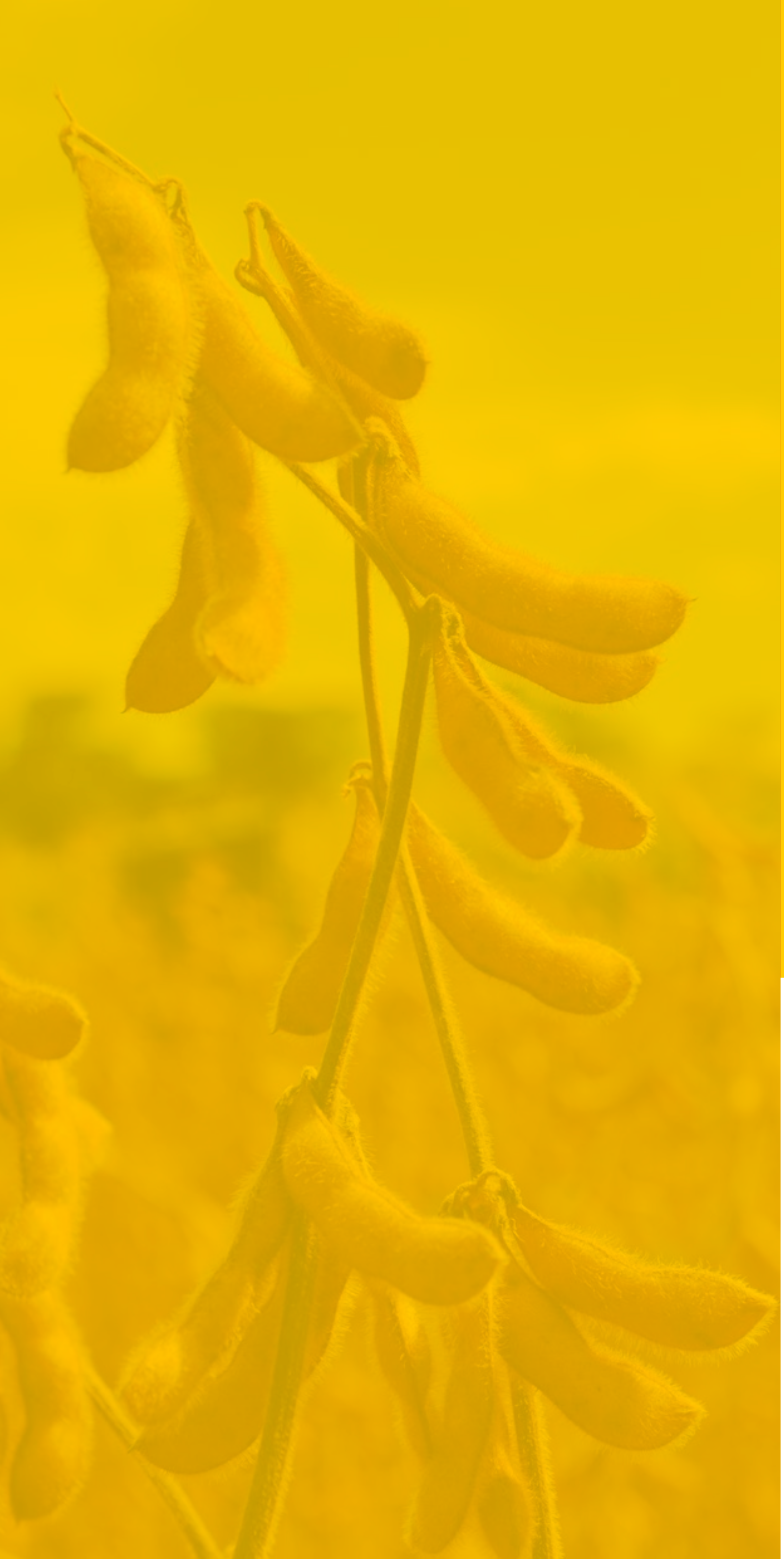
CARBON BALANCE IN MATOPIBA SOY PRODUCTION

Solidaridad



Solidaridad

SOLIDARIDAD

Country Manager
Rodrigo Castro

Programme Manager
Paula Freitas

Communications Manager
Luiz Fernando Campos

Project Coordinator
Juliana Monti

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CARBON BALANCE IN MATOPIBA SOY PRODUCTION

Authors
Renata Potenza (Imaflora)
Gabriel Quintana (Imaflora)

Co-authors
Camila Santos
Juliana Monti

Revision
Paula Freitas
Harry van der Vliet
Juliana Monti
Renata Potenza (Imaflora)

Technical revision
Marcos Heil Costa
Jorge da Silva Junior

Maps
Karine Costa

Photos
Shutterstock and Solidaridad

Graphic design, editorial design and text editing
Laboota

Editorial review
Luiz Fernando Campos

Translation
Harkin Translations

SOLIDARIDAD

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6. Soil Organic Matter 7. Low-Carbon Agriculture

OVERVIEW

Low-carbon agriculture and climate security

Solidaridad is an international civil society organization with more than 50 years of history and operates in more than 40 countries. It promotes partnerships and innovative solutions with governments, organizations, cooperatives, and companies to support rural men and women producers to produce better and reduce the climatic impact of food production. Its mission is to ensure the transition to an inclusive and sustainable economy, which maximizes the benefit for people and the planet.

In Brazil, it has been fostering the development of socially inclusive, environmentally responsible, and economically profitable agricultural chains for 13 years. It proposes to accelerate the transition to a low-carbon production model, contributing to the food and climate security of Brazil and the world.

It currently develops sustainability initiatives with its partners in the following chains: cocoa, coffee, sugarcane, yerba mate, orange, livestock, and soy.

The Soy Programme has been active in Brazil since 2010 and helps make the soy chain more sustainable in different biomes. Twenty-two (22) projects were supported under the Soy Fast Track Program, allowing the sustainable management of 2.1 million hectares of land on 1,014 properties.

Work was also done at the landscape scale in soybean origination areas based on three approaches. The first, Changes in Business Practices, resulted in 493 soy growers who have adopted continuous improvement systems. The second, Landscape Governance, had 848 farmers and employees trained in legislation and forest restoration and enabled multisectoral groups to be formed. The third approach, Sustainability in the Field, resulted in 493 trained producers and 698,731 hectares under good agricultural practices.

Since 2018, Solidaridad has structured its action based on the territorial dynamics of soy in the main production centers and on private organization engagement. The objective is to expand efforts toward low-carbon agriculture with the efficient land use in MATOPIBA within the Cerrado biome.

It is worth noting that the methodology developed and presented in this study and the carbon balance analysis of West Bahia will integrate the Environmental Information System of West Bahia's carbon balance calculator, a platform developed by Brazil's National Service for Industrial Apprenticeship (Serviço Nacional de Aprendizagem Industrial – SENAI/CIMATEC), and the Association of Farmers and Irrigators of Bahia (Associação de Agricultores e Irrigantes da Bahia – AIBA) will manage the platform.

This study was produced in technical partnership with the Institute of Forest and Agricultural Management and Certification (Instituto de Manejo e Certificação Florestal e Agrícola – IMAFLORA) and aims to contribute to developing the Brazilian climate agenda by fostering and adopting good agricultural practices with low-carbon emissions in soy production.

CONTENTS

CLICK TO BROWSE

1.

Introduction

With an increase of approximately 0.2° C per decade, anthropic global warming could reach 1.5° C between 2030 and 2050. As part of measures to mitigate this impact, **greenhouse gas emissions, such as carbon from the energy and agriculture sectors, are the focus of sustainable initiatives implemented around the world.**

In Brazil, national policies have been implemented to enable a low-carbon economy in recent years.

According to the Nationally Determined Contribution (NDC), the Paris Agreement's ratifying instrument, **Brazil has committed to reducing carbon emissions to 37% below the 2005 levels by 2025 and by 43% by 2030** (BRAZIL, 2015).

Recently launched, the ABC+ 2020-2030 Program, the ABC Plan's new cycle, establishes strategies for climate change and low-carbon emissions and continuing to foster practices that adopt sustainable production systems considered in the previous cycle, such as integrating no-tillage systems, using bio-inputs, planted forests, degraded pasture recovery, and irrigation system implementation (BRAZIL, 2021).

In this case, **soy is a strategic commodity in Brazil, as it is associated with the energy and agriculture sectors**, positively impacting the first with increasing forecasts of including biodiesel in diesel of fossil origin and with possibilities of adopting production systems that significantly reduce emissions and that can promote increased soil carbon.

SOYBEAN PRODUCTION IN THE 2019/2020 HARVEST

BRAZIL REPRESENTED **38% OF THE WORLD'S SOY PRODUCTION IN THE 2019/2020 HARVEST**

THE COUNTRY RANKS **FIRST** IN GRAIN PRODUCERS

	WORLDWIDE	**1. BRAZIL**	**2. USA**	**3. ARGENTINA**
PLANTED AREA	**122,930,000 ha**	**36,900,000 ha**	**30,327,000 ha**	**16,700,000 ha**
PRODUCTION	**339,880,000 t**	**128,844,800 t**	**96,667,000 t**	**48,800,000 t**
PRODUCTIVITY	**2,765 kg/ha**	**3,492 kg/ha**	**3,187 kg/ha**	**2,922 kg/ha**

Source: (USDA, 2021)

From an economic point of view, **Brazil accounted for 38% of world soybean production in the 2019/2020 harvest and ranked first among grain-producing countries.** Thirty-six point nine (36.9) million hectares were cultivated, approximately 30% of the world's soy crop area (USDA, 2021). The country produces the most grain per cultivated area.

Eighty-five percent (85%) of the total 2019/2020 harvest was produced in the Central-South region and 15% in the North and Northeast regions, according to Brazil's National Supply Company (Companhia Nacional de Abastecimento – CONAB, 2021). MATOPIBA comprises the state of Tocantins, part of the states of Maranhão and Piauí, and Western Bahia. Just in

the soybean crop, the cultivated area in the 2019/2020 crop increased 20% over the 2014/2015 crop, and production increased by 46%, from 10,559,800 to 15,396,200 tons of soybeans (CONAB, 2021).

This report will present the carbon balance of soybean production in MATOPIBA, represented here by **50 farms in the region. In this scope, the carbon stock in the areas with native vegetation and the improved scenarios were also analyzed following the management practices adopted and changes in land use.**

36.9 MILLION HECTARES WERE GROWN IN BRAZIL, **30% OF THE WORLD AREA** OF SOY, WITH A **TOTAL PRODUCTION OF 128,844,800 TONS, WHICH IS EQUIVALENT TO A PRODUCTION RATE OF 3,492 KG/HA**

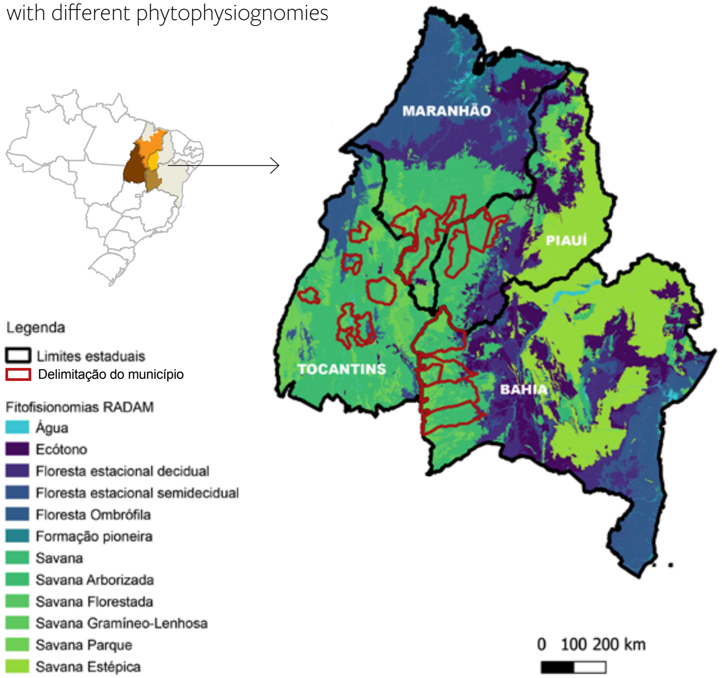
2.

