Solidaridad

CARBON BALANCE IN FAMILY AGRICULTURAL PRODUCTION IN THE AMAZON

Scenarios and Opportunities

2018

Solidaridad imaflora

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Aerial image of the Tuerê settlement
in Novo Repartimento, PA

CONTENTS

Cocoa fruit being peeled

PRESENTATION

The effects on society of rising temperatures, changes in water regimes, and a greater frequency and intensity of natural disasters are becoming more and more explicit. Though the relationship between the climate and society may be self-evident to most, the fact that social issues, particularly inequality and social exclusion, can compromise efforts to establish a low-carbon economy may be less clear. Thus, the reduction of inequality and the increase of social inclusion not only constitute an end, but also a means to sustainable development.

When the Brazilian federal government ratified the Paris Agreement during the 21st Conference of the Parties of the United Nations Framework Convention on Climate Change (COP 21), the county adopted the goals of reducing carbon emissions by 37% by 2025 and by 43% by 2030 when compared to level of carbon emissions generated in the county in 2005. In order to reach these goals and turn this process into a guiding light for Brazil's development of a low carbon economy, it will be necessary to consider the regional diversity and challenges of the country so that this transition takes place in a socially inclusive manner.

The goal of the present study, conducted by Solidaridad Brazil, which examined the Cocoa and Livestock Programs in the region of Trans-Amazonian Highway in a technical partnership with The Institute for Agricultural Management and Certification (Imaflora), is to understand how different social actors, specifically family farmers who have established

Tucuruí Lake, in Novo Repartimento (PA)

settlements in the Amazon, operate and how they can contribute to the achievement of the Paris Agreement goals. To do this, we sought to **develop an expeditious framework for measuring GHG emissions balance based on existing scientific models in order to estimate the GHG emissions balance of family farms in the Amazon and project future carbon balance scenarios.** Additionally, the study sought to offer support for the comprehensive monitoring of the GHGs generated by the diversified production systems used on family farms. Through the activities developed within the scope of the Cocoa and Livestock Programs that form part of the Inclusive and Sustainable Territories Initiative, Solidaridad is attempting to map opportunities and risks for family farming in the Amazon with the goal of collaborating in the improvement of public and sectorial policies for a low-carbon and inclusive economy.


Tuerê settlement plot, in Novo Repartimento (PA)

INTRODUCTION

Brazil is among the 10 largest producers of greenhouse gas (GHG) emissions in the world. The land use, land use changes, and forestry (LULUCF) sector and agriculture sector have been the main producers of these emissions, contributing to 74% of the county's GHG emissions in 2016 (SEEG, 2017) Within in these sectors, deforestation, livestock farming, soil degradation and the use of synthetic nitrogenated fertilizers have been the primary sources of greenhouse gases.

Though small farms account for 24% of the rural area and 75% of the rural population of the country (FAO, 2012; IBGE, 2006), efforts to quantify the emissions and removal of GHG in the context of Brazilian agriculture have been focused on large-scale crop farming and livestock operations (Brazil, 2016).

The scarcity of data on GHG emissions and removal with regard to small-scale farms have represented a limiting factor in the characterization of their emissions, thus constituting a gap in knowledge of the effects of practices currently in use and the necessary measures to promote change. The lack of this information and a lack of access to adapted technology and public incentives reduces Brazilian family farmers' ability to make a transition to low-carbon rural land development, to have access to relevant public programs, to secure opportunities to attract investments, including those available for the mitigation of carbon emissions, and to demonstrate their role in the global supply chains that have a commitment to the world climate agenda.

Generally, in Brazil, the farming systems utilized by family farmers are diversified, composed of both crop farming and livestock farming practices conducted on the same property. Due to the complexity of the interaction between these systems, **identifying adequate indicators and methods for analyzing GHG emissions balances at this scale is essential for establishing a baseline** that captures all the relevant information, as well as for indicating significant monitoring and evaluation systems for addressing climate mitigation and adaptation options in the context of small-scale farming (FAO, 2012; Rosenstock et al., 2013; Colomb et al., 2013).

Currently, field methods for measuring GHG are expensive, slow, and prone to error due to the variety of approaches and methods utilized. Furthermore, the variation of practices and heterogeneity of production systems used by family farmers, in addition to the diversity of landscapes on which their farms have been established, represent challenges to the acquisition of robust information, which suggests the need for the development and adjustment of calculators that can be used to quantify the GHG balances of these agricultural methods.

Considering the limitations presented by the GHG calculation tools most often used in Brazil and around the world, and the possible biases connected with their use, it has become evident that there is a need to develop specific strategies, combine, and adapt components of existing calculators in order to develop and use new models. These complementary models can also serve to strengthen the existing tools used to evaluate the carbon balance of family farms.

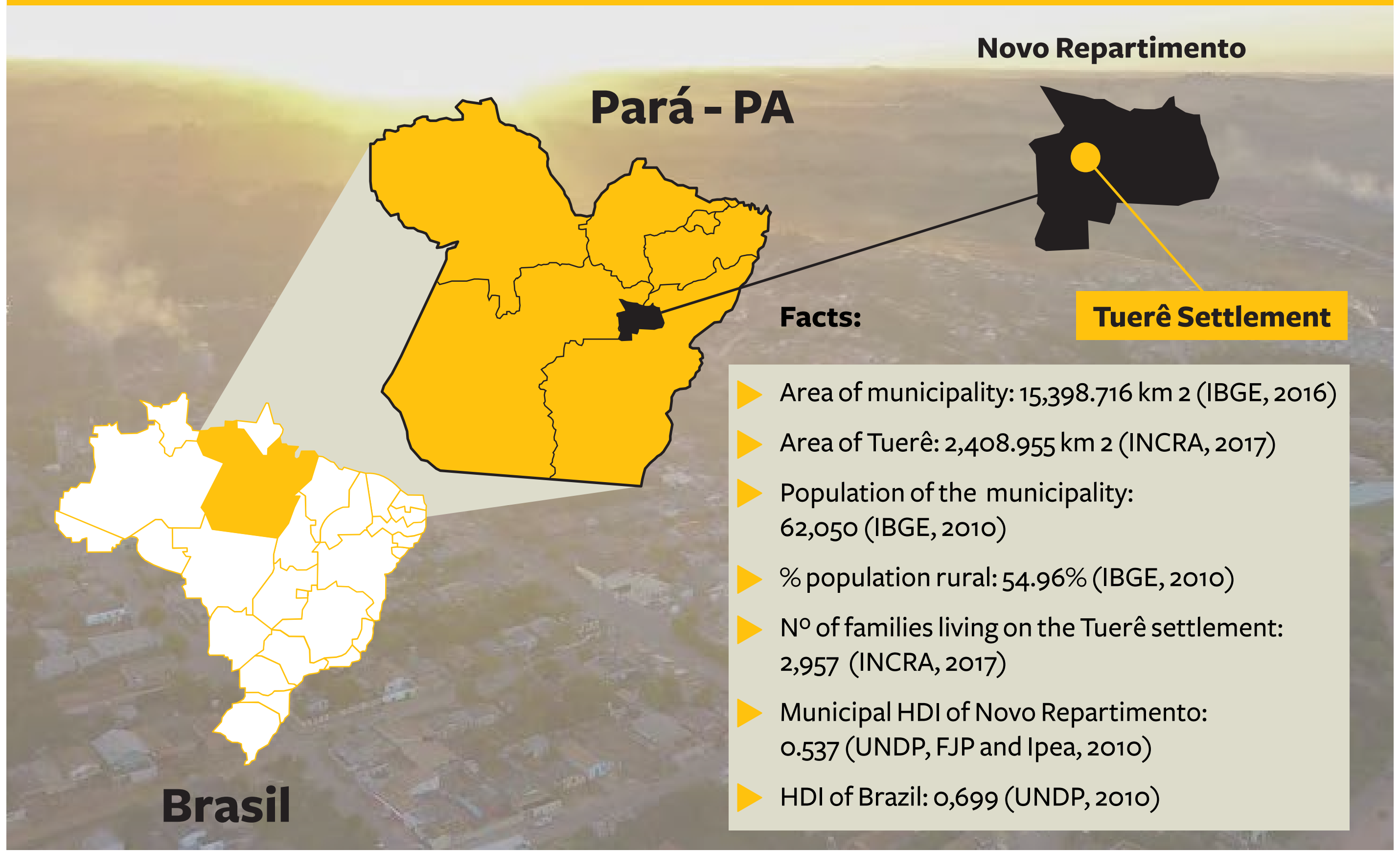
The present analysis, conducted in partnership with Imaflora, aims to contribute to an inclusive approach to land development and to Brazil's climate agenda through fostering the adoption of good, low-carbon agricultural practices on family farms. Through the results of this study, Solidaridad seeks to understand the risks and opportunities for family farming in the Amazon with the aim of collaborating in the development of improved public and sectorial policies promoting low-carbon agriculture.

Thus, the objective of the study was to create a framework to estimate the balance of GHG emissions and, with this information, evaluate future land use management scenarios for the average family farm in the Amazon based on the experiences and initiative of Inclusive and Sustainable Territories on the Tuerê settlement in the municipality of Novo Repartimento, Pará, Brazil. Furthermore, the study seeks to offer support for the comprehensive and expeditious monitoring of GHG generated from the diversified systems utilized by family farmers familiar.

METHODOLOGY

WHERE WE ARE: AMAZON BIOME – TUERÊ SETTLEMENT IN NOVO REPARTIMENTO, PARÁ

THE TUERÊ SETTLEMENT IN NOVO REPARTIMENTO – PA



Novo Novo Repartimento is a municipality in the southeastern part of the state of Pará. Established in 1991, whose origin go back to the establishment of a small village that arose with the construction of the Trans-Amazonian Highway (BR-230) and was later relocated due to the construction of the Tucuri Hydroelectric Power Plant. Logging and the harvesting of Brazil nuts were the principal drivers of the local economy up to the 1990s, while animal husbandry constituted a small contribution and was practiced only on a scale greater than 50 hectares.

