000 to 2500 Brazilian reais to take out a LAR. Only if it's to get funding. There, environmentally speaking, is very complicated." (Fagner, Unitec's technician)

It was observed that, in spite of a generalized perception that the protected areas by law in the rural property represent the loss of productive areas by the farmers, most of the interviewees demonstrated to identify themselves with pro-environmental attitudes, as it happens in this speech :

> "I like the woods! I've deforested before, but it's not because I do not like the woods. I like to get into the forest, I feel good, the weather (is nice). A fair share of my lot has cocoa reforestation, and the trees that I left there. Native trees, the tatajuba, ipê, bacaba, some sprouts that came from the forest and I left it there." (AJF, farmer)

In general, the interviews made it possible to highlight the demand for the continuity of the implementation of the activities (trainings, capacitation, technical assistance) with farmers in order to explore the possibilities of sustainable use of natural resources in protected areas by the Forest Code and to deepen knowledge in relation to the importance of conserving and restoring the native vegetation in the productive units for the maintenance of natural resources and the production processes, so that the process of the environmental regularization of the lots is viable in the medium and long term.

This demand is very much in line with the methodology proposed by Solidaridad's intervention model, which explains the success achieved so far in adopting good agricultural practices. According to Solidaridad's latest annual report, 150 farmers were engaged in the initiative,

being trained in low-carbon production practices. However, it is important to note that these farmers are at different levels of adoption of these practices, which is proportional to the time in which they participate in ATER's virtuous cycle and the technical training. The level of adoption directly reflects on the land use in the area under the influence of this new management view of the farmers.

6.2.3 Opportunities for an Innovation and Learning Hub for small-scale livestock breeding

The model of intervention developed by Solidaridad and applied to the small-scale farmers of Tuerê is perceived as a unique initiative in the region, representing a significant opportunity for the settlers who are seeking improvement in their living conditions, as stated by the following:

> "There isn't a job like that in a radius of 1500 kilometres. If there is another, it's in another area. People here want to see things evolve." (JSR, farmer)

Furthermore, it was possible to notice that the Tuerê settlement is seen as a suitable place to initiate the scaling process of the implemented model due to its size, and, especially, because it encompasses a large aggregate of farmers, who, in general, carry out the productive activities and use the soil in a similar way.

> "In fact, this Tuerê allotment is one of the largest in Latin America and everyone who lives in a place like this one has the interest to grow and progress because this place is good and everyone wants to grow. Someone sees the neighbour growing and then wants to grow and the work helps. Everyone wants to work to be able to live peacefully. " (BNL, farmer)

All interviewees - both technicians and farmers - believe that the intervention experience developed over these four years in Novo Repartimento presents great potential for scaling-up and replication in the region, making it possible to establish an ILH in the near future. In this regard, they observe the existence of interest and motivation on the part of the farmers of the settlement to participate in the initiative, which may lead to a virtuous circle in the adoption of sustainable production practices.

> "We, who are there every day, see that it is a region with a lot of potentials. They could develop it into this (ILH). With the adoption of the new practices, everyone will be focused on it and it is like a chain: someone sees it working, then the neighbour - who might be from a family that is not benefited by Solidaridad - will want to implement it as well. It will work! Then, another one joins, and then it will breach out the settlement, and it will go to everyone. If it works, if it really works, they will want to improve it." (Tiago, technician of Unitec)

In order for this scenario to happen, the technicians considered the need for more investments in order to make the implementation of more demonstration units feasible - which has been seen as a motivating element for the adoption of new management systems and good practices by the interviewees - as well as infrastructure improvements and the increase of the project's technical staff to carry out more trainings and capacitation courses.

> "I think that the (project) team and (financial) support would have to expand. We need to have all the infrastructure, vehicles, and equipment to assist more people. We should have more pilot projects. This would contribute to let people who are not in the project see it - people of the municipality itself - because it is too large. It is around 15 thousand square kilometres. Thus, it would be possible to bring farmers from outside the settlement to get to know the operational demonstration units and to replicate it within the municipality." (Pedro Santos, Solidarity coach)

In addition, in order for the intervention model implemented in Tuerê scale-up and be promoted to an ILH for small-scale livestock breeding in the region, the establishment of partnerships and agreements with other local institutions - such as universities, Embrapa, Ceplac, the Secretariat of Agriculture, the Secretariat of the Environment and Sustainable Development for the State of Amazonas (SEMAS), the National Institute of Colonization and Agrarian Reform (INCRA), among others - is a fundamental strategy proposed by this study and by the project's technicians.