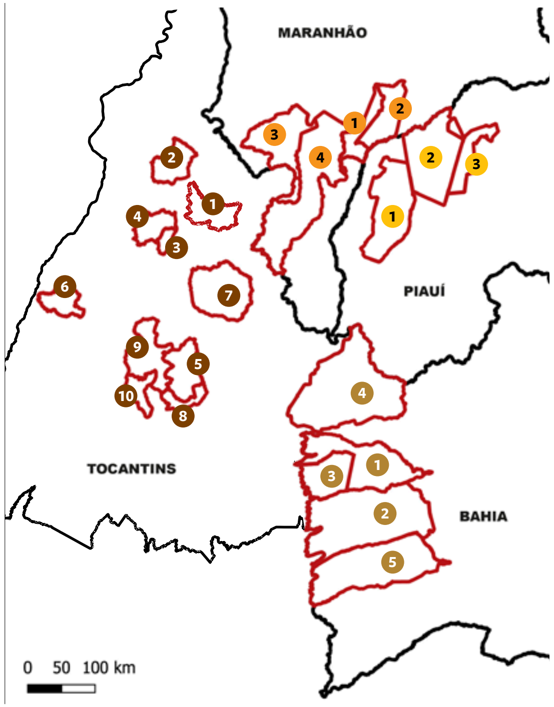
Methodology

THE ASSESSED FARMS ARE IN THE **MATOPIBA REGION**, WHICH COMPRISES THE CERRADO BIOME IN THE STATES OF MARANHÃO, TOCANTINS, PIAUÍ, AND BAHIA

THE EVALUATED FARMS

50 farms with at least five hectares of soy were chosen in 22 municipalities, with different phytophysiognomies





ESTADOS E MUNICÍPIOS

TOCANTINS
15 farms

MUNICIPALITIES

1. Itacajá
2. Palmeirante
3. Tupirama
4. Guaraí
5. Monte do Carmo
6. Marianópolis do Tocantins
7. Rio Sono
8. Silvanópolis
9. Porto Nacional
10. Brejinho de Nazaré

BAHIA
20 farms

MUNICIPALITIES

1. Barreiras
2. São Desidério
3. Luís Eduardo Magalhães
4. Formosa do Rio Preto
5. Correntina

MARANHÃO
9 farms

MUNICIPALITIES

1. Sambaíba
2. Loreto
3. Riachão
4. Balsas

PIAUÍ
6 farms

MUNICIPALITIES

1. Baixa Grande do Ribeiro
2. Uruçuí
3. Sebastião Leal

CLIMATE AND VEGETATION

Tropical with dry winter:

- **Estação chuvosa** | Summer | Nov-Ap
- **Dry season** | Winter | May-Oct
- **Average annual rainfall:** 800 e 2,000 mm

Main phytophysiognomies:

- Park Savannah
- Woodland Savanna
- Shrub Savannah
- Grassy-woody
- Savanna Submontane
- Semideciduous Seasonal Forest

2.1.

Assessment scope

The approach to **quantifying carbon emissions and sequestration follows the Brazilian GHG Protocol Program**, which classifies emissions into three scopes related to the organization's degree of control; in this case, farms, over their sources or activities that are precursors of carbon emissions.

- **Scope 1** considers emissions that belong to or can be controlled by the farm, characterized as direct.

- **Scope 2** deals with a special category of indirect emissions that arise from consuming electricity, which physically occurs where the energy is produced but brought within the farm's boundaries.

- **Scope 3** is an optional reporting category that includes other indirect emissions considered to be a consequence of farm activities and that do not occur in sources that the farm owns or controls. The freighting of inputs and farm production is an example of this.

The emission activities of Scopes 1 and 2 were considered in this assessment. It must be stressed that the carbon emission from the change in land use before the soybean crop was established was not accounted for in the carbon balance in this analysis. Only each farm's carbon emissions and sequestration related to agricultural practices were considered.

The precursor carbon activities/ sources accounted for Scope 1 are:

MECHANIZED AGRICULTURAL OPERATIONS BASED ON CONSUMPTION OF FUEL IN MOBILE SOURCES

FERTILIZATION OPERATIONS FROM THE SOIL, AFTER THE APPLICATION OF NITROGEN FERTILIZERS

LIMING OPERATIONS AND APPLICATION OF GYPSUM TO CORRECT SOIL ACIDITY

DECOMPOSITION OF CROP RESIDUES

Scope 2 estimates carbon emissions from electricity purchased from the utility company.

The assessment depicts the 2019/2020 harvest, which comprised the second half of 2019 (soybean cultivation) and the first half of 2020 (for those with a second harvest). Carbon emissions from soil preparation and decomposition activities were accounted for agricultural residues for the soybean crop and for the doubled crop. Data was collected from a questionnaire from interviews with producers.

The **baseline carbon balance from soy production was established for each farm** using data from the 2019/2020 harvest (within Scopes 1 and 2). This baseline helped to **design four scenarios of land use change and agricultural practices and their respective carbon balances.**

2.2.

Quantification method for carbon emissions

The methodology for calculating carbon emissions and sequestration estimates from soy production in the MATOPIBA region is divided into four main categories: emissions from agricultural production, **emissions and sequestration by land use, carbon stocks contained in areas with native vegetation, and net emissions, also called carbon balance**, detailed below.

Emission and sequestration factors proposed by national and international protocols were considered with methodological robustness that allows comparisons with other assessments. Regional studies assessing the long-term emission and sequestration of carbon are essential to improve the existing methodologies.

2.3.

Direct and indirect emissions from soy production

Direct and indirect emissions accounted for soy production were estimated according to carbon-emitting sources and activities:

- APPLICATION OF FERTILIZERS IN THE SOIL
- APPLICATION OF LIME AND GYPSUM IN THE SOIL
- DECOMPOSITION OF CROP RESIDUES
- BURNING FOSSIL FUELS
- BURNING RENEWABLE FUELS
- ELECTRIC POWER CONSUMPTION

2.4.

Emission and conversion factors

The emission and conversion factors recommended by this methodology include Tier1[1] of the Intergovernmental Panel on Climate Change (IPCC, 2006), in line with the 2019 report update. All factors considered in the equations in this first assessment were obtained from the IPCC literature, following the use of country-specific factors (when they exist) in their existing scientific literature.

For a more in-depth assessment, it is important to use factors that reflect the edaphoclimatic conditions in the region, which requires an existing historical monitoring series.

[1] Tier: represents a level of methodological complexity. There are three tiers for categorizing emission factors and activity data. Tier 1 is the basic method, often using national or international factors such as those provided by the IPCC. Tier 1 emissions estimates require the following information: data on the amount of fuel burned and a standard emission factor (e.g., provided by the IPCC).

2.5.

Carbon emissions and sequestration by land use

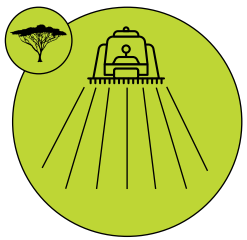
One of the ways to quantify carbon sequestration is to estimate the stock in the soil. It is recommended to quantify carbon stocks, contrasting the treatment with the control. In other words, the stocks of a given situation (treatment) were evaluated against a previous situation (control), such as the change of land use under native vegetation cover to agricultural areas or the adoption of conservationist management practices that replace conventional management practices.

It is known that **soil organic matter in equilibrium is a dynamic reservoir of the carbon (C) and nitrogen (N) cycles, and its content is supposedly stable in soils under natural vegetation (BORTOLON et al., 2009).**

Considering the phytophysiognomies of the Cerrado biome in this study, it can be considered that the maintenance of this balanced ecosystem provides an average underground carbon stock of 18.41 tC/ha (BRAZIL, 2020). When anthropic activities alter native vegetations, the dynamic balance is broken, and C inputs are generally smaller than outputs, which leads to a reduction in the quantity and modification of soil organic matter quality (CERRI et al., 2008).

Four scenarios for carbon balance analysis are presented in this report, with the respective conversion factors for each one:

SCENARIOS FOR CARBON BALANCE ANALYSIS

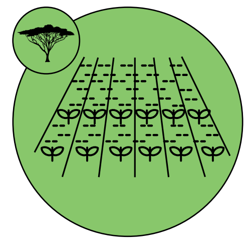


SCENARIO I

CERRADO FOR CONVENTIONAL TILLAGE SYSTEM

Emission Factor

0.9167 tCO_2e/ha/year

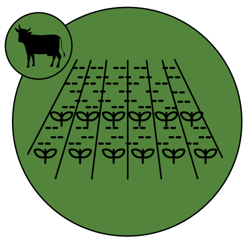


SCENARIO II

CERRADO FOR NO TILLAGE SYSTEM

Sequestration Factor

-0.44 tCO_2e/ha/year

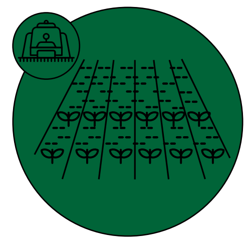


SCENARIO III

DEGRADED PASTURE FOR NO-TILLAGE SYSTEM

Sequestration Factor

-0.6967 tCO_2e/ha/year



SCENARIO IV

CONVENTIONAL TILLAGE SYSTEM FOR NO-TILLAGE SYSTEM

Sequestration Factor

-1.76 tCO_2e/ha/year

Despite the standard emission factors in the GHG Protocol – Agriculture, it was decided to use other values from the literature in two cases, as they seem to be more representative of the use and management conditions in the region. For the baseline scenario of farms concerning the use of a conventional tillage system (CTS) or no-tillage system (NTS), the emission or sequestration of CO_2 that the adoption of each model implies was considered to estimate the sequestration of carbon from the soil. **For those that already using the NTS, a sequestration factor of -1.53 tCO_2e/ha/year was applied (BERNOUX et al., 2006), resulting from the use of no-tillage, considering direct seeding and using organic matter as ground cover. These practices help to increase carbon in the most superficial layers of the soil by disturbing it less, contributing to the reduction of emissions.**

Some farms maintain the ground cover with other crops, such as grasses (Braquiaria sp.) that add more organic material. **For those that also use NTS with this extra contribution of carbon via the organic matter of the other cultures, the sequestration factor of -1.76 tCO_2e/ha/year was used to recognize this other source of maintenance and increment of carbon in the soil** (MAIA et al., 2013).