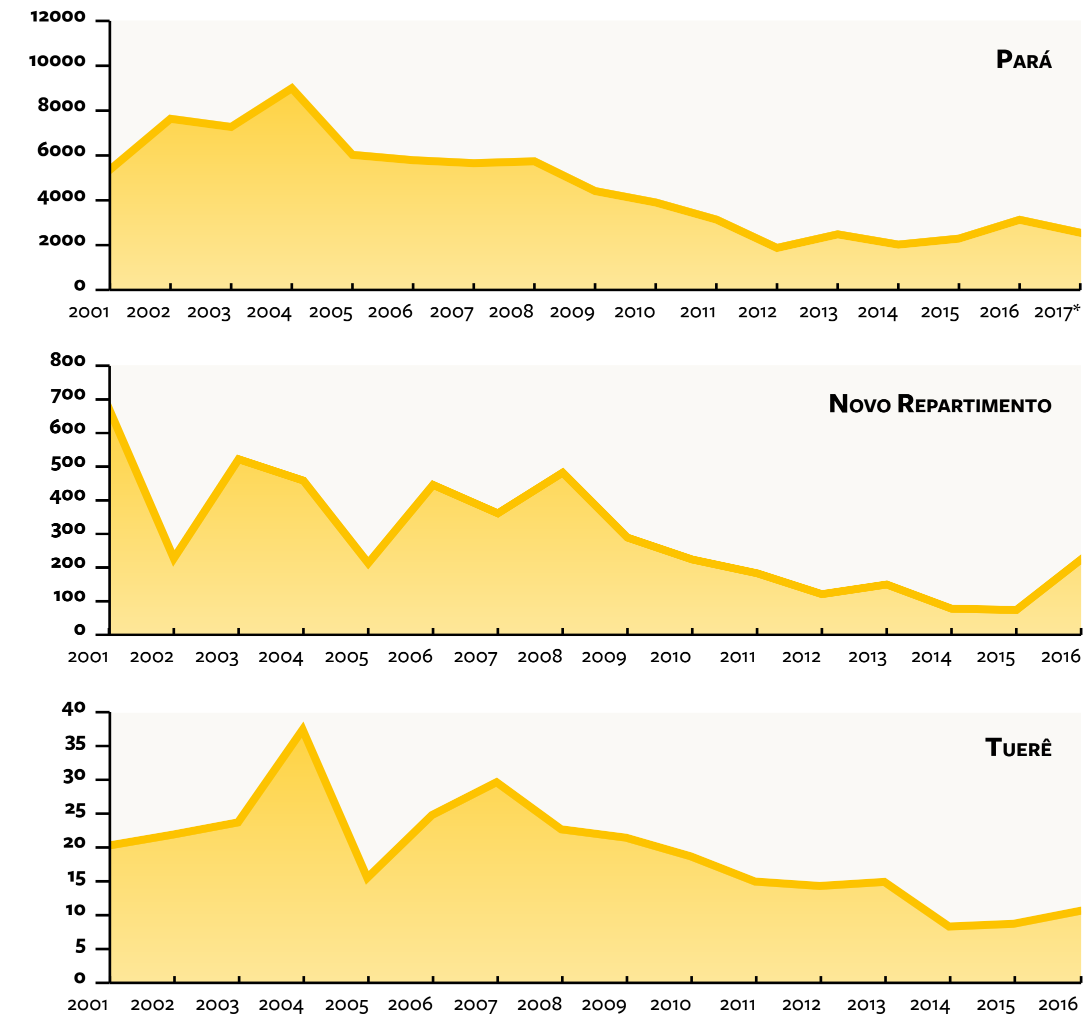
The following decade, due to incentives introduced by government institutions to establish agricultural settlements, among other factors, there was a considerable increase in deforestation rates. Alongside this process of converting undeveloped land to farmland, herds of cattle increased at a rapid rate in Novo Repartimento, reaching a population of 970,000 heads in 2016 (IBGE, 2016).

Beginning in the year 2000, cocoa farming began to expand along the Trans-Amazonian Highway in Pará. Despite being a relatively recent activity, cocoa farming now takes place on around 11,000 acres in the municipality and generates approximately 33 million BRL annually for the local economy (IBGE, 2016).

Because it's a species native to the Amazon and there is a high demand for it both domestically and internationally, the production of cocoa is considered a priority economic activity by the state's strategic plan, titled "Pará 2030." In addition to its economic potential, the production of cocoa constitutes a key activity for increasing forest cover through agroforestry, reducing soil degradation, promoting soil recovery and generating income for family farmers. In other word, a crop presents great potential for promoting social inclusion and ecosystem services.

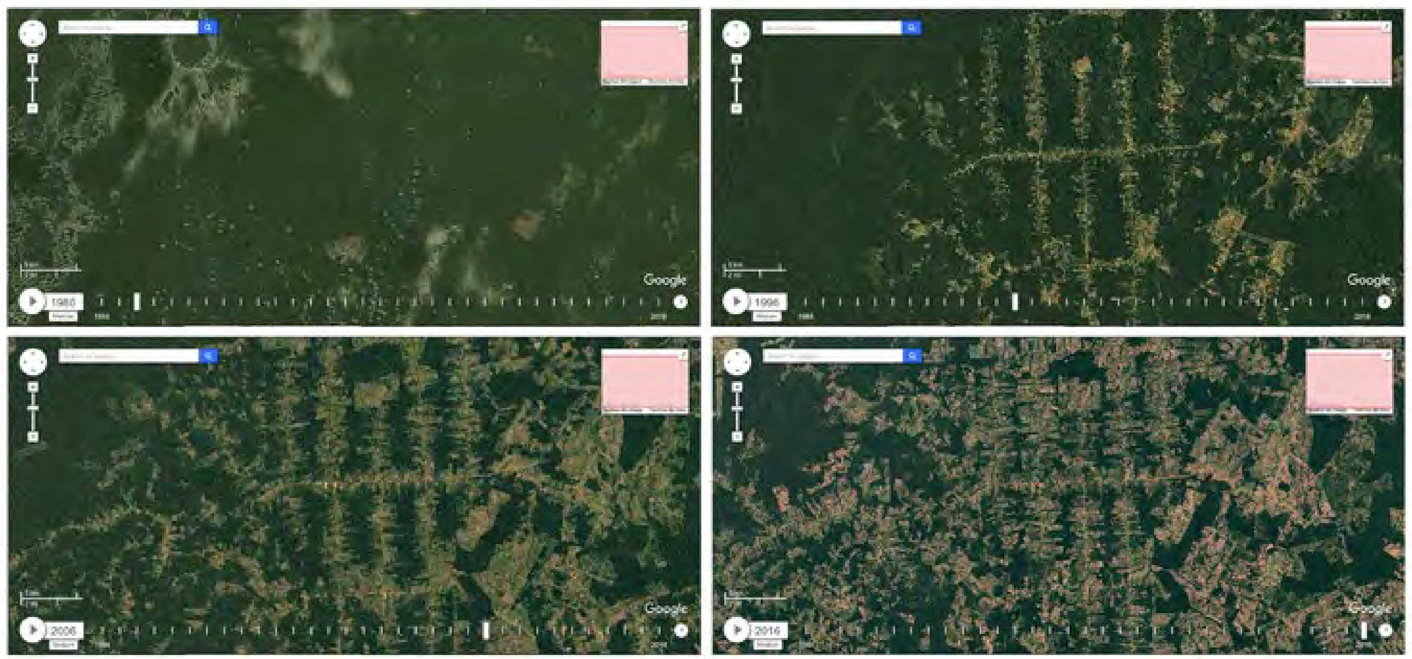
In this context, Tuerê, which is one of the largest rural settlements in Latin America, was established on an area of 240,000 hectares, all of which are within the Amazon biome. In the 2000s, Tuerê came to lead rural settlements in the Amazon in terms of deforestation rates, facing challenges such as illegal logging, inefficient agrar-

Deforestation rate (km²)



*as of November

Source: Data from PRODES with elaboration by Arnaldo Carneiro



Dynamic of land use changes on the Tuerê settlement between 1986 e 2016 ian regulation, and real estate speculation. The increase of land use on the Tuerê settlement led to a kind of deforestation process known as “fishbone deforestation” because it initially converts forestland along the roadways, leaving interspersed remnants of forest in between the farmland, as seen in the image on the previous page.

Today, cocoa farming constitutes the main source of income for farmers of the settlement (Horizonte Rural – Solidaridad Brazil, 2015), even though the majority of the land of the family farms is used for pasture. The current size of the remnants of forest varies from plot to plot, according to the strategies adopted by the farmers for converting forestland into pasture and/or fields for growing crops. Though these remnants of forest do not represent a direct source of income for the family farms, they are, in a general sense, important providers of regulating ecosystem services.

It bears mentioning that the Brazilian Forest Code (Lei 12.651/2012) requires that the owners, landholders or occupants of any kind conserve 80% of the native vegetation on rural properties in the legally recognized forest areas of the Amazon. These preserved areas are referred to as legal reserves. However, the size of the required legal reserve can be reduced to 50% of the property in some regions (such as Tuerê), according to the Ecological-economical Zoning Law (Lei 7.398/2010).

In the case of deforestation beyond the allowed limit conducted after July 2008, the restauration of forested area or the compensation for it on another property is required. However, in the case of small-scale farms (farms with an area smaller than 4 fiscal modules) where such deforestation took place before 2008, restauration of or compensation for forested areas is not required. However, in such cases new land conversion for other uses is prohibited.

Family farmers in Tuerê generally employ multiple combinations of different production systems and land use practices, which include various approaches to cocoa farming (full-sun and shaded, along with variations in shade-providing tress and densities of cocoa trees), animal husbandry (for milk production and meat production: breading, rearing and fattening), maintaining native forest (degraded or non-degraded), and subsistence crops such as manioc. This characteristic of land use on the settlement presents a special situation to GHG calculators, which are generally designed for evaluating one kind of crop.