> "To scale-up the work that we are doing, I would advocate for establishing more agreements with state institutions, bringing more professionals to carry out more training, both for technicians and farmers." (Daniel Costa, Solidarity technician in Pará)

According to the interviewed farmers, the main institution that has acted directly in the settlement, besides Solidaridad, is Ceplac, which has been contributing by providing technical assistance to cocoa farmers. From the perspective of technicians, although there is a disarticulation between the local, regional, and state institutions, there are several opportunities for establishing and strengthening institutional arrangements:

> "In the municipality, we have Sebrae, INCRA, SEMAS, Agriculture Secretariat, Fisheries Secretariat, Adepara, Emater. Each of these organs is a little seed with little firepower, because it does not have the resources for investing in improvements at the family units, but each one has a role in that sense. There is also Ceplac, Unitec and the Cooperativa, which gathers farmers in it, and there is Senar which does the training and courses here." (Cidson Cerqueira, Solidaridad's technician)

In addition to the aforementioned aspects, as described in topic 6.1, self-identification is one of the determining factors for the intention to promote sustainable production practices. In this context, the establishment of an ILH for small-scale livestock breeding can allow identification of the participating farmers with more sustainable and low carbon practices, as well as with the other participants of the group. In this regard, the identification of farmers who have a greater affinity with environmental issues and have a positive and proactive attitude towards the environmental regularization of the lots and the adoption of good agricultural practices - already carried out by Solidaridad's technicians - is key to making them become multiplication agents.

7 Conclusion: prospects for the future of ILHs

The present study aimed to evaluate the potential of an integrated low carbon model of small-scale livestock breeding in the Amazon based on the establishment of ILHs. As we have sought to elucidate in the previous sections, due to little institutional, sectoral and structural development, this activity constitutes an invisible link in the meat value chain for which intersectoral efforts are essential for solutions to reach the rural areas.

At this point in the study, it is critical to understand that solutions are already in place to overcome the challenges of small-scale livestock breeding, which can be achieved through the implementation of low-carbon GAPs. However, these are dispersed and the initiatives that promote them, disarticulated. On the other hand, local challenges for the adoption of sustainable production techniques are also known. Thus, the major contribution provided by this study is to systematically look at existing knowledge - both in terms of methods to foster adoption of practices, and content - and organize it into an intervention strategy that makes it accessible to the smallholder farmer of livestock breeding in the Amazon.

Regarding the proposed intervention model for the ILHs - developed and tested by Solidaridad Brazil with family farmers in Novo Repartimento / PA - composed by continuous, integrated, and individual ATER actions; methodology that includes the farmer in the experience of solving their problems (UDs); tools that facilitate access to existing technology; and the commitment of the public and private sectors to its establishment; we conclude that it generates productive and social impacts on the territory. By simultaneously providing to the farmer tools to problematize their practices and access to knowledge, we have seen the triggering of transformations that generate social inclusion and innovation processes.

In this way, the “Innovation” pillar of the ILHs stands out for its ability to introduce technological processes to smalholderl farmers in order to achieve production efficiency while at the same time reducing GHG emissions. The "Learning" pillar is characterized by facilitating access to information and by training the farmers, so that, finally, these processes are established in practice, serving as an example so that the solutions provided by the ILHs multiply and benefit the entire livestock value chain.
We understand that ILHs are responsible for creating a business-friendly environment and attracting new investments in the territory. However, for these hubs to materialize, it is essential to establish international or national partnerships that bring resources to this initiative, and the effort on the part of the public sector in the provision of an environmental regularization, since, currently, regional development policies need to be strengthened. In this context, it is worth mentioning that although the model tested by Solidaridad in the Tuerê settlement presents opportunities for the future establishment of an ILH, it still requires the concretization of a solid partnership, with long term commitment for the implementation of other ILHs. It is precisely in this link between innovation, public and private partners, and the adoption of practices in the field that focuses on the performance of civil society.

The configuration of ILHs brings together the necessary components to promote impactful interventions that result in the establishment of a sustainable value chain. Through actions involving the productive unit, the landscape, the relevant actors and the governance of the territory, it is possible to promote efficient soil use, access to knowledge and inputs, fair commercial relations and valorization of the labor force from family agriculture, thus creating a favorable environment for the maintenance and dissemination of sustainable and inclusive practices.

In the long term, it is concluded that future results from the implementation of ILHs will significantly contribute to climate change mitigation at the national level, helping Brazil achieve its goals and commitments contained in the Paris Agreement, and to the global conservation efforts of the Amazon region. We highlight the crucial role of countries benefiting from the Brazilian livestock industry in contributing to its sustainability. Historically, the most substantial investments for the conservation of the Amazon were made by Norway, Germany, and the United States. However, it is also worth noting the increasing involvement of the Dutch government in this subject, for example, through funding this study.