These factors can be considered conservative estimates. These are some of the lowest values found in the literature, chosen in consultation with specialists to minimize the technical limitations in obtaining the sequestration based on each farm's real-field and edaphoclimatic conditions.

The emission factor for farms that adopt a conventional tillage system (CTS) was 0.88 tCO_2e/ha/year (COSTA JUNIOR et al., 2013).

2.6.

Carbon stocks in native vegetation areas

The carbon stocks in the biomass of conservation areas, legal reserves, and permanent preservation areas should be reported separately, as these areas under natural vegetation have already been established and, above all, protected by law. Therefore, it is understood

that there are no additional carbon increments beyond what the property owns through its legal duty, with the carbon stock having already reached its equilibrium state. **Therefore, this information does not enter the carbon balance analysis.**

The proposed methodology for estimating carbon stocks contained in native vegetation areas on farms consists of crossing the following data:

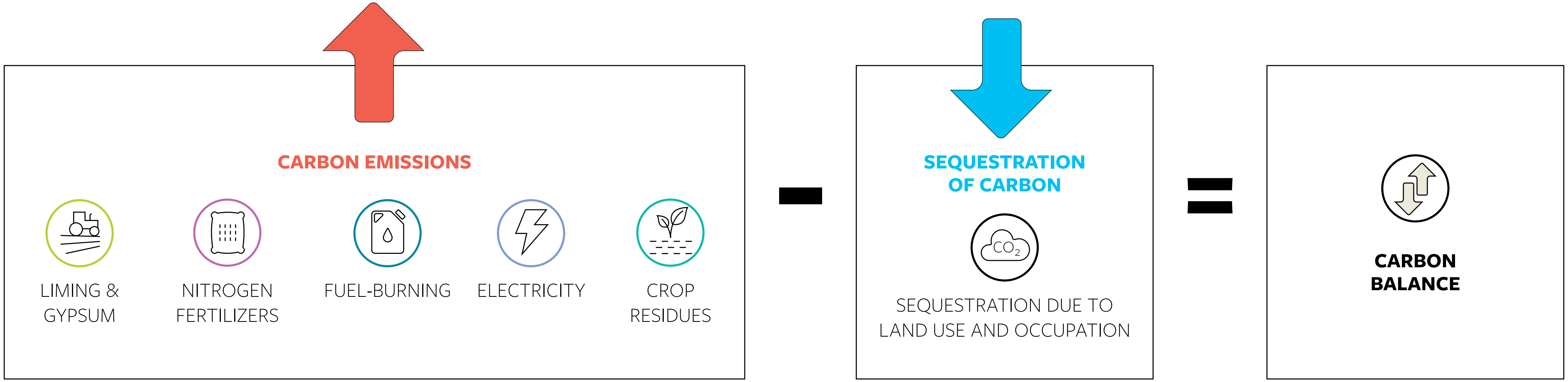
- IDENTIFICATION OF NATIVE VEGETATION AREAS ON FARMS (IN HECTARES)
- CROSSING THE BOUNDARIES OF THE FARMS' MUNICIPALITIES ASSESSED WITH THE MAP OF BIOMES AND PAST VEGETATION FROM THE DATABASE OF THE BRAZILIAN INSTITUTE OF GEOGRAPHY AND STATISTICS (*INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA – IBGE*)
- SURVEY IN THE LITERATURE OF AVERAGE VALUES OF CARBON CONTAINED IN THE FARMS' PLANTS[2]
- APPLICATION OF ESTIMATED EQUATIONS OF CARBON STORE IN THE PHYSIOGNOMY OF THE FARMS' NATIVE VEGETATION AREAS

[1] The phytophysiognomies that are part of the scope of this analysis are indicated on map 1

2.7.

Carbon balance and expression of results

In the methodology of the GHG Protocol for Agriculture, the following equation is recommended for calculating the balance of carbon emissions and sequestration (or, simply, carbon balance).



The final results were expressed in tons of carbon equivalent per bag of soybeans,[3] per kilogram of soybeans, and per area for farms with a single crop and for those with a double crop. Production values were considered a function of the harvested areas for estimating carbon emissions by the quantity of soy produced.

Biogenic emissions[4] are not accounted for carbon balance purposes, only reported separately.

[3] 3 One bag is equivalent to 0.06 tons.

[4] The GHG Protocol Brazil recommends that CO_2 emissions from biomass combustion are reported separately. The CO_2 released during biomass combustion is equivalent to the CO_2 taken from the atmosphere during photosynthesis, which is considered biogenic. Biogenic carbon emissions generally come from land use from the decomposition of organic matter, burning agricultural residues, and biofuels.

2.8.

Emission and sequestration factors for soil carbon sequestration scenarios and extrapolation of carbon balances

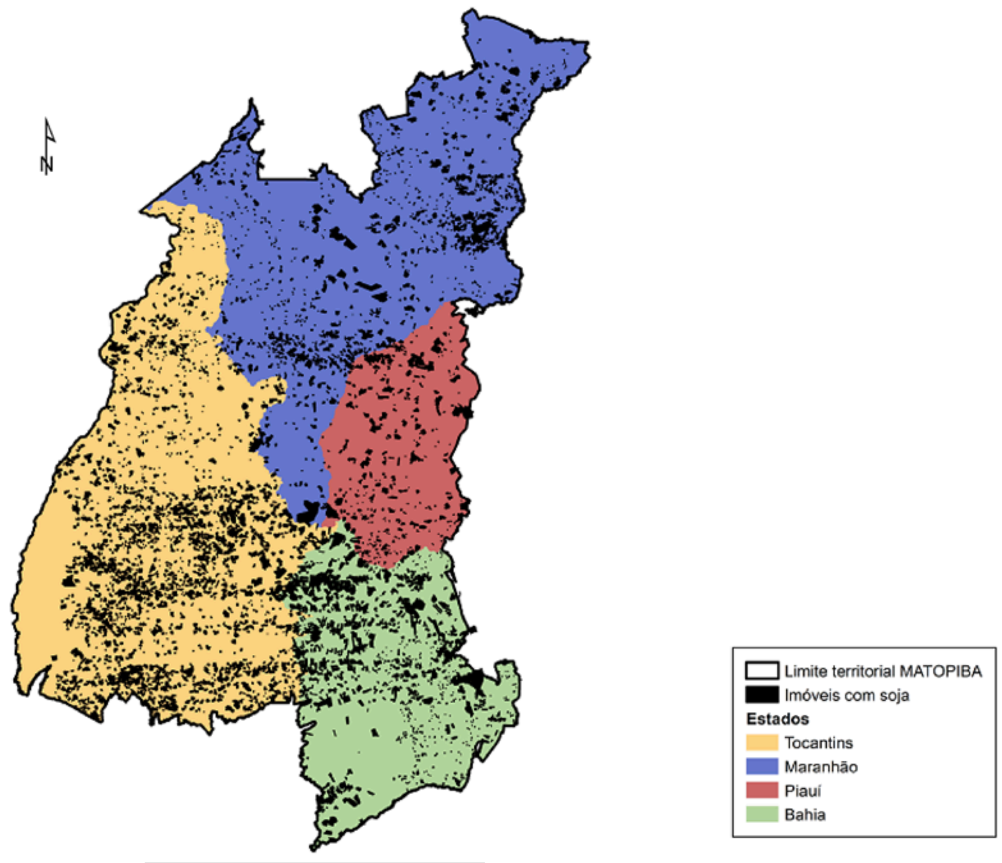
Models of changes in land use and management (which imply new values of carbon sequestration or emission by the soil) were used to design different carbon balance scenarios based on land use transitions for the group of farms evaluated **according to the characteristics of each scenario.**

The estimated values of Scope 1 and 2 emissions were used to calculate the 2019/2020 harvest. Each of the four projected scenarios (detailed on page 11) implies land use and management changes with different emission factors.

Soybean properties in MATOPIBA were identified to extrapolate the averages of the results obtained from the baseline and projected scenarios by combining the land network published by IMAFLORA researchers (SPAROVEK et al., 2019) and the 2016/2017 Amazon and Cerrado Biome Soy Maps produced by Agrosatél (AGROSATÉLITE, 2018).

All MATOPIBA properties with at least five hectares of soybean were selected after overlapping the two layers. This filter was used to avoid polluted results, which could occur due to the scale difference between the bases. After this step, the estimated values of carbon balances from the baseline and the scenarios were applied to all the identified soy properties in MATOPIBA. The project field data were used as a primary source of information, extracting the amount emitted per hectare for the farms analyzed.

SOYBEAN-PRODUCING FARMS IN MATOPIBA



Source: Maps produced by IMAFLORA in partnership with Solidaridad

3.

Results

The results of the estimates of carbon emissions, carbon stocks in the native vegetation biomass, and the carbon balance of the farms evaluated in the MATOPIBA states are presented below. Given the characterization of the evaluated farms, a weighted average was used for the aggregated values, considering the agricultural areas and estimates obtained.

CARBON EMISSIONS AND SEQUESTRATION

MARANHÃO

9 farms

The estimate of carbon emissions from nine farms in Maranhão was **39,848.72 tCO_2e/year in the 2019/2020 harvest**, 64.5% by liming and gypsum application. Nitrogen fertilizers contributed to 24.5% of total emissions, 52.3% from urea application, and 30.4% from indirect emissions. Lastly, 17.3% were from direct emissions from nitrogen fertilizer application.

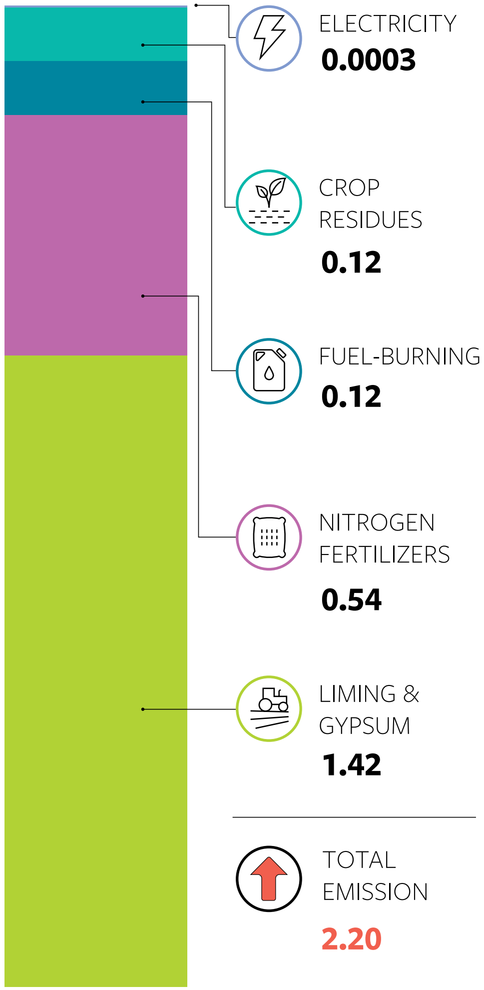
Emissions from the decomposition of crop residues, fossil fuels in mechanized operations, and electricity consumption contributed 5.5%, 5.4%, and 0.02%, respectively.

The Maranhão farms' average per-area carbon emissions were 2.20 tCO_2e/ha/year and 0.0389 tCO_2e/bag/year of soybean produced in the 2019/2020 harvest.