In the face of this challenge and based on the existing methods and guidelines for calculating GHG balance of different agricultural systems and kinds of land use, Solidaridad, in a technical partnership with Imaflora, sought to find alternative approaches to conducting this task.

TOOLS UTILIZED FOR CALCULATING THE GHG BALANCE OF INTEGRATED SYSTEMS

Based on a compilation of scientific work available for estimating emissions and removal of GHG in the agricultural and land use sectors, the Intergovernmental Panel on Climate Change (IPCC) developed a protocol for tracking GHG at a national level (IPCC, 2006). Based on this protocol, new tools were developed to support more precise quantification of GHG emissions from agricultural and forestry activities according to the area occupied by the activity considered (Colomb et al., 2013; Denef et al., 2012). However, due

Cocoa fruit arranged in a “flag” after harvest to the variety of land uses and management practices of family farms, like those in Tuerê, these tools do not consider the main sources of GHG sinks present on these types of farms.

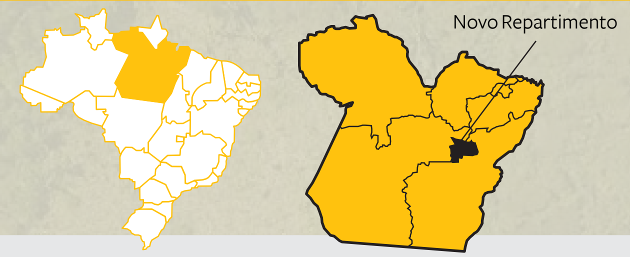
Therefore, in order to develop a customized tool for measuring the GHG balance of family farms in Tuerê, a preliminary study of the most recognized and globally utilized calculators was conducted. Its main characteristics and limitations2 are presented in Table 1.

Table 1 – Characteristics of GHG balance calculators and limitations regarding the evaluation of family farms on the Tuerê settlement

TOOL FOR CALCULATING GHG	Characteristics	Limitations
GHG-Protocol Agriculture	Presents a good framework for analyzing livestock farming in Brazil and large-scale farming of major crops, such as soy and corn.	**Does not include:** ▸ cocoa farming; ▸ reforestation and deforestation of native vegetation.
Cool Farm Tool	**Considers GHG emissions coming from:** ▸ the use of nitrogenated fertilizers based on the type of soil; ▸ the use of fossil fuels; ▸ burning of crop waste.	**Does not include:** ▸ cocoa farming; ▸ carbon emissions from pastures and the carbon stock in pastures; ▸ Carbon stock and biomass in the soil is not specific to cocoa; ▸ Does not allow users to adjust emission factors in order to customize according to region/location; ▸ N2O emissions from nitrogenated fertilizers are limited to tropical soil.
EX-ACT	**Considera emissões de GEE a partir de:** ▸ desmatamento; ▸ pecuária; ▸ sistemas de cultivo. Permite ajustes de fatores de emissão pelos usuários.	**Does not include:** ▸ sistemas cocoa farming. Calibration for perennial crops is limited; Does not specify the category of beef cattle productio.

²This data was collected in 2016. Any more recent updates to any of these tools were not incorporated into this study.

STEP BY STEP



1 Identification of typical land use on a family farm in Tuerê

2 Data collection on activities of GHG sources and sinks on the farms

3 Customization of a calculator using multiple methods to estimate the GHG emissions balance

4 Use of calculator to project scenarios that contemplate changes in land use and agricultural management practices

STEP 1: CHARACTERIZATION OF LAND USE ON THE FARMS

In order to identify the land uses and management practices of the farms in Tuerê, data was collected through self-evaluations administered to the farmers via Horizonte Rural. Because it provided quantitative and qualitative information about production and socio-environmental aspects of the family farms, this tool was effective at supplementing the initial evaluation of the GHG balance of Tuerê. The data compiled using **Horizonte Rural** (Box 1) were essential to understanding the current scenario and projecting future scenarios regarding land use and agricultural practices on the settlement.

Box 1 • Rural Horizons is a continuous improvement tool developed by Solidaridad that offers farmers, their organizations, and value chain partners a combination of solutions for identifying challenges, planning adjustments and monitoring long-term progress. Through a self-evaluation, farmers compare their practices to legal requirements and relevant international sustainability standards adapted to local situations. Horizonte Rural has been used by more than 5,000 farms for 10 different communities as part of various projects in both Latin America and Africa. Based on this experience, Solidaridad is currently developing digital applications that will allow farmers to always have these and other functionalities within their reach.

STEP 2: REFINEMENT OF FIELD DATA

In order to refine qualitative information to a quantitative level and develop a framework for calculating the GHG balance of a characteristic plot, the data obtained through Horizonte Rural were supplemented with data collected during field visits. These visits to the family farms participating in Solidaridad's program and interviews with farmers allowed for the analysis of the identified variables for each kind of farming system and land use—in this case, cocoa farming, livestock farming, and forestry—all described in step 4.

STEP 3: DEVELOPING A FRAMEWORK FOR CALCULATING THE GHG EMISSIONS BALANCE OF FAMILY FARM

The calculation framework created for evaluating the GHG emissions balance of a family farm in Tuerê was the result of the use of the GHG Protocol, EX-ACT, and Cool Farm Tool calculators, as well as scientific literature, the IPCC guidelines (IPCC, 2006), and allometric equations used for cocoa farming. Below, the methods and variables considered for each the systems employed on a characteristic Tuerê settlement family farm are described.

GHG balance method for cocoa farming

To determine the GHG emissions balance of cocoa farming systems, the variables accounted for according to the method used (shaded or full-sun) included: the production of biomass, pruning waste (IPCC, 2006 and Guerrero, Chalapud, 2006), and the use of soil inputs and the adopted soil management practices (CFT, WRI, 2014).

To calculate the aboveground cocoa tree biomass in the case of full-sun cocoa farming systems, the allometric equation proposed by Ortiz Guerrero and Riascos Chalupud (2006) was used. However, this does not take into account the impacts of pruning on the carbon balance. In the case shaded cocoa farming systems, the above-soil biomass was estimated using the multispecies allometric equation proposed by Brown (1997).

$$\text{Cocoa biomass (Kg)} = 10^{(-1{,}625 + (2{,}626 \times \log(D30)))}$$

$$\text{Shade tree biomass (Kg)} = \exp^{(-2{,}289 + 2{,}649\ (\text{in}\ (DBH) - 0{,}021\ (\text{in}(DBH)))}$$

The conversion of above-soil biomass to permanent carbon content was carried out using a coefficient of 45%. The following conversion from the permanent carbon content to equivalent atmospheric CO2 (CO2e) was carried out using a transformation factor of 3.67.

GHG balance method for livestock farming

To calculate the GHG emissions balance of livestock production systems, the variables considered where the number of animals per hectare and their age (WRI, 2014), the quantity of inputs added to the soil, management practices (CFT, WRI, 2014) and the condition of the soil on the farms (WRI, 2014).

To calculate the GHG emissions of cattle, the emissions factors considered varied according to the sex and age (0-12 moths, 12-24 months, above 24 months) of the individuals. Additionally, data was collected on milk and calf productivity per hectare and per farm. In the case of GHG emissions from the use of soil inputs and soil management practices, the variables considered were the use of limestone and nitrogenated fertilizers, the use of fossil fuels, and the burning practices employed. Finally, to calculate GHG emissions based on the soil conditions of the farms, the emissions factors utilized were determined by one of three categories: degraded, nominal and improved.

GHG balance method for forested areas

The forested areas are natural reserves and carbon sinks. It is estimated that the carbon stock of tropical forests is close to 700 tCO_2e/ha and that they sequester an additional 0.5 tCO_2e/ha/year to maintain their structure (IPCC, 2006).

The total estimate of the carbon stock of the Tuerê farms' forested areas was carried out using the data on above-soil carbon stocks from Brown (1997) and the data on below-soil carbon stocks from Mokany et al. (2006), which came out to 648 tCO_2e/ha. When modeling the scenarios, the above-soil and below-soil carbon stocks were taken into account to determine the carbon emissions balance of deforestation.

The calculation of GHG emissions from deforestation via slash and burn practices in tropical forests was conducted using EX-ACT, which estimates CO_2, CH_4 and N_2O emissions (Bernoux et al., 2010).

STEP 4: PROJECTED SCENARIOS FOR THE AVERAGE FAMILY FARM IN TUERÊ

Based on the variables utilized to determine the GHG carbon balance of an average family farm in Tuerê for the 2016 baseline scenario, five future scenarios for GHG carbon emissions and their reduction were projected according to changes in land use (deforestation, changes in practices, and forest restauration), the management practices of livestock production and cocoa farming systems, productivity, and the soil condition of pasture land (Tables 2 and 3).

The "Business as Usual" (BAU) scenarios represent the absence of the adoption of the good agricultural practices (low-carbon agriculture), and consequently, the absence of improvement and support programs for family farmers. In contrast, the "Improved" scenarios represent the expected impact of the adoption of low-carbon good practices proposed to the participants of the program (Box 2).

The creation of these scenarios was based on interviews with local and regional actors, such as family farmers, private technical assistance companies, technicians from the Executive Commission on Cacao Farming Planning (CEPLAC), local livestock and cocoa sales agents, the trends in land use changes seen in previous years and the technical experience of Solidaridad and Imaflora.

Table 2 – Variables considered for the baseline and projected scenarios for an average Tuerê settlement family farm

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 Restauration
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**

Box 2 – Good practices for livestock production and cocoa farming systems

Activities that were considered improvements in livestock and cocoa farming practices were those that both enable carbon stocking and an increase in productivity without deforestation—through the conversion of degraded pasture to the forest restauration related to cocoa farming. This basically includes:

1. *Livestock production systems: the implementation of improved animal management (reproductive, sanitary, and rearing), pasture rotation, fertilization of pastureland with nitrogen and limestone (100 kg of urine/he/year and 1.5 t of limestone every 5 years), and the end of burning practices. The use of diesel fuel, 10 liters/ha/year, was also taken into account.
2. **Cocoa Farming: use of fertilizers, pruning, and the increase in the number of shade trees on the farms.