In general, we recognize that livestock farming, even if criticized as being incompatible with the conditions offered by the Amazon, is very representative and socially and economically important in the region. As the primary source of livelihood for thousands of families, it is of great importance for the Brazilian economy and the international market. Therefore, it is fundamental that initiatives such as ILHs, and the national and international engagement obtained in this study can make visible the importance of sustainability of this link in the livestock value chain. Finally, it is recommended the establishment of institutional arrangements to highlight the importance of ILHs to funding agencies and the private sector so that they are no longer a concept but a reality, contributing in a concrete way to the transformation of livestock breeding into an economic activity with low environmental and climate impact in the Amazon.

8 Acknowledgments

The authors would like to thank the agriculture department of the Dutch Embassy in Brazil, especially their attaché Bert Rikken and his team Ramon Gerrits and Amanda Molenaar. Without their commitments to sustainable livestock farming in Brazil, optimism regarding the Brazilian and Dutch initiatives, and engagement with the Dutch Ministry of Agriculture, Nature, and Food Quality (funding body), this study probably would not have started. Likewise, we thank the regional representative of WUR for Latin America and the Caribbean, the highly esteemed Ria Hulsman. The forerunner actor of the efforts in this study and of the relations between WUR, WLR, and the Embassy. Finally, we thank the reviewers and collaborators of this study, Daniela Mariuzzo (IDH), Rodrigo Castro (Solidaridad Brazil), Alexandre Bernedt (Embrapa) and Vivian Timpani (Embrapa). Every comment and minute of their efforts were of paramount importance for the improvement of the study. It is worth mentioning the contribution of Vivian since the first stage of the study, not only for her technical knowledge but also for the active and engaging activity with the institutions of Pará and her fundamental participation for the success of the launch events. We are also grateful to all the contributors who were not mentioned so far, but who, to some degree, were supportive of the results presented here. For example, our translator, Paula Martinelli and the farmers and technicians of the Tuerê settlement. We are grateful to all of you, and we hope that the efforts to develop sustainable livestock farming in the Amazon continue moving forward in an integrated, long lasting, and prosperous way. We are confident that improving the livelihood of local actors while generating micro and macroeconomic outcomes for Brazil's economy, not only benefits the Amazon Biome but improves climate change scenarios globally.

References

AGÊNCIA DE DEFESA AGROPECUÁRIA DO ESTADO DO PARÁ - ADEPARA. Relatório de Monitoramento do Trânsito Pecuário: bovídeos, 2017. Disponível em: <http://www.adepara.pa.gov.br/sites/default/files/Relat%C3%B3rio%20do%20Tr%C3%A2nsito%20de%20Bov%C3%ADdeos%202017.pdf>. Acesso em: 22 dez. 2018.

AGUIAR, A. P. D. et al. (2016). Land use change emission scenarios: Anticipating a forest transition process in the Brazilian Amazon. Global Change Biology. Disponível em: <https://doi.org/10.1111/gcb.13134>. Acesso em 10 dez. 2018.

AJZEN, I., The theory of planned behaviour Organizational behaviour and human decision processes. Organizational Behavior and Human Decision Processes. V. 50, n. 2, 179-211, 1991.

BERNOUX, M. et al. Ex-ante greenhouse gas balance of agriculture and forestry development programs Sci. Agric. V. 67 p. 31– 40, 2010.

BRANDÃO JR. A. Situação do desmatamento nos assentamentos de reforma agrária no Estado do Pará / Amintas Brandão Jr.; Carlos Souza Jr.; Adalberto Veríssimo; Andréia Pinto; Paulo Amaral. – Belém, PA: Instituto do Homem e Meio Ambiente da Amazônia (IMAZON), 2013.

BRASIL. Decreto Nº 9.073, de 5 de jun. de 2017. Promulga o Acordo de Paris sob a Convenção-Quadro das Nações Unidas sobre Mudança do Clima. Diário Oficial da União, Brasília, DF, 5 de jun. de 2017. Disponível em: <http://www.planalto.gov.br/ccivil_03/_ato2015-2018/2017/decreto/D9073.htm>. Acesso em: 3 dez. 2018.

BRASIL. Lei n° 12.651, de 25 de maio de 2012. Dispõe sobre a proteção da vegetação nativa; altera as Leis nºs 6.938, de 31 de agosto de 1981, 9.393, de 19 de dezembro de 1996, e 11.428, de 22 de dezembro de 2006; revoga as Leis nºs 4.771, de 15 de setembro de 1965, e 7.754, de 14 de abril de 1989, e a Medida Provisória nº 2.166-67, de 24 de agosto de 2001; e dá outras providências. Diário Oficial da União, Brasília, DF, 25 mai. 2012. Disponível em: < http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/lei/l12651.htm>. Acesso em: 2 dez. 2018.

BRASIL. Lei Nº 12.187, de 29 de dez. de 2009. Institui a Política Nacional sobre Mudança do Clima. Diário Oficial da União, Brasília, DF, 29 dez. 2009. Disponível em: <http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2009/lei/l12187.htm>. Acesso em: 2 dez. 2018.