Considering the carbon sequestration by the soil of the areas that adopted NTS practices, the average carbon balance per estimated area was 0.51 tCO_2e/ha/year emitted, with a **per-bag carbon balance of 0.0083 tCO_2e/bag/year**. That accumulation of carbon in the soil **offset 76.7% of carbon emissions, with a per-area sequestration rate of -1.68 tCO_2e/ha/year.**

Carbon emission

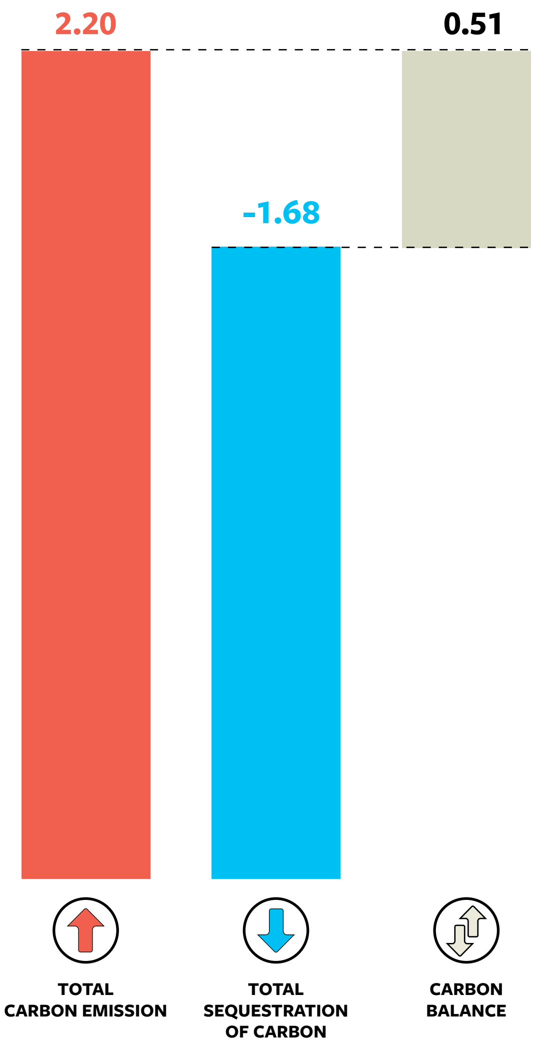
(tCO_2e/ha/year)



LIMING AND GYPSUM CORRESPOND TO
64.5%

Carbon balance

(tCO_2e/ha/year)



CARBON EMISSIONS AND SEQUESTRATION

TOCANTINS — TO

15 farms

The nine farms in Tocantins had estimated carbon emissions of **22,179.05 tCO_2e/year in the 2019/2020 harvest**, 55.8% by liming and gypsum application. Nitrogen fertilizers contributed to 31.2% of total emissions, 62.1% from urea application, and 30.7% from indirect emissions,

with leaching and/or surface runoff accounting for 17% and volatilization and subsequent atmospheric deposition for 13.8%. Lastly, 7.1% were from direct emissions from nitrogen fertilizer application.

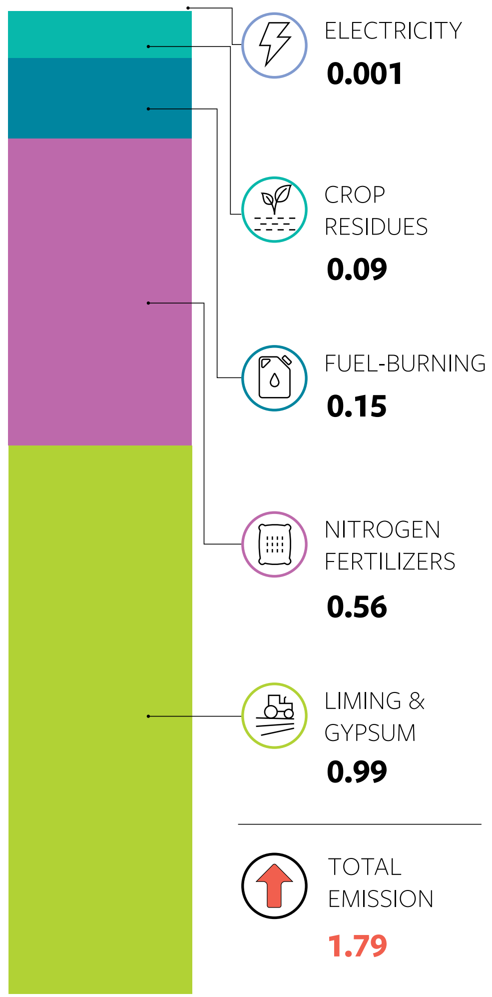
Emissions from burning fossil fuels in mechanized operations, from the decomposition ofcrop residues, and from the consumption of electricity contributed 8.2%, 4.8%, and 0.04%, respectively.

The Tocantins farms' average per-area carbon emissions were 1.79 tCO_2e/ha/year and 0.0321 tCO_2e/bag/year of soybean produced in the 2019/2020 harvest.

Considering the carbon sequestration by the soil of the areas that adopted NTS practices, **the estimated average per-area carbon balance was 0.39 tCO_2e/ha/year emitted, with a per-bag carbon balance of 0.0076 tCO_2e/bag/year.** That carbon accumulation in the soil offsets only 78.4% of carbon emissions, with a per-area sequestration rate of -1.40 tCO_2e/ha/year. The estimated emissions were higher than the sequestration.

Carbon emission

(tCO_2e/ha/year)

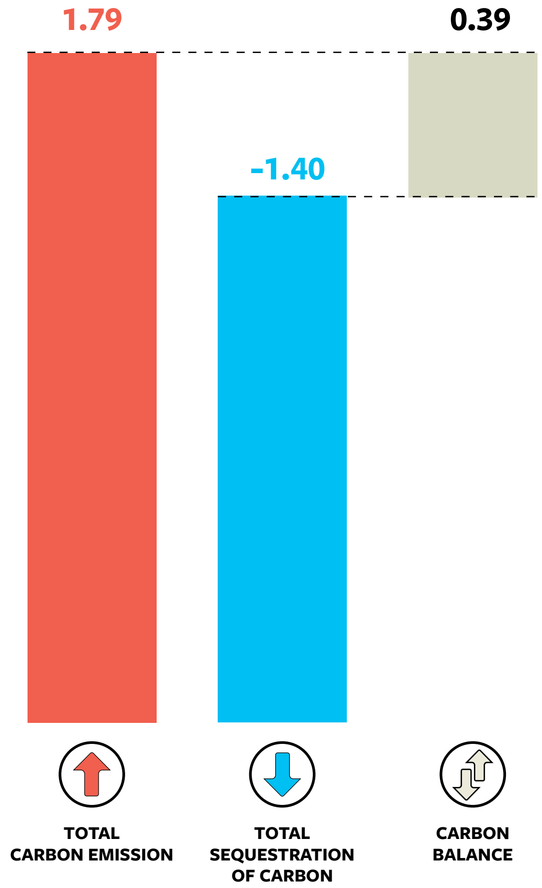


LIMING AND GYPSUM CORRESPOND TO

55.8%

Carbon balance

(tCO_2e/ha/year)



CARBON EMISSIONS AND SEQUESTRATION

PIAUÍ

6 farms

The six farms in Piauí had estimated carbon emissions of **23,734.90 tCO_2e/year in the 2019/2020 harvest**, 54.4% by burning fuel, and 21.1% by liming and gypsum application.

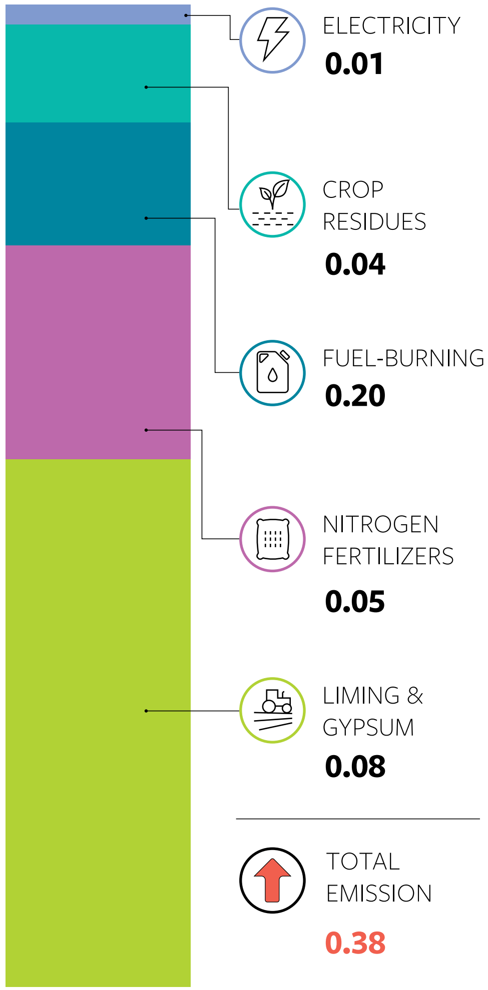
Nitrogen fertilizers contributed to 12.7% of total emissions, 69% from urea application, and 31% from indirect emissions, with leaching and/or surface runoff at 16.9% and volatilization and subsequent atmospheric deposition at 14.1%. Emissions from the decomposition of crop residues and electricity consumption contributed 9.5% and 1.4%, respectively.

The Piauí farms' average per-area carbon emissions were 0.38 tCO_2e/ha/year and 0.0077 tCO_2e/bag/year of soybean produced in the 2019/2020 harvest.

Considering the carbon sequestration by the soil of the areas that adopted NTS practices, **the estimated average per-area carbon balance was -1.30 tCO_2e/ha/year sequestered, with a per-bag carbon balance of -0.0278 tCO_2e/bag/year**. That carbon accumulation in the soil **offset 445% of carbon emissions, with a per-area sequestration rate of -1.67 tCO_2e/ha/ year.**

Carbon emission

(tCO_2e/ha/year)

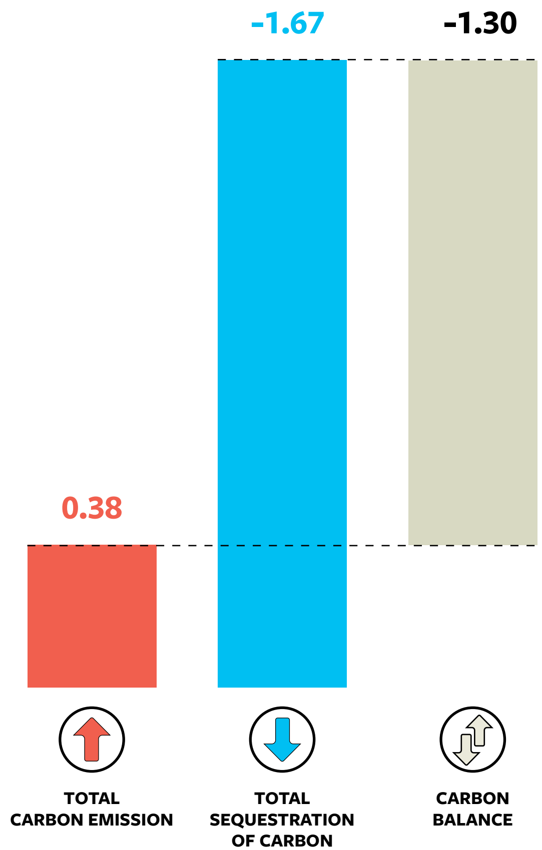


LIMING AND GYPSUM CORRESPOND TO

54.4%

Carbon balance

(tCO_2e/ha/year)



CARBON EMISSIONS AND SEQUESTRATION

BAHIA

20 farms

The 20 farms in Bahia had an estimated carbon emission of **64,813.23 tCO_2e/year in the 2019/2020 harvest**. About 62% were caused by liming and gypsum application. Nitrogen fertilizers contributed to 19.5% in the soybean and double crop. Of this total, 65% were caused by urea application, and 30.8% came from indirect emissions (leaching and/or surface runoff accounting for 16.9% and 13.9% by volatilization and subsequent atmospheric deposition).