The GHG emissions caused by deforestation were proportionally allocated to the land that became pasture (90%) and cocoa orchards (10%).

Table 3 – Land use on family farms in the 2016 and projected scenarios

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

Tuerê settlement family farm, in Novo Repartimento (PA)

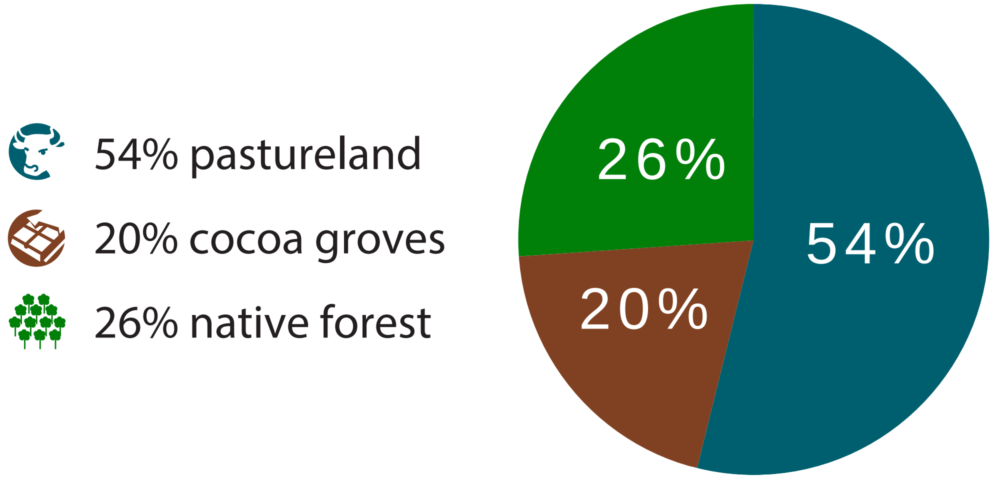
Farmer Jose Antonio de Oliveira in his cocoa grove during harvest

RESULTS

2016 BASELINE SCENARIO GHG EMISSIONS BALANCE

Through the identification of land use on the average family farm in Tuerê, it was possible to calculate a **GHG emissions balance of 1.76 tCO2e/year (50 ha), or 0.04 tCO2e/ha/year.**

Example of land use on an average plot used for crop farming on the Tuerê settlement (50 ha).



* The system method is organic or almost extractivist by default, as only 9% of the farmers who participated in the program in 2016 stated that they had used chemical fertilizers in the past. Source: Horizonte Rural, 2016.

Example of land use on an agricultural plot of the Tuerê settlement (50 ha)

Below are descriptions of the characteristics and results of the GHG balance calculations for livestock production cocoa farming systems and forested areas on the family farms during the baseline scenario.

CHARACTERISTICS AND GHG EMISSIONS BALANCE OF LIVESTOCK PRODUCTION SYSTEMS (2016)

0.9 cows per hectare

0.7 (or 119.3 kg) calves per hectare/year

40 kg CO2e emitted per kg produced

On the Tuerê settlement, the pastureland is predominately degraded land (at a moderate level) and frequently divided into three plots, which are managed according to a simple rotational grazing system. The use of soil inputs (limestone and fertilizer) is practically non-existent and a regimen of burning the pastureland, generally every two years, is practiced to control the regrowth of vegetation that takes place during this period. The average size of a herd per farm is 44 heads (25 cows, 18 calves, and 1 bull). Based on the burning regimen adopted, it was estimated that the amount of accumulated biomass from secondary vegetation on the degraded pasturelands was 5.0 t/ha/year (Uhl, 1988).

The results indicate that the characteristic livestock farming method of the family farms on the Tuerê settlement emit **4.8 tCO2e/ha/year, or 128.8 tCO2e/year per pasture per farm** (27 ha).

129 tCO2e/year EMISSION

Around 47% of these emissions come from the cattle (enteric fermentation and manure fermentation), 43% from pasture degradation, and 10 from burning of pasture. Even though the literature on evaluating the GHG balance of cattle grazing and breeding livestock is limited, a similar amount of emissions was estimated for livestock production systems, taking into account the predominance of degraded soil in the Amazon region (Imaflora, 2016). Thus, the results suggest that livestock systems in degraded pastures may present similar emission profiles, likely because of the lack of pasture and animal management.

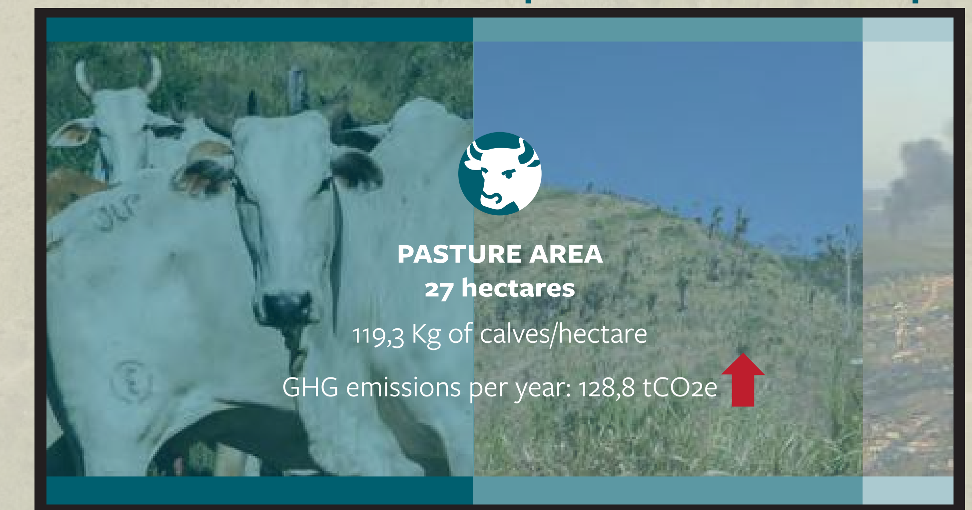
The primary product of livestock farming in Tuerê are calves, which are sold after they are weaned (8-10 months) and generally weigh 185 kg. Considering that the livestock production system in the area accounts for 0.9 cows per hectare and produces around 0.7 calves (or 119.3 kg) per hectare annually, a typical farm on the Tuerê settlement emits **40 kg of CO2e per kilogram of calf production**. These rates are consistent with those found in the relevant literature (Bencoña et al., 2014; Beauchemin et al., 2006; Pelletier et al., 2010).

HG EMISSIONS OF PASTURELAND ON FAMILY FARM / YEAR

48% cattle

43% degradation of pastureland

10% burning of pasture



CHARACTERISTICS AND GHG EMISSIONS BALANCE OF COCOA FARMING SYSTEMS (2016)

According to the data collected, there are no sources of GHG emissions that arise from the cocoa farming methods used on a characteristic farm in Tuerê. Although N_2O emissions have been identified from the decomposition shell of the cocoa bean after harvest, cocoa trees and their accompanying shade trees are natural CO_2 sinks.

The GHG emissions balance of 26 cocoa farming systems were evaluated, which presented variations due to the ages of the trees and the shading configuration on 14 farms. The farming systems evaluated also showed a wide variation in the number of shade trees per area, with the average density being 58 trees her hectare.

An analysis of the results indicate that shaded cocoa farming systems using native trees tends to stock and sequester more carbon than full-sun cocoa farming systems. While cocoa farming systems using shaded methods stocked an average of 300 tCO2e/ha over a period of 18 years, those using the full-sun method stocked around 100 tCO2e/ha. With regard to the sequestration of carbon, the cocoa farming systems present rates between 16.6 mg of CO2e/ha/year in the case of shaded systems and 5.4 mg of CO2/e/ha/year in the case of full-sun systems. This is consistent with the rates found in the relevant literature, which vary between 10 and 40.7 mg of CO2e/ha/year.

The average carbon balance of the cocoa farming systems found to be most common on the farms of Tuerê is -120.6 tCO2e/year or -12.1 tCO2e/ha/year. The carbon balance per ton of cocoa beans produced is -16.7 tCO2e.

Cocoa fruit arranged in a "flag" after harvest

CHARACTERISTICS AND GHG EMISSIONS BALANCE OF FORESTED AREAS (2016)

The land occupied by native forest is a natural carbon sink. It is estimated that tropical forests stock 648 tCO2e per hectare and sequester an additional 0.5 tCO2e per year to maintain their structure due to growth. Thus, the results indicate that an average family farm in Tuerê has around **8.424 tCO2e stocked in native forest remnants (13 hectares) and sequesters an additional 6.5 tCO2e per year due to its maintenance**.