BROWN, S. Estimating biomass and biomass change of tropical forests: a primer. Food & Agriculture Org. Vol. 134, 1997.

BURTON, R.J.F., PARAGAHAWEWA, U.H. Creating culturally sustainable agri-environmental schemes. J. Rural Stud. Nº 27, p. 95–104, 2011.

CASWELL, K.F. et al. Adoption of agricultural production practices: lessons learned from the US Department of Agriculture Area Studies Project. US Department of Agriculture, Economic Research Service. 2001.

CAVALCANTI, M. R. Rentabilidade da cria é comparável a recria e engorda? 2011. Disponível em: https://www.beefpoint.com.br/rentabilidade-da-cria-e-comparavel-a-recria-e-engorda-74256/. Acesso em: 18 fev. 2019.

COMISSÃO EXECUTIVA DO PLANO DA LAVOURA CACAUEIRA - CEPLAC. Manejo estratégico da pastagem. Disponível em: <http://www.ceplac.gov.br/radar/semfaz/pastagem.htm>. Acesso em: 20 dez. 2018.

CONFEDERAÇÃO NACIONAL DA AGRICULTURA. Panorama do Agro. 2017. Disponível em: <https://www.cnabrasil.org.br/cna/panorama-do-agro>. Acesso em 15 dez. 2018.

COLOMB, V. et al., 2013. Selection of appropriate calculators for landscape-scale greenhouse gas assessment for agriculture and forestry. Environ. Res. Lett. Nº 8 015029.

CORRÊA, L.A. 2000. Pastejo Rotacionado para produção de bovinos de corte. https://ainfo.cnptia.embrapa.br/digital/bitstream/CPPSE/13156/1/PROCILAC2000.00034.pdf acesso em: 27/12/2018

DE PAIVA SEROA DA MOTTA, R.; HULSMAN, R. 2018. Brazilian Livestock (beef-cattle) sectoral profile. WUR & WLR.

DIAS-FILHO, M.B. Degradação de pastagens: processos, causas, e estratégias de recuperação. Editora do autor. 4 Ed. Belém, PA, 2011.

DO VALLE, E; ANDREOTTI, R; THIAGO, L.R.S. Técnicas de manejo reprodutivo em bovinos de corte. Documento: 93, Embrapa, Campo Grande, MS, p.61, 2000.

EMBRAPA GADO DE CORTE. Programa Boas Práticas Agropecuárias – Bovinos de Corte. 2012. Disponível em: < https://cloud.cnpgc.embrapa.br/bpa/>. Acesso em: 20 dez. 2018.

EMBRAPA AGROSSILVIPASTORIL. Capacitação Continuada de Técnicos da Cadeia da Pecuária de Corte. 2014. Disponível em: <https://www.embrapa.br/agrossilvipastoril/capacitacao-continuada-corte/-/document_library_display/YBmIHme6eDA1/view_file/1752787>. Acesso em: 25 nov. 2018.

FOOD AND AGRICULTURE ORGANIZATION – FAO. By the numbers: GHG emissions by livestock. 2018. Disponível em: <http://www.fao.org/news/story/en/item/197623/icode/>. Acesso em: 20 dez. 2018.

FOOD AND AGRICULTURE ORGANIZATION - FAO. The 2014 International Year of Family Farming (IYFF). 2012. Disponível em: <http://www.fao.org/family-farming-2014/home/what-is-family-farming/en/>. Acesso em 17 dez. 2018.

FRANKS, J. R.; MC GLOIN, A. (2007). Environmental co-operatives as instruments for delivering across-farm environmental and rural policy objectives: lessons for the UK. Journal of Rural Studies, V. 23(4), p. 472–489. Disponível em: <https://doi.org/10.1016/J.JRURSTUD.2007.03.002>. Acesso em: 10 jan. 2019.

FUJISAKI, K. et al. (2015). From forest to cropland and pasture systems: a critical review of soil organic carbon stocks changes in Amazonia. Global Change Biology, Nº 21(7), 2773–2786. Disopnível em: <https://doi.org/10.1111/gcb.12906>. Acesso em 12 dez. 2018.

GARCIA, S. Geração agPastto: o que precisamos saber para ajustar a a taxa de lotação? Disponível em: http://www.agroceresmultimix.com.br/blog/geracao-agpastto-o-que-precisamos-saber-para-ajustar-lotacao/. Acesso em: 20 dez. 2019.

GIBBS, H. K. Did Ranchers and Slaughterhouses Respond to Zero-Deforestation Agreements in the Brazilian Amazon? Conservation Letters, 9(1), p. 32–42, 2016. Disponível em: <https://doi.org/10.1111/conl.12175>. Acesso 5 jan. 2019.