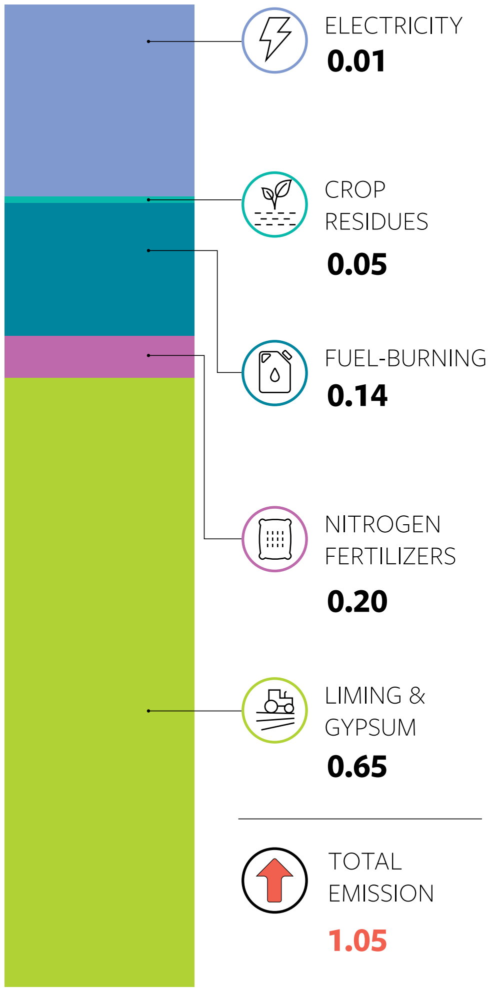
Emissions from burning fossil fuels in mechanized operations, decomposition ofcrop residues, and electricity consumption contributed 13.6%, 4.3%, and 0.6%, respectively.

The Bahia farms had average carbon emissions of 1.05 tCO_2e/ha/year and 0.0149 tCO_2e/bag/year.

Considering the carbon sequestration by the soil of the areas that adopted NTS practices, the **estimated average per-area carbon balance was -0.39 tCO_2e/ha/year sequestered, with a per-bag carbon balance of -0.006 tCO_2e/bag/year.** That carbon accumulation in the soil **offset 137.5% of carbon emissions, with a per-area sequestration rate of -1.45 tCO_2e/ha/year.**

Carbon emission

(tCO_2e/ha/year)

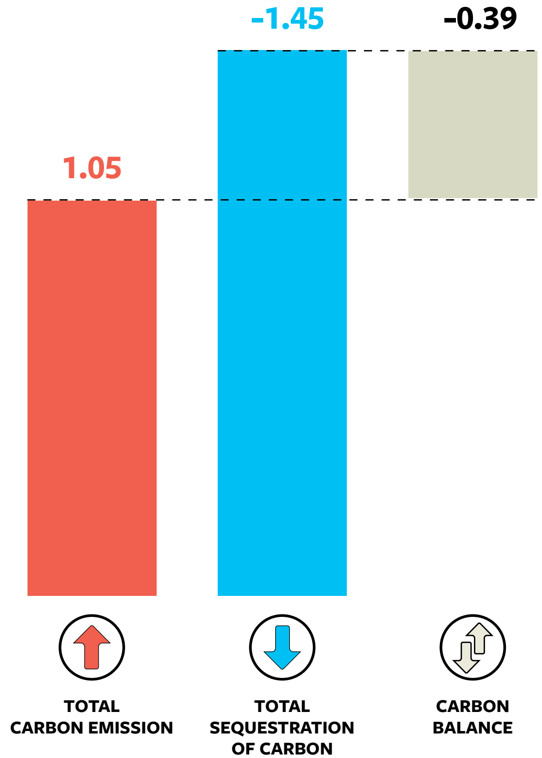


LIMING AND GYPSUM CORRESPOND TO

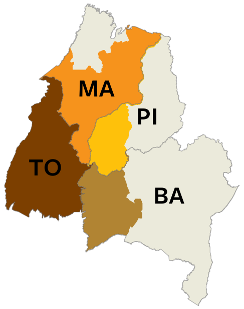
62%

Carbon balance

(tCO_2e/ha/year)



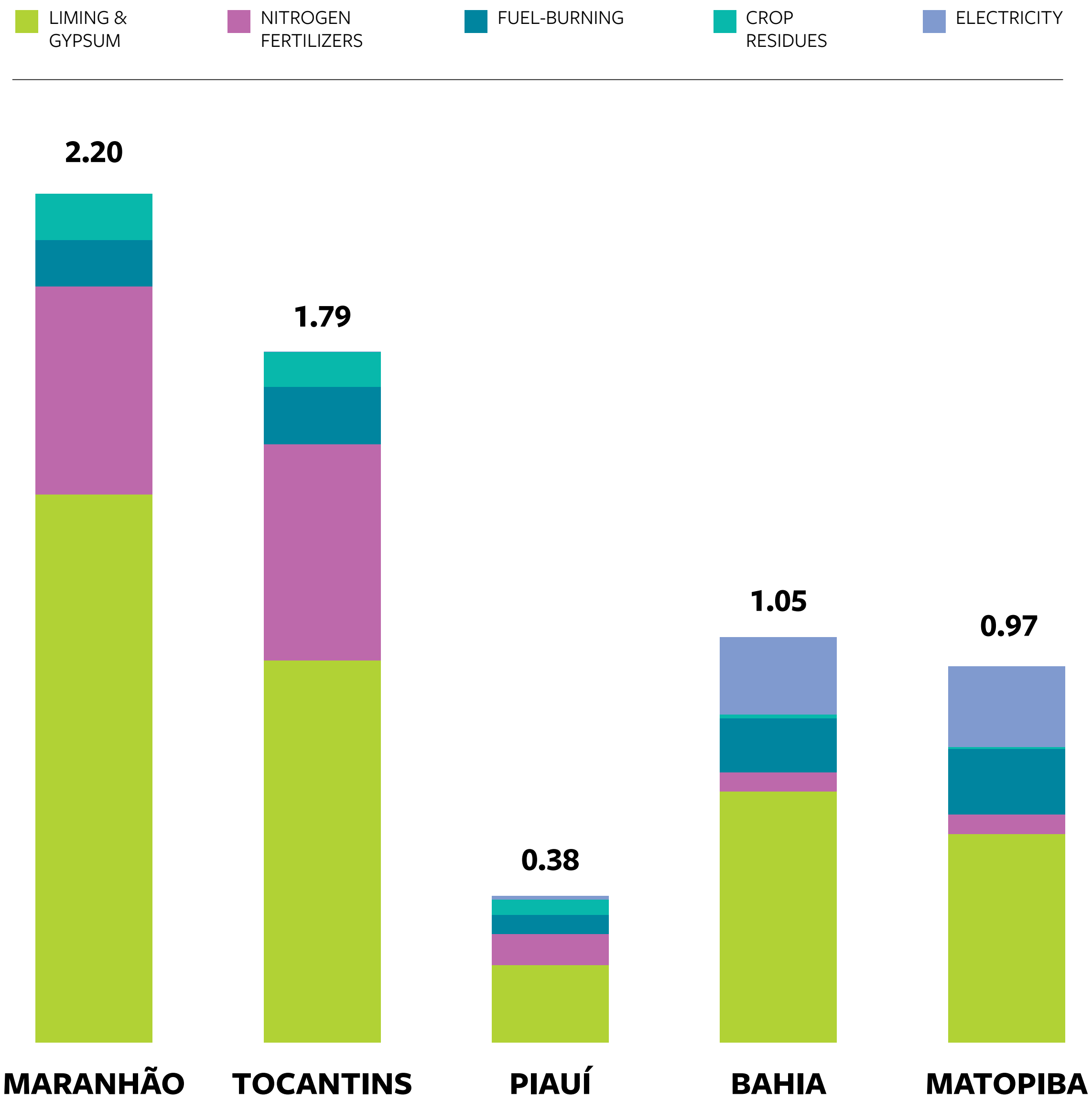
CARBON EMISSIONS AND SEQUESTRATION



MATOPIBA

The estimated total of Scope 1 and 2 carbon emissions from the 50 farms assessed in the MATOPIBA region resulted in 150,575.90 tCO_2e/year in the 2019/2020 harvest. The graph to the side shows the total emissions from each group of farms in each state and the aggregated total for the region.

Total carbon emission
(tCO_2e/ha/year)



- Approximately 50.5% of the total emissions from the MATOPIBA region came from using agricultural soil conditioners due to frequent, focused liming and gypsum application.

- The second-largest source of emission was nitrogen fertilizer application, which contributed to 21.5% of total emissions, with 60.9% originating from urea application, 30.7% from indirect emissions, 17% from leaching and/or surface runoff, and 13.7% from volatilization and subsequent atmospheric deposition of N in the forms of NH4 and NOX. The use of these inputs is more associated with double crop harvests. Lastly, 8.4% corresponds to direct emissions from different nitrogen fertilizer applications, accounting for the amount applied in soybean and second-crop areas.

- The other sources of emissions from farms were the use of fuels in agricultural operations (17%), decomposition of crop residues (5.5%), and electricity consumption (0.5%).

The total area analyzed with soybean cultivation was 155,453 ha. The area destined for double cropping was 38,653 ha (75.1% smaller than the soybean area). Soybean productivity was 58 bags/ha/year (3.5 ton/ha/year), while the second-crop productivity was 98 bags/ha/year (5.9 ton/ha/year).

Considering the balance of soil emissions between farms that use NTS (carbon sequestration) practices and those that still perform CTS (carbon emission) practices, it is possible to estimate a contribution of total soil sequestration of -242,660.63 tCO_2e/year, offsetting 161.2% of the estimated Scope 1 and 2 emissions, and an emission balance of -92,085.73 tCO_2e/year.