FORESTED AREA OF FAMILY FARM

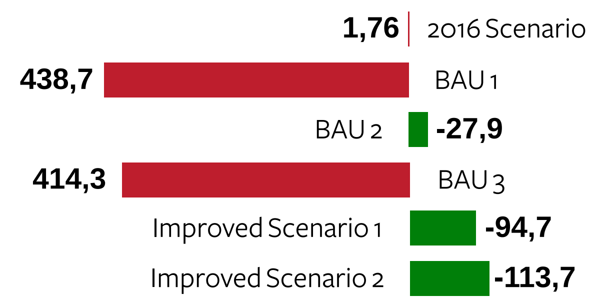
GHG EMISSIONS BALANCES IN THE PROJECTED SCENARIOS

Table 4 – GHG emissions from an average family farm in Tuerê (50 ha) in the five projected scenarios and the baseline scenario

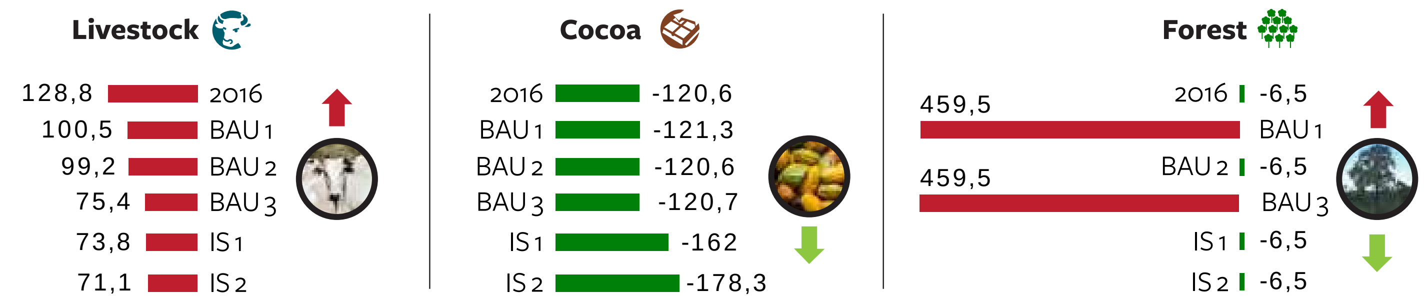
GHG emissions per year	Scenarios BAU 1	BAU 2	BAU 3	Scenario 2016	Improved 1	Improved 2
Livestock	100,5	99,2	75,4	128,8	73,8	71,1
GHG emissions per hectare (tCO2e)	3,6	3,7	2,7	4,8	2,7	2,7
GHG emissions per animal (tCO2e)	4,7	4,8	0,9	3,1	0,9	0,9
GHG emissions per kg of weaned calves (considering deforestation (kgCO2e)	338,10	65,95	70, 39	39,98	10,74	10,74
Cocoa	-121,3	-120,6	-120,7	-120,6	-162	-178,3
GHG emissions per hectare (tCO2e)	-12,1	-12,1	-12,0	-12,1	-16,2	-16,2
GHG emissions per ton of cocoa beans produced (considering deforestation) (kgCO2e)	-10,3	-16,7	-5,9	-16,7	-13,5	-13,5
Forest	459,5	-6,5	459,5	-6,5	-6,5	-6,5
Forest carbon stock (tCO2e)	8002,8	8424,0	8002,8	8424,0	8424,0	8424,0
GHG emissions per hectare (tCO2e)	37,2	-0,5	37,2	-0,5	-0,5	-0,5
Total balance (tCO2e)	438,7	-27,9	414,3	1,76	-94,7	-113,7
Balance per hectare (tCO2e)	8,77	-0,56	8,29	0,04	-1,89	-2,27

CARBON BALANCE

GHG emissions per year (tCO2e)

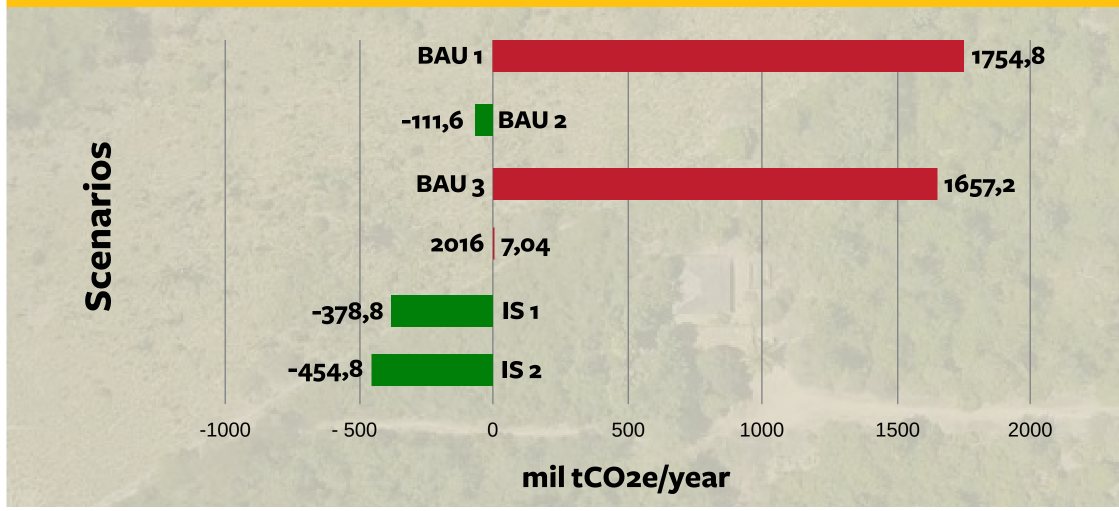


- **2016 Scenario**
- **BAU 1** - Deforestation and reduced agricultural productivity
- **BAU 2** - Reduced productivity and zero deforestation
- **BAU 3** - Deforestation and better agricultural management
- **Improved Scenario 1** - Improved agricultural management
- **Improved Scenario 2** - Improved agricultural management and pastureland restauration



Based on the elaborated scenarios and taking into account Solidaridad's preliminary study, which indicates the direct potential of a course of action involving 4,000 farms, there is a great opportunity for the Trans-Amazonian region to become a GHG sink through the implementation of efficient and sustainable agricultural practices, as can be seen in the following charts.

TOTAL GHG BALANCE OF 4,000 FARMS



- **2016 Scenario**
- **BAU 1** - Deforestation and reduced agricultural productivity
- **BAU 2** - Reduced productivity and zero deforestation
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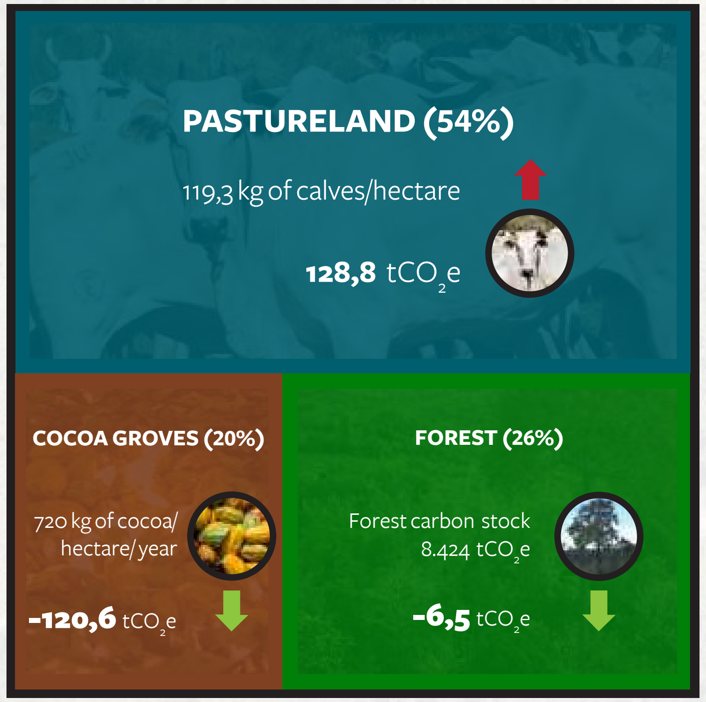
- **Improved Scenario 1** - Improved agricultural management
- **Improved Scenario 2** - Improved agricultural management and pastureland restauration

2016 Scenario

Land use, production, and carbon balance of an average farm on the Tuerê settlement (50 hectare plot).



GHG emissions per year (tCO2e)

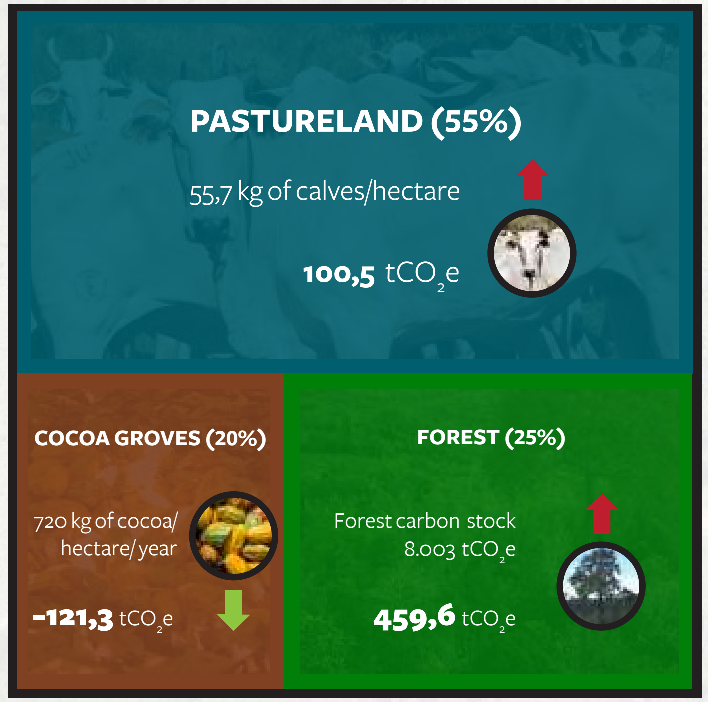
Livestock	128,8
Cocoa	-120,6
Forest	-6,5
TOTAL BALANCE	1,76

BALANCE PER HECTARE

0,04

BAU Scenario 1 – Deforestation and Reduced Productivity

Land use, production, and carbon balance of an average farm on the Tuerê settlement (50 hectare plot).