GOBESSO, A. A. et al. Novos desafios da pesquisa em nutrição e produção animal. Edição 2018. Pirassununga: 5D Editora. 2018. 294 p. Disponível em: <https://posvnp.org/novo/wp-content/uploads/2019/02/USP-XII-SIMP%C3%93SIO-VNP-P%C3%93S-Livro-15x214cm.pdf>.

GOTTSCHALL, C.S.; DE ALMEIDA, M.R.; MAGERO, J. Princípios de manejo para aumento da eficiência reprodutiva em bovinos de corte. 2013. Disponívek em: <https://www.beefpoint.com.br/principios-de-manejo-para-o-aumento-da-eficiencia-reprodutiva-em-bovinos-de-corte-2/>. Acesso em: 20 dez. 2018.

GRUPO DE TRABALHO PARA PECUÁRIA SUSTENTÁVEL - GTPS, SOLIDARIDAD Manual de Práticas para a Pecuária Sustentável. São Paulo, 2016. Disponível em: <http://gtps.org.br/manual/>. Acesso em: 20 dez. 2018.

GUERRERO, A. M. O.; CHALAPUD, L. D. R. 2006. Almacenamiento Y Fijacion De Carbono Del Sistema Agroforestal Cacao Theobroma Cacao L Y Laurel Cordia Alliodora (Ruiz & Pavón) Oken En La Reserva Indígena De Talamanca, Costa Rica.

HALL, S. C. Zero Deforestation and the Cattle Sector in Brazil: Understanding the Current Context and Potential Solutions for Monitoring and Traceability of Indirect Cattle Suppliers. Tropical Forest Alliance 2020 (TFA) and Latin America Workgroup (LAWG). 26 de maio de 2017.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA - IBGE. Produção Pecuária Municipal. Sistema IBGE de Recuperação Automática (Sidra). Rio de Janeiro: IBGE, 2017. Disponível em: <http://www.sidra.ibge.gov.br/>. Acesso em: 19 nov. 2018.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA - IBGE. Produção agrícola municipal. Rio de Janeiro: IBGE, 2016. Sistema IBGE de Recuperação Automática (Sidra). Disponível em: <http://www.sidra.ibge.gov.br/>. Acesso 23 nov. 2018.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA - IBGE. Produção Pecuária Municipal. Rio de Janeiro: IBGE, 2014. Sistema IBGE de Recuperação Automática (Sidra). Disponível em: <http://www.sidra.ibge.gov.br/> Acesso em 23 nov. 2018.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA - IBGE. Mapa de biomas do Brasil. Rio de Janeiro: IBGE, 2004. Disponível em: <https://ww2.ibge.gov.br/home/presidencia/noticias/21052004biomashtml.shtm>. Acesso em: 17 nov. 2018.

INICIATIVA PARA O COMÉRCIO SUSTENTÁVEL – IDH. Position paper: a sustainable Brazilian Beef Sector. 2018. Disponível em: <https://www.idhsustainabletrade.com/uploaded/2019/02/Brazil-4-Pager-Sustainable-Beef.pdf>. Acesso em 3 jan. 2019.

INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS - INPE. PROJETO PRODES DIGITAL: Mapeamento do desmatamento da Amazônia com Imagens de Satélite. Disponível em: <http://www.obt.inpe.br/OBT/assuntos/programas/amazonia/prodes>. Acesso em 05 dez. 2018.

INSTITUTO NACIONAL DE COLONIZAÇÃO E REFORMA AGRÁRIA (INCRA). Informações gerais sobre os assentamentos da reforma agrária. Disponível em: <http://painel.incra.gov.br/sistemas/index.php>. Acesso em: 12 jan. 2019.

INTERNATIONAL PANEL ON CLIMATE CHANGE (IPCC). 2006 IPCC guidelines for national greenhouse gas inventories. Japan: IGES, 2006.Disponível em: http://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html

KASSIE, M. et al. 2013 Adoption of interrelated sustainable agricultural practices in smallholder systems: evidence from rural Tanzania. Technol. Forecast.Soc. Change 80, 525-540.

LALANI, B. (n.d.). Smallholder farmers' motivations for using Conservation Agriculture and the roles of yield, labour and soil fertility in decision making. Retrieved from http://gala.gre.ac.uk/16176/7/16176 LALANI_Smallholder_Farmers_Motivations_2016.pdf

LATAWIEC et al. 2014, Intensification of cattle ranching production systems: socioeconomic and environmental synergies and risks in Brazil. In : Animal (2014) 8:8 p 1255-1263

MACHADO, L.A.Z.; KICHEL, A.N. Ajuste de Lotação no Manejo de Pastagens. Documento 62. Embrapa. Dourados, MS. 2004

MARCUZZO, S.F. Programa Novo Campo: Estratégia de pecuária sustentável na Amazônia. Alta Floresta, MT: ICV. 2015.