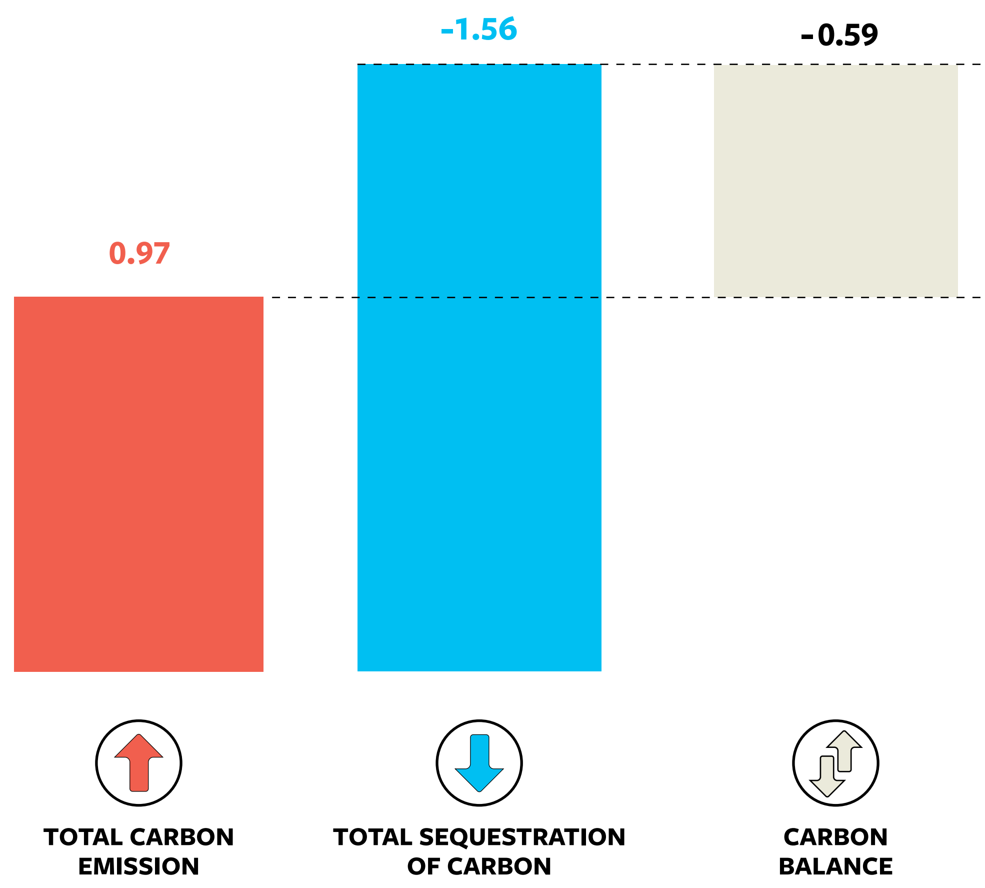
The figure on the right shows the emission sources of Scopes 1 and 2, as well as the soil-promoted carbon sequestration.

The 50 MATOPIBA farms' average per-area carbon emissions were 0.97 tCO_2e/ha/year and 0.02 tCO_2e/bag/year (0.27 tCO2e/ton/year) of soybean produced in the 2019/2020 harvest.

Considering the aggregate net emissions of all farms evaluated, the per-area carbon balance was -0.59 tCO_2e/ha/year and -0.01 tCO_2e/bag/year (-0.20 tCO_2e/ton/year) of soy produced, presenting an average per-area sequestration of -1.56 tCO_2e/ha/year.

AVERAGE CARBON BALANCE IN MATOPIBA

(tCO2e/ha)



3.1.

Carbon stocks in native vegetation

All farms assessed are located in the Cerrado biome, and the areas of native vegetation contained within the Legal Reserve (LR) were accounted for to measure the carbon stock, as well as on farms with a Permanent Preservation Area (PPA) and areas with a forest surplus.

The carbon stocks in the native vegetation areas of the farms assessed in the MATOPIBA region were estimated at 3,059,577 tC.

	AREA WITH NATIVE VEGETATION (ha)	CARBON STOCK (tC)
MARANHÃO	9,868	326,050
TOCANTINS	7,905	330,322
PIAUÍ	45,292	1,315,457
BAHIA	36,654	1,087,741
MATOPIBA	99,720	3,059,577

3.2.

Carbon balance scenarios designed with different land use changes

Additionality, values were used with land use and management changes to design carbon balance scenarios for the farms based on the change in land use defined by the project, which implies new values of carbon sequestration or emission, according to the characteristics of each one.

SCENARIOS FOR CARBON BALANCE ANALYSIS

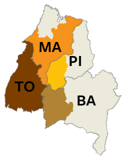
Scenarios	tCO_2e/ha/year
SCENARIO I Cerrado for conventional tillage system	**Emission Factor** **0.9167**
SCENARIO II Cerrado for no-tillage system	**Sequestration Factor** **-0.44**
SCENARIO III Degraded pasture for no-tillage system	**Sequestration Factor** **-0.6967**
SCENARIO IV Conventional tillage system for no-tillage system	**Sequestration Factor** **-1.76**

The estimated values of Scope 1 and 2 emissions were used to calculate the 2019/2020 harvest. The table to the left has **the changes in the use and management of the farms' productive soil for the four scenarios and the soil emission or sequestration of each projected system**. The values presented consider only the increase of carbon in the soil of the areas, not considering other carbon reservoirs, such as above-ground biomass and native vegetation.

Each scenario was applied to the 50 farms, allowing the changes in terms of the carbon balance for each one, the state that each group represents, and the regional territorial scope of MATOPIBA in which they are located to be understood and compared with the baseline scenario values.

The table on the next page shows the carbon balance values for the 2019/2020 harvest (tCO_2e/year), per area (tCO_2e/ha/year), and per bag of soybeans produced (tCO_2e/bag/year) for the states and for the assessed region of MATOPIBA.

CARBON BALANCE BY YEAR, AREA, AND BAG OF SOYBEAN PRODUCED FOR THE PROJECTED SCENARIOS

Farms	Carbon balance	Baseline	Scenario I	Scenario II	Scenario III	Scenario IV
 MARANHÃO	**Per year** (tCO_2e/year)	-24,283.79	121,325.32	37,688.40	21,863.54	-43,686.06
	Per area (tCO_2e/ha/year)	-0.39	1.97	0.61	0.35	-0.71
	Per bag (tCO_2e/bag/year)	-0.0062	0.0284	0.0085	0.0047	-0.0110
 TOCANTINS	**Per year** (tCO_2e/year)	9,288.53	56,480.41	31,865.80	27,208.49	7,917.04
	Per area (tCO_2e/hayear)	0.51	3.11	1.76	1.50	0.44
	Per bag (tCO_2e/bag/year)	0.0083	0.0554	0.0309	0.0263	0.0071
 PIAUÍ	**Per year** (tCO_2e/year)	-81,890.95	81,679.96	-4,077.71	-20,303.85	-87,515.56
	Per area (tCO_2e/ha/year)	-1.30	1.29	-0.06	-0.32	-1.38
	Per bag (tCO_2e/bag/year)	-0.0278	0.0271	-0.0017	-0.0072	-0.0298
 BAHIA	**Per year** (tCO_2e/year)	4,801.48	33,593.80	16,700.17	13,503.74	263.53
	Per area (tCO_2e/ha/year)	0.39	2.70	1.34	1.08	0.02
	Per bag (tCO_2e/bag/year)	0.01	0.0487	0.0242	0.0196	0.0004
 MATOPIBA	**Per year** (tCO_2e/year)	-92,084.73	293,079.49	82,176.66	42,271.93	-123,021.05
	Per area (tCO_2e/ha/year)	-0.59	1.89	0.53	0.27	-0.79
	Per bag (tCO_2e/bag/year)	-0.0122	0.0327	0.0082	0.0036	-0.0156

By grouping the values of the scenarios of the 50 farms using a weighted average, the scenarios presented a variation for the carbon balance by area of **1.89 tCO_2e/ha/year to -0.79 tCO_2e/ha/year**, for Scenarios I and IV, respectively. Concerning the baseline value, -0.59 tCO_2e/ha/year, Scenario IV showed an increase in sequestration of approximately 33.6%, while Scenario I showed a 418.3% increase in emissions. The same occurs for Scenarios II and III, with the balance indicating an increase in emissions of 189.2% and 145.9%, respectively.

The trend is the same for the states: only Scenario IV presents a sequestration rate higher than the baseline, and the other scenarios start to emit more carbon.

After identifying the properties with soybeans eligible for extrapolations with the values of the estimates of the baseline carbon balances and scenarios, which scenarios have the potential for greater mitigation of emissions can be better understood.

Before extrapolating, we sought to correlate each farm's characteristics and the values of the carbon balances and identify which information collected on the farms could be inferred for the MATOPIBA eligible soybean farms based on remote sensing and geoprocessing. For example, the soil type was part of the information collected in the field that could be collected for all farms by crossing a soil map with the boundaries of the properties. How additional factors influenced the balances was also verified, such as the form of cultivation.

Several correlations were tested, and a correlation between the carbon balances and the characteristics of the farms that could be surveyed by remote sensing and/or geoprocessing could not be observed. **The carbon balances were significantly more correlated with management and cultivation practices than with a farm's biophysical characteristics, so the initial approach had to be modified.**

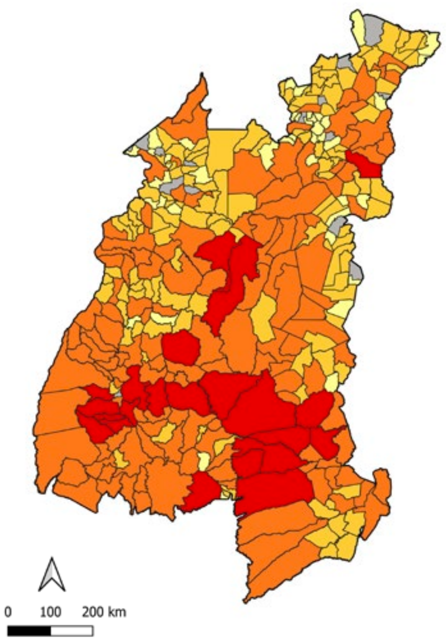
It was therefore decided that the values of the baseline and scenarios used in the project would be extrapolated with data from all the farms assessed to the MATOPIBA soybean farms, assuming that they all have the same behavior in terms of per-hectare carbon balance within each scenario. With all agents presenting similar behavior in this approach, extreme results can be interpreted as maximum and minimum potentials concerning the analyzed carbon balances.

The averages of the carbon balances of the farms in each scenario and the baseline average were calculated to apply this approach, resulting in five distinct variations for all of MATOPIBA.

Applying the average of the values obtained from the carbon balances (tCO_2e/ha/year) in each scenario to the soybean planting areas allowed a total balance value for each property in the region to be obtained and, then, total that value for all of MATOPIBA.