GHG emissions per year (tCO2e)

Livestock	100,5
Cocoa	-121,3
Forest	459,6
TOTAL BALANCE	438,7

BALANCE PER HECTARE

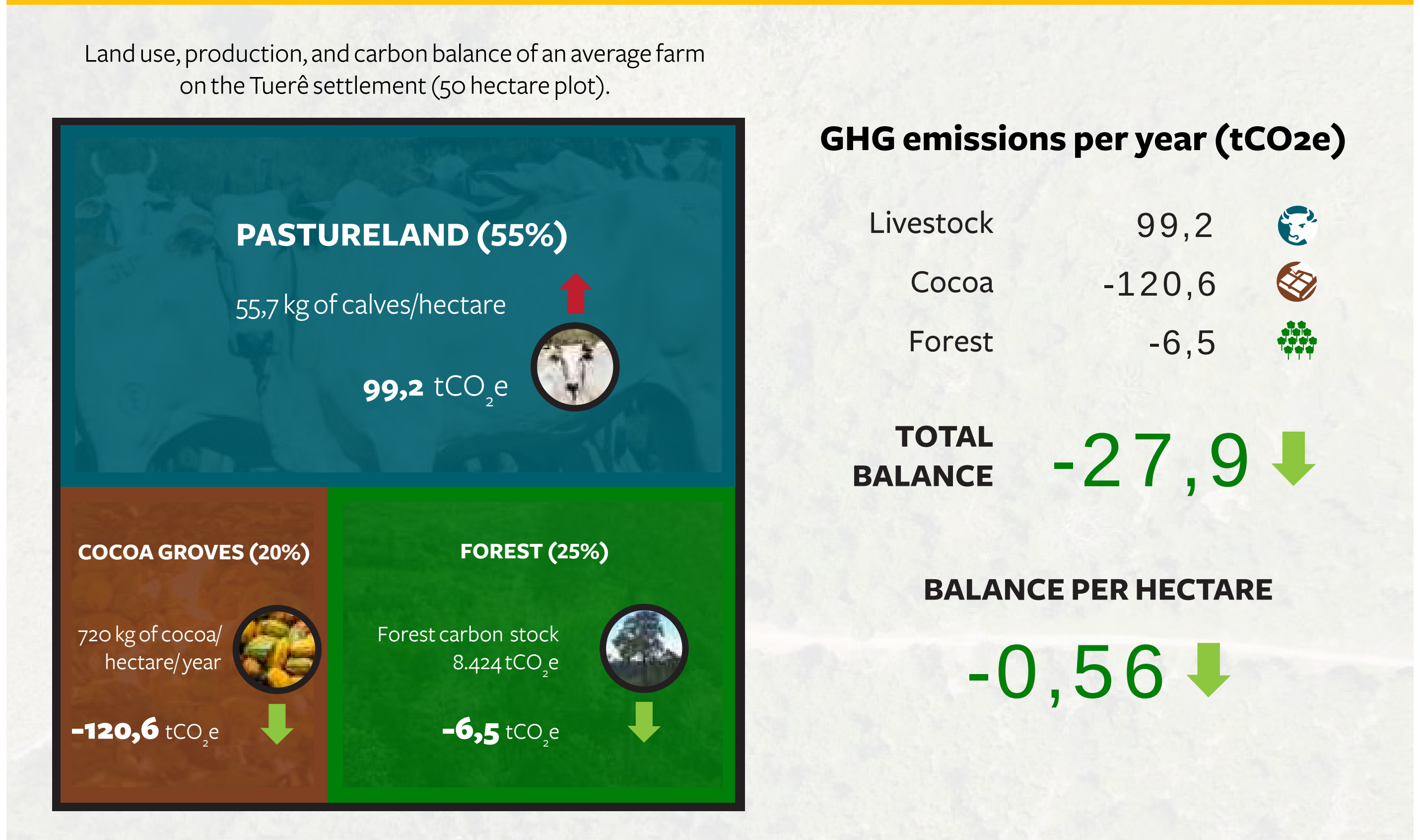
8,77

BAU Scenario 1 – Deforestation and Reduced Productivity

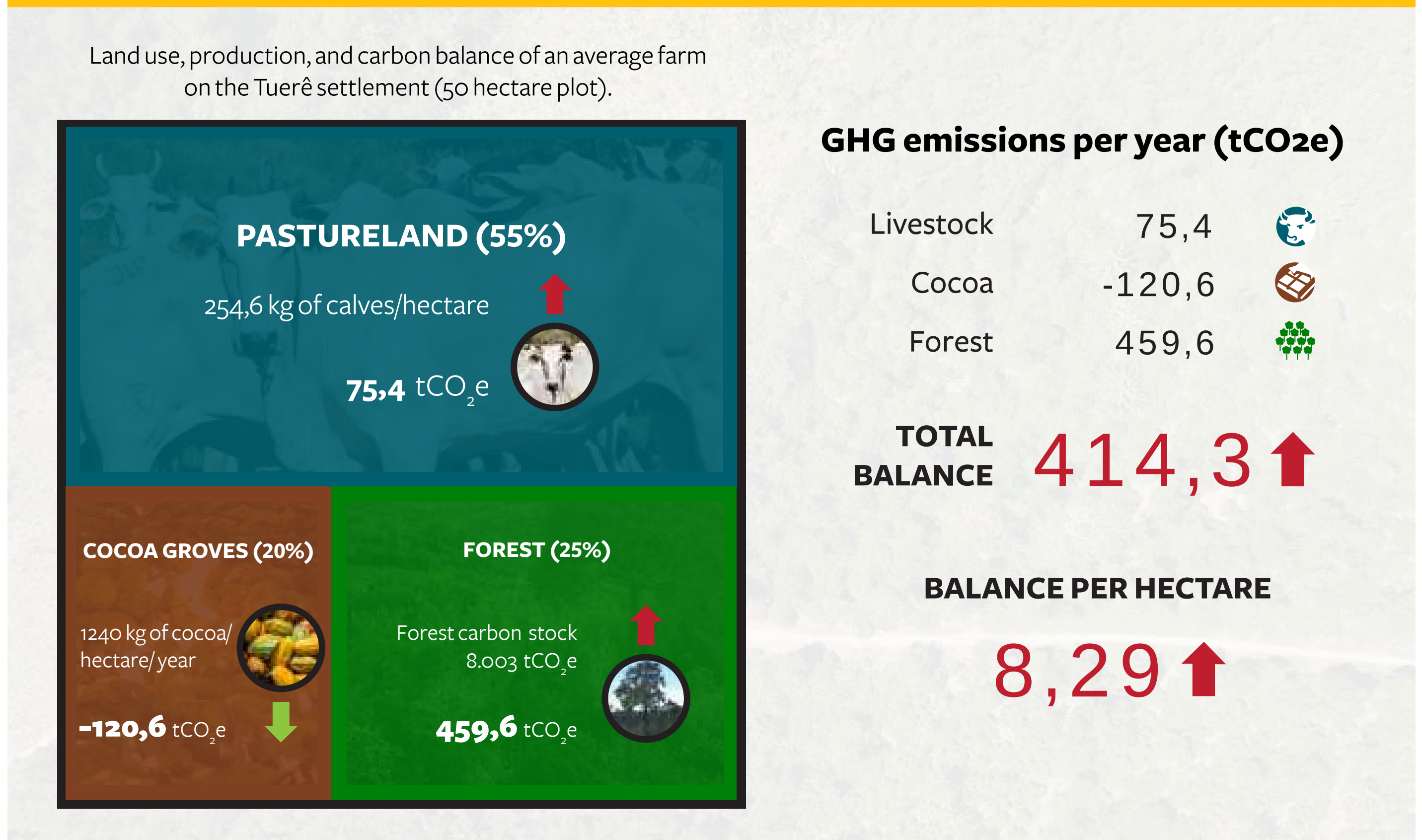
This scenario contemplated a deforestation rate of 5% and reduced livestock productivity, with a 50% decrease in cattle stocking capacity and a 5% decrease in their fertility compared to the 2016 baseline. **The GHG emissions balance for a family farm was estimated to be 8.8 tCO2e/ha/year**, which represents increase in emissions equivalent to 220 times those observed in the 2016 scenario.

In this case, the principal cause of this large increase in emissions (+220%) would be deforestation due to slash and burn practices. Furthermore, by allocating 90% of the deforested area to pasture and 10% to cocoa farming, the intensity of emissions per product increased by a factor of 8.5, 746% per kg of weaned calves and 62% per ton of cocoa bean.

BAU Scenario 2 – Reduced Productivity



BAU Scenario 3 – Deforestation and Improved Management



BAU Scenario 2 – Reduced Productivity

In this scenario, like in BAU Scenario 1, there was a reduction in livestock productivity, however with zero deforestation. **The GHG balance of a family farm was estimated to be -0.56 tCO2e/ha/year**. In other words, in this case, there was a reduction of GHG, which suggests that with zero deforestation, a large part of the GHG emissions would be avoided.