MARGULIS, S. (2003). Causas do Desmatamento da Amazônia Brasileira. Retrieved from http://www.fineprint.com

MCGUIRE, J.; MORTON, L. W.; CAST, A. D. (2013). Reconstructing the good farmer identity: shifts in farmer identities and farm management practices to improve water quality. Agriculture and Human Values, 30(1), 57–69. https://doi.org/10.1007/s10460-012-9381-y

MELO FILHO, G.A.; QUEIROZ, H.P. Coleção 500 perguntas 500 respostas – gado de corte. Brasilia, DF. 2011

NASPETTI, S. et al. (2017). Determinants of the acceptance of sustainable production strategies among dairy farmers: Development and testing of a modified technology acceptance model. Sustainability (Switzerland). https://doi.org/10.3390/su9101805

NWF, GLUE. (2015) A Path Towards Zero Deforestation Cattle. Disponível em: <http://www.zerodeforestationcattle.org/index.html>. Acesso em: 4 dez. 2018.

Observatório ABC (2017). Impactos econômicos e ambientais do Plano ABC: relatório completo. Disponível em: < http://observatorioabc.com.br/wp-content/uploads/2017/09/Relatorio5-Completo.pdf>. Acesso em: 7 jan. 2019.

ORTIZ GUERRERO, A. M.; RIASCOS CHALAPUD, L.D. (2006) Almacenamiento y fijación de carbono del sistema agroforestla cacao Theobroma cacao y laurel Cordia alliodora (Ruiz y Pavón) Oken en la Reserva Indígena de Talamanca, Costa Rica. Disponível em: <http://repositorio.bibliotecaorton.catie.ac.cr/handle/11554/245>. Acesso em: 1 dez. 2018.

OMETTO, J. P.; AGUIAR, A.; MARTINELLI, L. A. (2014). Amazon deforestation in Brazil : e ects , drivers and challenges, (July 2015). https://doi.org/10.4155/cmt.11.48

Pacheco, P., M. Piketty, R. Poccard-Chapuis, I. Garcia-Drigo, J. C El Husny m. Gomes and J-F Tourrand, 2017 Beyond zero deforestation in the Brazilian Amazone – Progress and remaining challenges to sustainable cattle intensification.

PIATTO, M.; COSTA JÚNIOR, C. Good Livestock Production Practices Reduce GHG Emissions and Increase Meat Production in the Amazon. Piracicaba, SP: Imaflora, 2016, 68 p.

PROFOREST. Zero Deforestation and Cattle sector in Brazil: understanding the current context and proposing solution for monitoring and traceability – TFA Latam Working Group. 26 mai. 2017.

RATHMANN, R. et al. (2017) Trajetórias de mitigação e instrumentos de políticas públicas para alcance das metas brasileiras no acordo de Paris. Brasília: Ministério da Ciência, Tecnologia, Inovações e Comunicações, ONU Meio Ambiente, 2017. 64 p. – (Opções de mitigação de emissões de gases de efeito estufa em setores chave do Brasil)

ROSENSTOCK, T.S. et al., 2013. Toward a protocol for quantifying the greenhouse gas balance and identifying mitigation options in smallholder farming systems. Environ. Res. Lett. 8 021003.

ROXBURGH, C.W.; RODRIGUEZ, D., 2016. Ex-ante analysis of opportunities for the sustainable intensification of maize production in Mozambique. Agricultural Systems 142, 9-22

RUGGIERI,A.C. Manejo de pastagens. Disponível em: <http://www.fcav.unesp.br/Home/departamentos/zootecnia/ANACLAUDIARUGGIERI/manejo_de_pastagem.pdf>. Acesso em 20 dez. 2018.

EMBRAPA AGROSSILVIPASTORIL. Eficiência reprodutiva em bovinos. Disponível em: <https://www.embrapa.br/documents/1354377/1743406/Eficiencia+Reprodutiva+FINAL.pdf/484058fa-e237-4a3a-9f37-52088e9475e9?version=1.0> Acesso em: 20 dez. 2018.

SISTEMA DE ESTIMATIVA DE EMISSÕES DE GASES DE EFEITO ESTUFA – SEEG. Emissões de GEE no Brasil e suas implicações para políticas públicas e a contribuição brasileira no Acordo de Paris. Observatório do Clima, 2018.

SISTEMA DE ESTIMATIVA DE EMISSÕES DE GASES DE EFEITO ESTUFA – SEEG. Emissões do setor de agropecuária: período 1970-2015. Observatório do Clima e Imaflora, 2017. Disponível em: <http://seeg.eco.br/wp-content/uploads/2017/08/Relatorios-Seeg-2017-Agro_final.pdf>. Acesso em: 26 nov. 2018.