TOTAL EMISSIONS FROM MATOPIBA FOR PROJECT ANALYSIS SCENARIOS

BASE



CARBON BALANCE

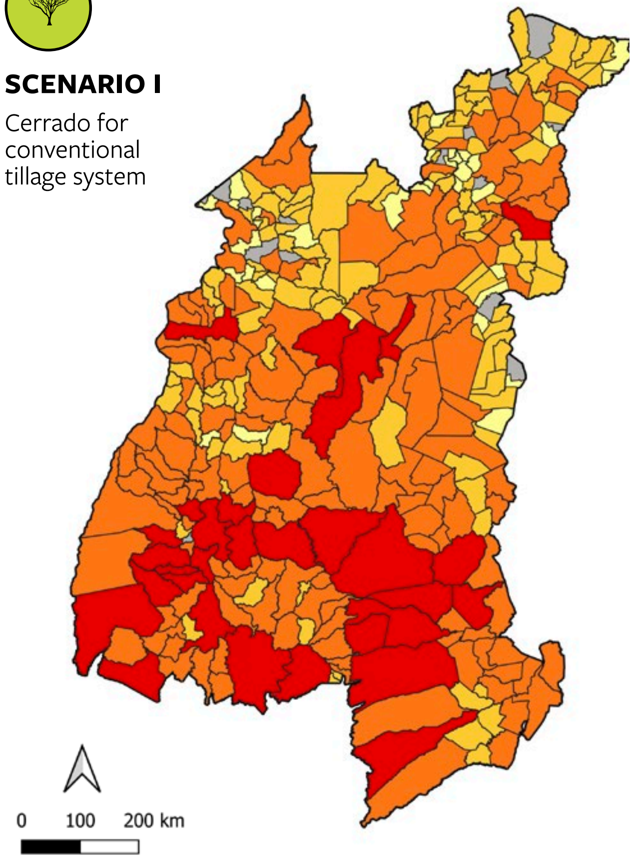
4,323,331
(tCO_2e/year)

LEGEND

Limite MATOPIBA
Emissão (ton Co2e)
-21474 - 0
0 - 500
500 - 5000
5000 - 50000
50000 - 400000
Sem informação

SCENARIO I

Cerrado for conventional tillage system



CARBON BALANCE

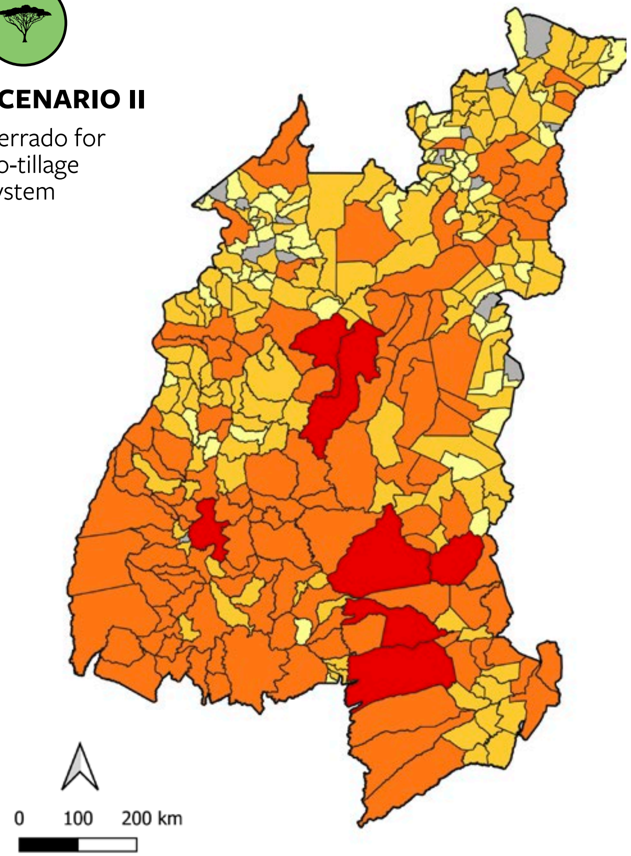
5,754,797
(tCO_2e/year)

VARIATION TO BASE SCENARIO

33%

SCENARIO II

Cerrado for no-tillage system



CARBON BALANCE

2,656,682
(tCO_2e/year)

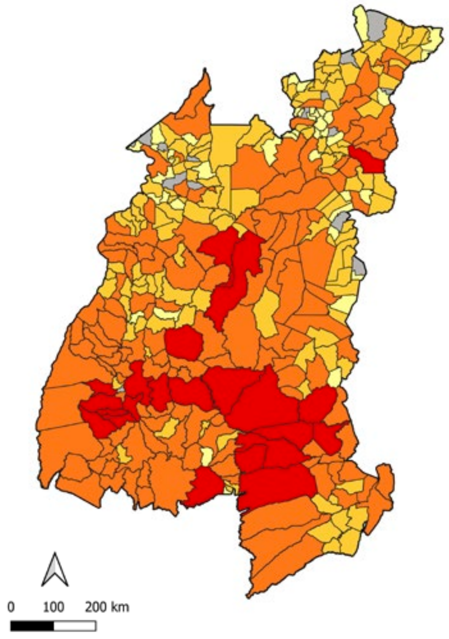
VARIATION TO BASE SCENARIO

-39%

Source: Maps produced by Imaflora in partnership with Solidaridad

TOTAL EMISSIONS FROM MATOPIBA FOR PROJECT ANALYSIS SCENARIOS

BASE



BALANÇO DE CARBONO

4,323,331
(tCO_2e/year)

LEGENDA

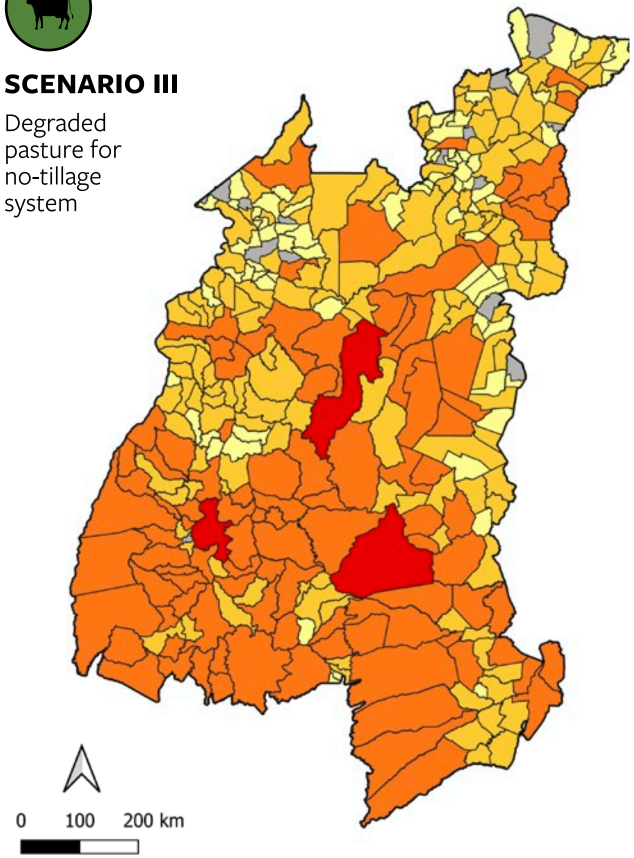
Limite MATOPIBA

Emissão (ton Co2e)

- -21474 - 0
- 0 - 500
- 500 - 5000
- 5000 - 50000
- 50000 - 400000
- Sem informação

SCENARIO III

Degraded pasture for no-tillage system



CARBON BALANCE

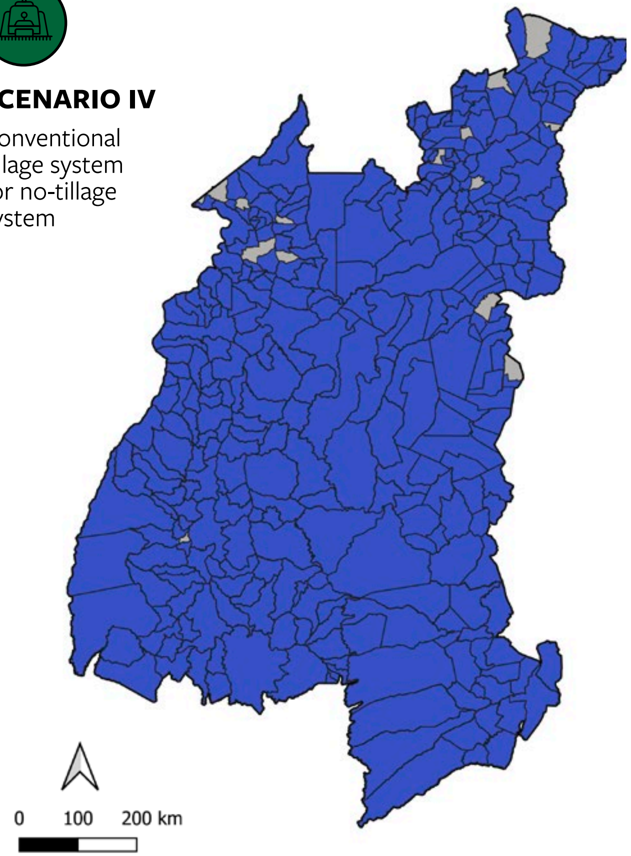
2,070,490
(tCO_2e/year)

VARIATION TO BASE SCENARIO

-52%

SCENARIO IV

Conventional tillage system for no-tillage system



CARBON BALANCE

-357,627
(tCO_2e/year)

VARIATION TO BASE SCENARIO

-108%

Source: Maps produced by Imaflora in partnership with Solidaridad

As expected, the values obtained indicate a contribution to carbon sequestration at increasing rates. Scenarios II and III consider land use and management changes with greater capacity to reduce emissions. Scenario IV, on the other hand, assigns a higher carbon sequestration factor to all cultivated areas due to generalized NTS conservation practices.

When comparing these scenarios, **note how many emissions can be mitigated by adopting an NTS, indicating the role is fundamental to encourage the adoption, maintenance, and expansion of such practices among the different production systems of grains and other cultures in the region.** The result benefits emissions and promotes more resilient systems by adaptation, even when faced with the productive challenges of the climate crisis. The losses of carbon stocks above and below the ground of native vegetation due to the conversion of their areas must be considered, as demonstrated in the average stock that many farms still have. **Any effort to increase carbon sequestration by the productive area can be easily lost if the transition is from an area with native vegetation.**

Deeper projections are recommended to better understand the impact on emissions from using NTS on MATOPIBA farms. Scenario IV extrapolated to the entire region indicates a reduction potential of approximately **-357.6 thousand tCO_2e/year, equivalent to a 0.06% abatement of national emissions from the agricultural sector in 2020, which was 567.7 million tCO_2e/year (GWP-AR5)** (SEEG, 2021).

Thus, analyses such as these indicate ways for rural producers to reduce the environmental impacts generated by their activities when information is provided so that the decisions taken are guided by local and global priorities (POORE et al., 2018). However, they also indicate the need for further investigation to lessen some assumptions made in this study and minimize the uncertainties about the emission factors used.

4.

Conclusions

The average carbon emission of the farms analyzed was 0.97 tCO_2e/ha/year. The use of agricultural correctives was the main source of emission. Liming and gypsum application, which represented about 55.5% of the total emitted, were followed by the use of nitrogen fertilizers (21.5%), burning of fuels (17%), decomposition of crop residues from soybeans and the second harvest (5.5%), and electricity consumption (0.5%).