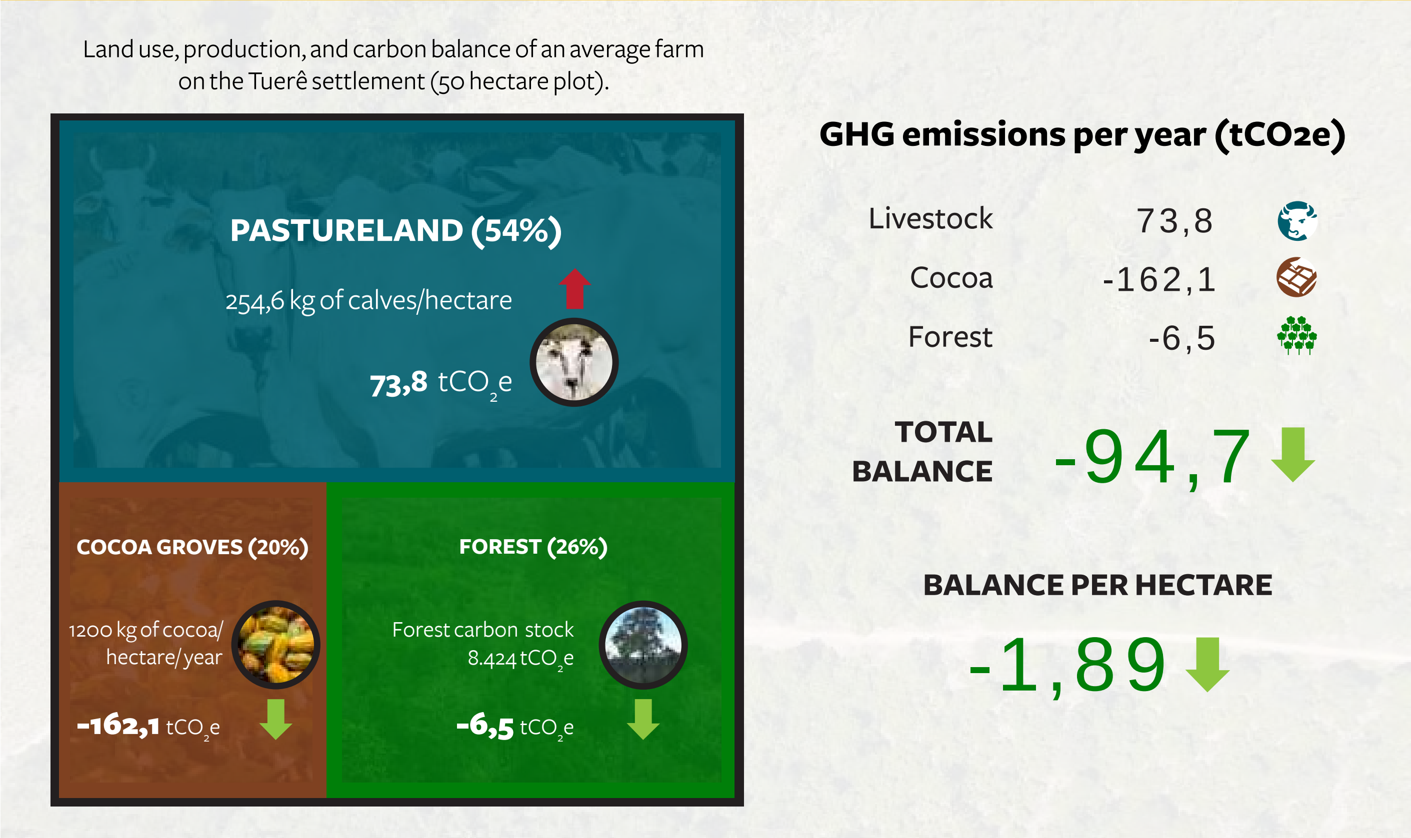
Although there are much less GHG emission in the BAU Scenario 2 than in the 2016 scenario (0.04 tCO2e/ha/year) the increasing pastureland, degradation would reduce significantly the production capacity of the pasture on each farm. With the 50% reduction in capacity and the 55% reduction in calf production, the emissions per kilo of weaned calves would increase 65% in this scenario.

BAU Scenario 3 – Deforestation and Improved Management

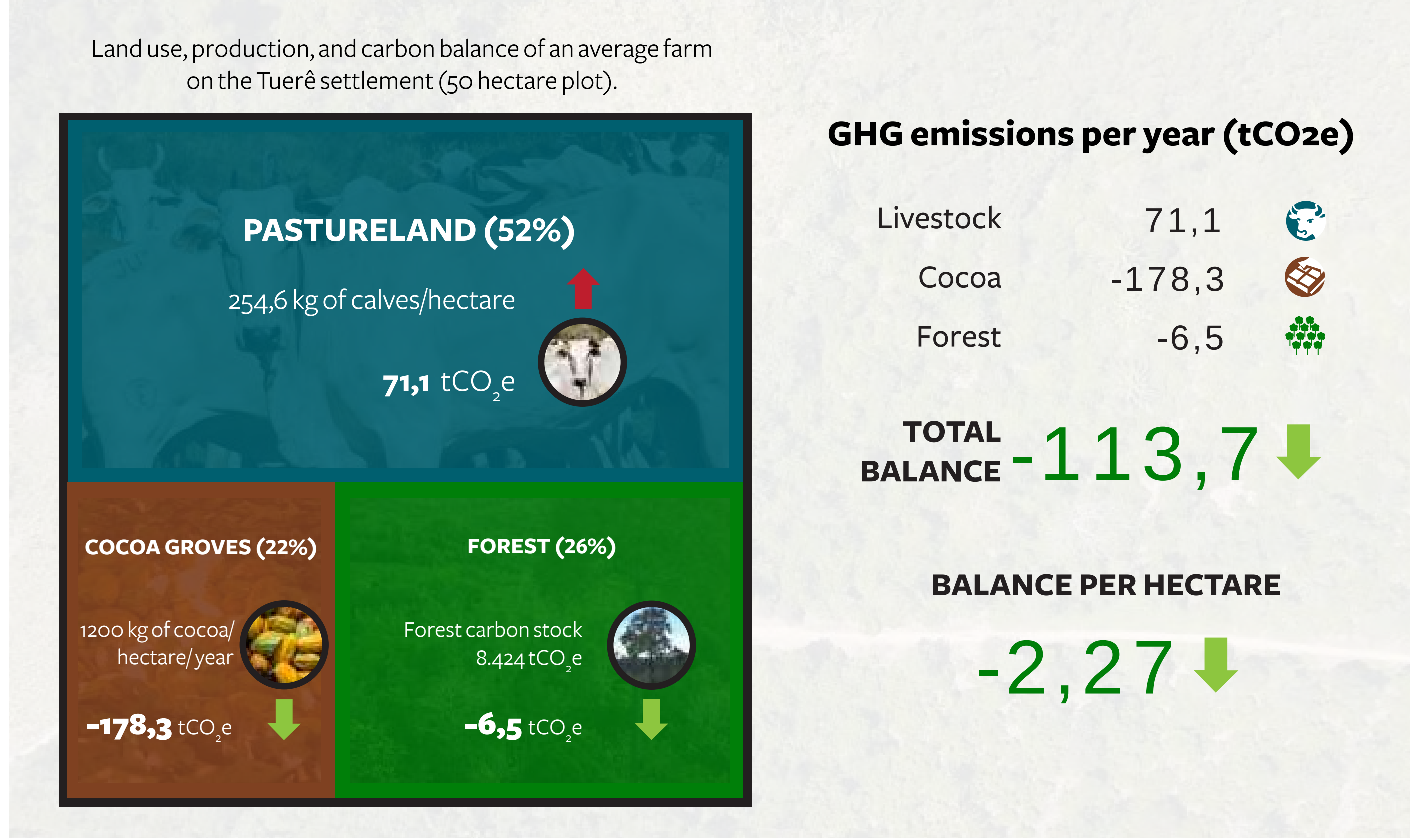
As with BAU Scenario 1, in BAU Scenario 3, new forested area would be cleared to increase the area of productive land (90% of the deforested area would become pasture, and 10% would become cocoa groves) on each family farm. However, there would be an improvement in management practices in the livestock production and cocoa farming methods. **The GHG balance of a family farm was estimated to be 8.29 tCO2e/ha/year**, which represents an increase of a factor of 207 in GHG emissions per family farm and 76% per kilo of weaned calves compared, as well as a 65% reduction in emissions for every ton of cocoa beans produced compared to the 2016 scenario.

Even though there would be an improvement in livestock management practices on Tuerê family farms in this scenario, with a 200% increase in livestock capacity and the increase in efficiency of calf production (115% more calves per hectare), these practice would not compensate for the emissions from the deforestation that would result from this livestock production system.

Improved Scenario 1 – Improved Management



Improved Management 2 – Better Management and Restauration



Improved 1 – Improved Management

In Improved Scenario 1, there would be an increase in production on each family farm with zero deforestation due to the intensification of livestock production and crop farming. **The GHG balance of a family farm was estimated to be -1.89 tCO2/e/ha/year**.

Through the pasture restauration and improved management practices in cocoa farming, the GHG emissions would be reduced by a factor of 55 compared to the 2016 scenario (from 0.04 to -1.89 tCO2e/ha/year). Thus, in this scenario, there is an increase both in climate performance and productivity, which means the family farms would turn into GHG sinks.

Improved 2 – Improved Management and Restauration

In Improved Scenario 2, the improvement in management practices and the conversion of 1 hectare of pasture into cocoa groves would reduce the GHG emissions by a factor of 65 compared to the baseline scenario. **The GHG balance of a family farm was estimated to be -2.27 tCO2/e/ha/year**.

It should be noted that, for both improved scenarios, GHG emissions would be reduced by 75% per kilo of weaned calves and 20 per ton of cocoa beans produced.

Farmer Anísio de Souda Filho drying his cocoa beans

CONCLUSIONS AND RECOMMENDATIONS

Information regarding land use and agricultural management practices on family farms in Brazil and their effect on the GHG emissions balance is scarce. This being the case, the study presented in this publication was conducted with the objective of contributing to the discussion surrounding this issue with information and reliable local data that offers support and resources for the development of public policies regarding the development of low-carbon family farming.

The data collected in interviews with farmers and during field visits conducted in 2016 allowed for the establishment of a land use baseline for the average family farm on the Tuerê Rural Settlement in Pará, on which 54% of the total area is occupied by pasture land for the rearing and breeding of cattle, 20% by cocoa groves, and 26% by native forest remnants.

Considering the variables presented by each of the livestock and cocoa farming systems and the type of land use currently in effect, the study utilized a combination of calculators that allowed it to estimate carbon emissions, which came out to 0.04 tCO2e/ha/year for an average family farm in the 2016 baseline scenario. It should be emphasized that, because emissions resulting from deforestation were not considered for this scenario, it was found that the main vector for GHG emissions on a family farm was livestock farming (4.8 tCO2e/ha/year). In this system, the main sources of emissions where pasture degradation and the management system employed, which were partially compensated for by the carbon removal by cocoa groves and forestlands at the rates of -12.1 and - 0.5 tCO2e/ha/year respectively. Based on this model, five scenarios were projected, in which the GHG emissions balance was estimated according to variations in land use and management practices adopted for each kind of agricultural production system.