SOLIDARIDAD E IMAFLORA. Balanço de carbono na produção agrícola familiar na Amazônia: cenários e oportunidades / Solidaridad; Imaflora. São Paulo: 2018.

SOLIDARIDAD. Diagnóstico Horizonte Rural. Disponível em: <https://ruralhorizon.org/>.

VAN DIJK, W. F. A. (2016). Factors underlying farmers' intentions to perform unsubsidised agri-environmental measures. Land Use Policy. Disponível em: <https://doi.org/10.1016/j.landusepol.2016.09.003>. Acesso em: 10 nov. 2018.

ZEWELD, W. et al. (2017). Smallholder farmers' behavioural intentions towards sustainable agricultural practices. Journal of Environmental Management. Disponível em: <https://doi.org/10.1016/j.jenvman.2016.11.014>. Acesso em: 10 nov. 2018.

ZU ERMGASSEN, E. et al. (2018). Results from On-The-Ground Efforts to Promote Sustainable Cattle Ranching in the Brazilian Amazon. Sustainability, 10(4), 1301. https://doi.org/10.3390/su10041301

WORLD RESOURCES INSTITUTE - WRI. GHG Protocol Agriculture calculator. 2014. Disponível em: <http://www.ghgprotocol.org/Agriculture-Guidance/Vis%C3%A3o-Geral%3A-Projeto-Brasil-Agropecu%C3%A1ria>.

Annex A Matrix of public, private, financial and non-profit initiatives for small-scale livestock farmers in the Amazon from the year 2000 onwards

Table 1 *Matrix of public, private, financial and non-profit initiatives for small-scale livestock farmers in the Amazon from the year 2000 onwards.*

Institution	Initiative	Institution type/level	Location	Period
Bank of the Amazon S/A	PRONAF - Financing of types: A, A / C, B and Costs	Financial	North Region, comprising the States of Acre, Amapá, Amazonas, Pará, Rondônia, Roraima and Tocantins.	Ongoing
Bank of the Amazon S/A	FNO	Financial	North Region, comprising the States of Acre, Amapá, Amazonas, Pará, Rondônia, Roraima and Tocantins.	Ongoing
BNDES (indicators of the GTPS)		Financial		Ongoing
CIFOR/CIRAD/Embrapa			Paragominas/PA	Ongoing
	Project for land and environmental regularization of small farmers. Training, qualifying courses and technology transfer.			
EMBRAPA	Projeto Biomas Amazonia (Biomes Project Amazon)	Public	São Domingos do araguai	2014-2019
EMBRAPA	Dairy farming in family agriculture	Public	Southeast region and the state of Pará	2015-2018
EMBRAPA + SEAGRI MARABA	Dairy farming in family agriculture	Public	MARABÁ - PA Sarandí/ Cedrinho/ Lajedo	2018 - onwards
EMBRAPA+TNC	Beef Cattle	Public	SÃO FELIX DO XINGU	2014 - onwards
Fundação Solidaridad Latinoamericana (Solidaridad Latin-American Foundation)	Intensification in Production and Protection for Smallholders and Indigenous Reserves in the Amazon	CSO	Novo Santo Antônio/MT	2012 - 2015
Amazon Fund (verificar)		Financial		Ongoing
GIZ		State		
Greenpeace	Amazon campaign	CSO		
CIFOR/CIRAD/Embrapa			Paragominas/PA	Ongoing
	Project for land and environmental regularization of small farmers. Training, qualifying courses and technology transfer.			
EMBRAPA	Projeto Biomas Amazonia (Biomes Project Amazon)	Public	São Domingos do araguai	2014-2019