The “Business as Usual (BAU) scenarios showed that the deforestation rate of 5% would increase GHG emissions by a factor of 220 per family farm in Tuerê. On the other hand, it was found that with the promotion of practices that do not include the conversion of forest land into farmland, the increase of shade trees in cocoa groves, and improvements pasture management, the farms can become carbon sinks and at the same time increase their calf production by 100% and cocoa bean production by 70%. As a result, the intensity of GHG emissions from livestock farming would be reduced by 75% per kilo of weaned calves and, with every ton of cocoa beans produced, the farms' capacity to sequester carbon would increase by 20%.

The greatest impact of the improved scenarios (Improved 1 and 2) would be the advances in livestock management practices, which would reduce GHG emissions by 43.8% in both scenarios compared to the baseline scenario. The majority of this reduction would result from the end of burning practices, the sequestration of carbon by the soil, thanks to the recuperation of degraded pasture, and the improved livestock management practices. These factors would compensate for the additional emissions resulting from the use of soil inputs and the increase in cattle.

Furthermore, cocoa crops would benefit from the improvements in management practices. When compared to the baseline, the total adoption of shaded cocoa farming systems would lead to the removal of 16.2 tCO2e/ha/year and the production of 83% more cocoa beans, which would mean a 19% decrease in GHG per ton of cocoa beans produced.

This study seeks to, in an unprecedented manner, prompt a discussion about the role of family farming in the reduction of emissions and the potential of increasing GHG sinks in the Amazon. The results of the study contribute to the dissemination of a new perspective that seeks to reposition family farmers as part of the solution and provide them with opportunities that would arise the transition to low-carbon agriculture.

In a general sense, prioritizing the elimination of deforestation is the most important action that can be taken to drastically reduce the emissions from an average farm on the Tuerê rural settlement over the next several years, even if the soil management practices and agricultural production systems employed continue to be those considered in the BAU scenarios. However, if the elimination of deforestation were to be combined with the incorporation of improved management practices in both livestock production and cocoa farming systems, the Tuerê settlement could improve its climate performance, becoming a carbon sink, and at the same time improve its agricultural productivity.

Finally, this study provides a framework for monitoring and evaluating emissions produced in different scenarios and generating information that can be used to improve both current and future GHG calculators in order allow for more comprehensive evaluations of the emissions of small-scale farms.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José Antônio de Oliveira
UD2 - T2
SEM PODA | COM ADUBO EM 2017
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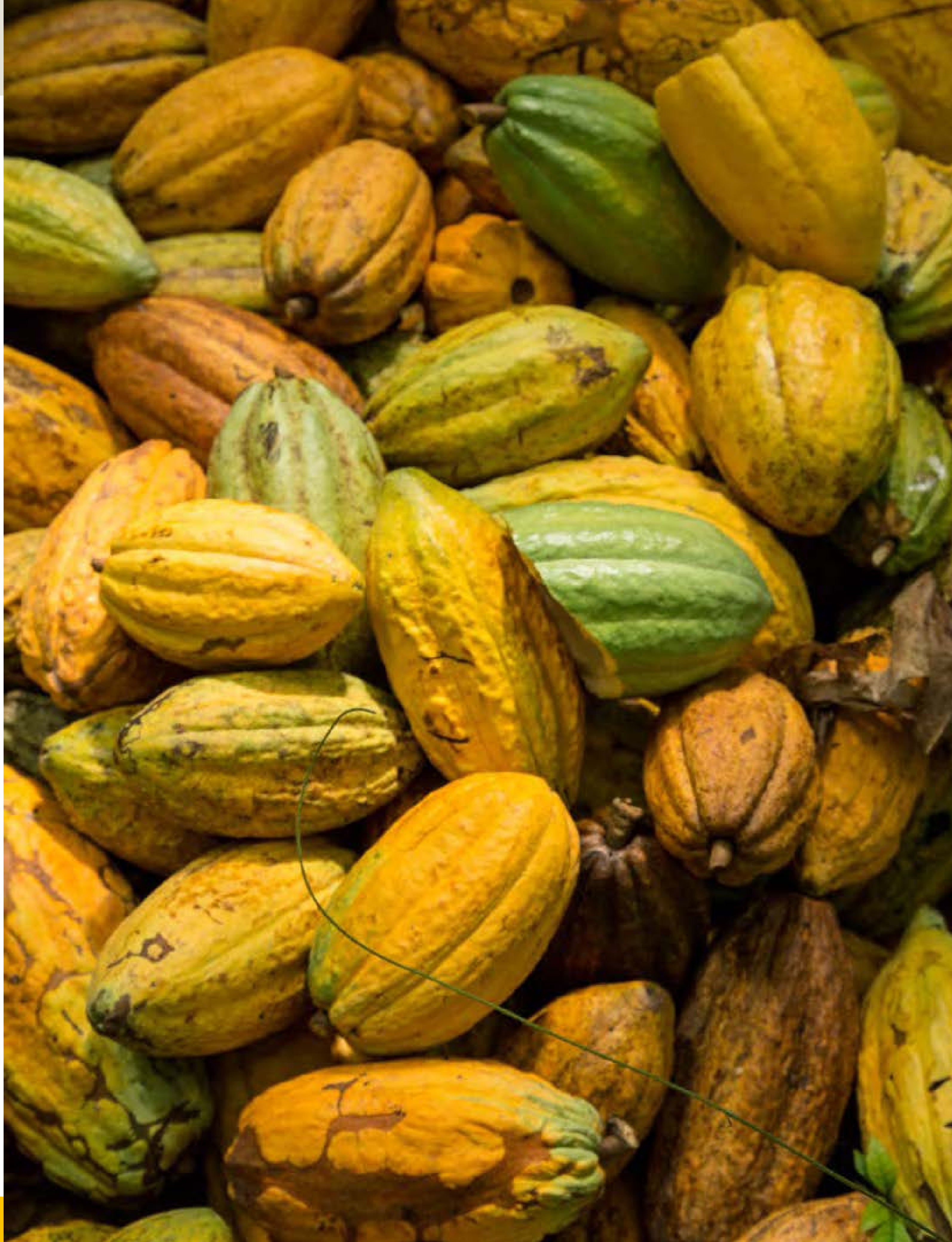

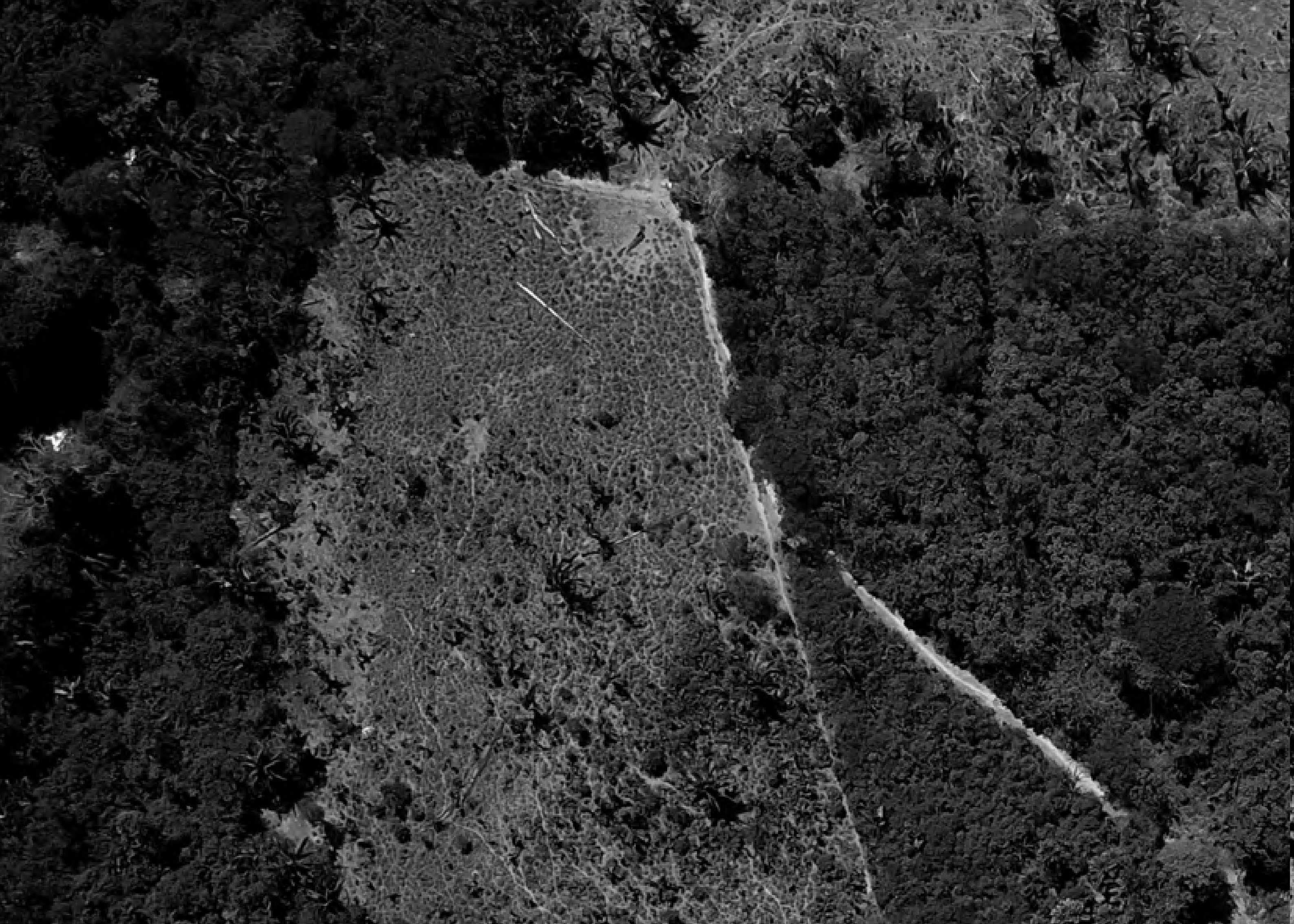

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