Institution	Initiative	Institution type/level	Location	Period
EMBRAPA	Dairy farming in family agriculture	Public	Southeast region and the state of Pará	2015-2018
EMBRAPA + SEAGRI MARABA	Dairy farming in family agriculture	Public	MARABÁ - PA Sarandí/ Cedrinho/ Lajedo	2018 - onwards
EMBRAPA+TNC	Beef Cattle	Public	SÃO FELIX DO XINGU	2014 - onwards
Fundação Solidaridad Latinoamericana (Solidaridad Latin-American Foundation)	Intensification in Production and Protection for Smallholders and Indigenous Reserves in the Amazon	CSO	Novo Santo Antônio/MT	2012 - 2015
Amazon Fund (verificar)		Financial		Ongoing
GIZ		State		
Greenpeace	Amazon campaign	CSO		
CIFOR/CIRAD/Embrapa			Paragominas/PA	Ongoing
	Project for land and environmental regularization of small farmers. Training, qualifying courses and technology transfer.			
EMBRAPA	Projeto Biomas Amazonia (Biomes Project Amazon)	Public	São Domingos do araguai	2014-2019
EMBRAPA	Dairy farming in family agriculture	Public	Southeast region and the state of Pará	2015-2018
EMBRAPA + SEAGRI MARABA	Dairy farming in family agriculture	Public	MARABÁ - PA Sarandí/ Cedrinho/ Lajedo	2018 - onwards
EMBRAPA+TNC	Beef Cattle	Public	SÃO FELIX DO XINGU	2014 - onwards
Fundação Solidaridad Latinoamericana (Solidaridad Latin-American Foundation)	Intensification in Production and Protection for Smallholders and Indigenous Reserves in the Amazon	CSO	Novo Santo Antônio/MT	2012 - 2015
Amazon Fund (verificar)		Financial		Ongoing
GIZ		State		
Greenpeace	Amazon campaign	CSO		
Sustainable Livestock Working Group, Consultoria ViaVerde, Imaflora, Marfrig e VTS Consultoria.	Project: Fazenda Goioerê	Private	Rolim do Moura/RO	No
ICV		State		
IDH	Sustainable Production of Calves			
	CSO	Vales do Juruena e Araguaia	Ongoing	The aim is to support smallholder farmers in a stronger and fairer production chain, building a viable socio-economic model. IDH is also part of the program, with a co-investment of 1.6 million euros.
Imaflora	Agroforestry systems and Agroecology in São Félix do Xingu - PA	CSO	São Félix do Xingu	2015-2016
Imazon		State		
Imazon (verificar)		Financial		Ongoing
IPAM		State		
Pará ATER Network		Private		

Institution	Initiative	Institution type/level	Location	Period
SEBRAE + IBS (Bio-systemic Institute)	Support to dairy farming	Public	Autazes, Parintins, Manacapuru, Presidente Figueiredo, Apuí e Distrito de Santo Antônio do Matupi.	2016 - present
Solidaridad		CSO	Novo Repartimento/PA	2016-2020
TNC		State		
WWF		State		
Fundação Solidaridad Latinoamericana (Solidaridad Latin-American Foundation)	Intensification in Production and Protection for Smallholders and Indigenous Reserves in the Amazon	CSO	Novo Santo Antônio/MT	2012 - 2015
Amazon Fund (verificar)		Financial		Ongoing
GIZ		State		
Greenpeace	Amazon campaign	CSO		
Sustainable Livestock Working Group, Consultoria ViaVerde, Imaflora, Marfrig e VTS Consultoria.	Project: Fazenda Goioerê	Private	Rolim do Moura/RO	No
ICV		State		
IDH	Sustainable Production of Calves			
	CSO	Vales do Juruena e Araguaia	Ongoing	The aim is to support smallholder farmers in a stronger and fairer production chain, building a viable socio-economic model. IDH is also part of the program, with a co-investment of 1.6 million euros.
Imaflora	Agroforestry systems and Agroecology in São Félix do Xingu - PA	CSO	São Félix do Xingu	2015-2016
Imazon		State		
Imazon (verificar)		Financial		Ongoing
IPAM		State		
Pará ATER Network		Private		

Annex B Matrix of online and offline tools for small-scale livestock farmers

Table 2 *Matrix of public, private, financial and non-profit initiatives for small-scale livestock farmers in the Amazon from the year 2000 onwards.*

Online/Offline	Tool/method	Developer	Scope	Target Audience
Offline	Demonstration Unit	Responsible technical team	Local	Farmers and technicians
Offline	Continued technical assistance	Responsible technical team	Local	Farmers
Offline	Collective training (itinerant structure)	Responsible technical team	Local	Farmers and technicians
Offline	Field day	Responsible technical team	Local	Farmers and technicians
Online	MPME Developer Channel		Nacional	
Online	Publications of Embrapa	Embrapa	Nacional	General public
Online	SAC - customer service support	Embrapa	Regional	General public
Online	Farming solution	Solidaridad		
Online	GIPS - Sustainable Livestock Indicators Guide	GTPS		

To explore the potential of nature to improve the quality of life

Wageningen Livestock Research
P.O. Box 338
6700 AH Wageningen
The Netherlands
T +31 (0)317 48 39 53
E info.livestockresearch@wur.nl
www.wur.nl/livestock-research

Wageningen Livestock Research creates science based solutions for a sustainable and profitable livestock sector. Together with our clients, we integrate scientific knowledge and practical experience to develop livestock concepts for future generations.

Wageningen Livestock Research is part of Wageningen University & Research. Together we work on the mission: 'To explore the potential of nature to improve the quality of life'. A staff of 6,500 and 10,000 students from over 100 countries are working worldwide in the domain of healthy food and living environment for governments and the business community-at-large. The strength of Wageningen University & Research lies in its ability to join the forces of specialised research institutes and the university. It also lies in the combined efforts of the various fields of natural and social sciences. This union of expertise leads to scientific breakthroughs that can quickly be put into practice and be incorporated into education. This is the Wageningen Approach.