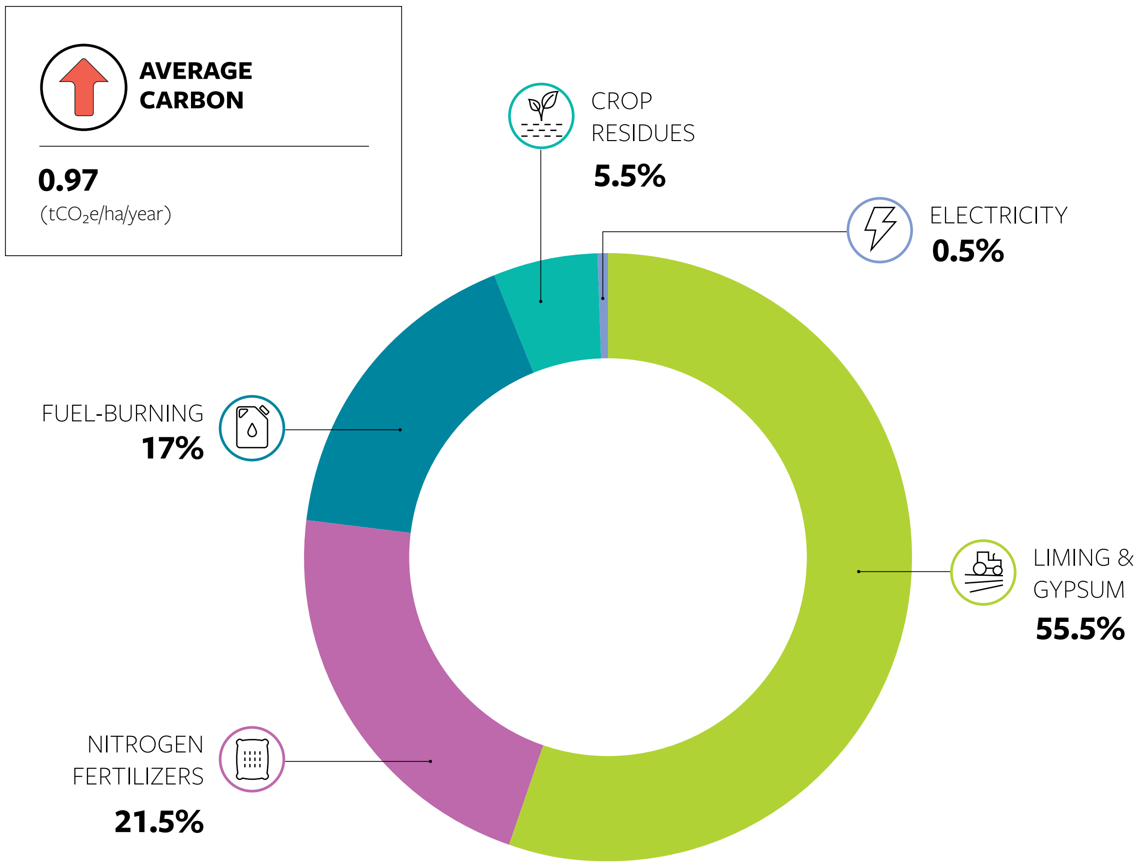
Therefore, considering the emissions by area of Scopes 1 and 2, the main sources of emissions came from agricultural inputs, which accounted for 76.9% of the total emissions in the group of farms.

On the other hand, soil carbon sequestration offset 161.2% of those emissions, removing carbon at an average rate of -1.56 tCO_2e/ha/year. The average carbon balance of the 50 soy farms in the MATOPIBA region was -0.59 tCO_2e/ha/year, with each bag of soy produced having a sequestration of -0.0122 tCO_2e/bag/year (0.2034 tCO_2e/ton/year).

Concerning carbon balances, the group of farms in Piauí presented the highest carbon sequestration contribution with -1.30 tCO_2e/ha/year.

The farms in Maranhão had the highest emission from liming and gypsum application, with 1.42 tCO_2e/ha/year, followed by Tocantins (0.99 tCO2e/ha/year), Bahia (0.65 tCO_2e/ha/year), and Piauí (0.08 tCO_2e/ha/year). Except for farms in Piauí, that was the largest source of emission.

SOURCES OF CARBON EMISSIONS IN THE EVALUATED FARMS



Concerning carbon balances, the group of farms in Piauí presented the highest carbon sequestration contribution with -1.30 tCO_2e/ha/year.

The farms in Maranhão had the highest emission from liming and gypsum application:

LIMING & GYPSUM	tCO_2e/ha/year
MARANHÃO	1.42
TOCANTINS	0.99
BAHIA	0.65
PIAUÍ	0.08

Regarding the use of nitrogen fertilizers, those from Tocantins emitted the most:

NITROGEN FERTILIZERS	tCO_2e/ha/year
TOCANTINS	0.56
MARANHÃO	0.54
BAHIA	0.20
PIAUÍ	0.05

As the **third-most emitting source in the region, due to the burning of fuels, the farms in Piauí emitted the most** concerning the productive area (0.20 tCO_2e/ha/year), also being the champions in terms of gross emissions (12,899.96 tCO_2e/year).

Other sources of carbon emissions, such as crop residues and electricity use, accounted for 6.1% of the rest of the total gross emissions of the entire region assessed. They are also important emission sources to consider from a strategic perspective of mitigation. However, without the same reduction weight compared with the most representative emitting sources.

Characterizing these emission and sequestration sources by farm and by region is the first step to identifying opportunities for mitigating carbon emissions. Thus, the aim is to maintain and increase the productivity presented through the efficient use of these inputs and considering circumstances that really justify their adoption in the producers' set of practices.

A better understanding of other land use and management practices in the region makes it possible to make decisions to foster more resilient production systems in the climate context, with a view to

reduced dependence on resources for production. For example, farms that use irrigation produced 24.3% more soy per area than those that used rain-fed systems. However, carbon balances indicate that they emit more per area and per bag of soybeans produced. The use of irrigation also favors the second-crop cultivation, another source of income for producers. However, irrigation should be a practice adopted to conserve natural resources in very specific cases and with great caution, guided by robust public policies.

Another example is carbon sequestration by the soil. The effects of the use of NTS management practices by the vast majority of producers contributed to the soil sequestering carbon for all groups of farms, ranging from -1.40 tCO_2e/ha/year in Tocantins to -1.68 tCO_2e/ha/year in Maranhão.

The expansion and continuity of these good practices in line with what is recommended as NTS enable the continuity

BETTER UNDERSTANDING THE OTHER **LAND MANAGEMENT AND USE PRACTICES** IN THE REGION MAKES IT POSSIBLE TO MAKE DECISIONS THAT **FOSTER PRODUCTION SYSTEMS MORE RESILIENT IN THE CLIMATE CONTEXT**, AIMING TO REDUCE DEPENDENCE ON RESOURCES FOR PRODUCTION of soil-promoted sequestration. This is what Scenario IV indicates, stipulated with broader NTS practices disseminated to all the producers assessed, arriving at a carbon balance per area that removes about 33.6% more than the base scenario.

Continuing to monitor the carbon balance, especially the soil's ability to sequester carbon, is recommended to strengthen this evidence. As such, the correlation between management decisions and the balance is identified over time with greater precision, seeking to positively influence other actors in the sector and in the region to incorporate these practices. Given the sustainability differential, the market can help broaden the adoption of these practices and benefit from financial arrangements based on currently existing carbon indicators. It also endorses the importance of intensifying sustainable production so that the demand for agricultural products is met without incorporating new areas of vegetation into production, which implies an increase in emissions, according to Scenario I. Conserving this native vegetation contributes significantly to maintaining or increasing carbon stocks in the farms' productive areas, and provides other socio-environmental benefits.

This study indicates the possibilities of developing and applying methodologies that meet the demands of the productive profiles of the different sizes of producing farms in the MATOPIBA region. We seek to reconcile increased productivity with systems that are more adapted and resilient to the climate crisis, contributing to low-emission production.

REFERENCES

■ ALVARES, Clayton Alcarde et al. Köppen's climate classification map for Brazil. Meteorologische Zeitschrift, [S.L.], v. 22, n. 6, p. 711-728, 1 dez. 2013. Schweizerbart. http://dx.doi.org/10.1127/0941-2948/2013/0507.

■ ANDREWS, Mitchell et al. Nitrogen fixation in legumes and actinorhizal plants in natural ecosystems: values obtained using15n natural abundance. Plant Ecology & Diversity, [S.L.], v. 4, n. 2-3, p. 131-140, jun. 2011. Informa UK Limited. http://dx.doi.org/10.1080/17550874.2011.644343.

■ BERNOUX, Martial et al. Cropping systems, carbon sequestration and erosion in Brazil: a review. In: Sustainable Agriculture. Springer, Dordrecht, 2009. p. 75-85.

■ BORTOLON, Elisandra Solange Oliveira et al. Simulação da dinâmica do carbono e nitrogênio em um Argissolo do Rio Grande do Sul usando modelo Century. Revista Brasileira de Ciência do Solo, v. 33, p. 1635-1646, 2009.

■ BRASIL, 2006. MINISTÉRIO DA CIÊNCIA E TECNOLOGIA. COORDENAÇÃO-GERAL DE MUDANÇAS GLOBAIS DE CLIMA. Primeiro Inventário Brasileiro de Emissões Antrópicas de Gases de Efeito Estufa. Relatórios de Referência. Emissões e Remoções de Dióxido de Carbono por Conversão de Florestas e Abandono de Terras Cultivadas. Brasília: Ministério da Ciência e Tecnologia, 2006.

■ BRASIL, 2010. MINISTÉRIO DA CIÊNCIA E TECNOLOGIA. COORDENAÇÃO-GERAL DE MUDANÇAS GLOBAIS DE CLIMA. Emissões de óxido nitroso de solos agrícolas e de manejo de dejetos (Segundo inventário brasileiro de emissões antrópicas de gases de efeito estufa – Relatório de Referência). Coordenação Geral de Mudanças Globais, Ministério da Ciência e Tecnologia, Brasília, DF, Brasil, 106 pp. 2010.

■ BRASIL, 2015. Pretendida Contribuição Nacionalmente Determinada Para Consecução Do Objetivo Da Convenção-Quadro Das Nações Unidas Sobre Mudança Do Clima, 2015. http://www.itamaraty.gov.br/images/ed_desenvsust/BRASIL-iNDC-portugues.pdf.

■ BRASIL, 2016. MINISTÉRIO DA CIÊNCIA E TECNOLOGIA. COORDENAÇÃO-GERAL DE MUDANÇAS GLOBAIS DE CLIMA. Terceiro inventário de emissões anuais de gases de efeito estufa no Brasil. Ministério da Ciência, Tecnologia e Inovação. Secretaria de Políticas e Programas de Pesquisa e Desenvolvimento. Brasília: MCTIC. 2016.

■ BRASIL, 2020a. MINISTÉRIO DA CIÊNCIA E TECNOLOGIA. COORDENAÇÃO-GERAL DE MUDANÇAS GLOBAIS DE CLIMA. Fatores de Emissão de CO2 para utilizações que necessitam do fator médio de emissão do Sistema Interligado Nacional do Brasil, como, por exemplo, inventários corporativos, 2020.

■ BRASIL, 2020b. MINISTÉRIO DA CIÊNCIA E TECNOLOGIA. COORDENAÇÃO-GERAL DE MUDANÇAS GLOBAIS DE CLIMA. Quarta Comunicação Nacional do Brasil à Convenção-Quadro das Nações Unidas sobre Mudança do Clima. Brasília, Brasília: Ministério da Ciência e Tecnologia, 2020.

■ BRASIL, 2021. MAPA. Plano Setorial para Adaptação à Mudança do Clima e Baixa Emissão de Carbono na Agropecuária 2020-2030: plano operacional. Brasília: Mapa, 2021. 136 p.

■ CARVALHO, J.L.N. et al. Carbon sequestration inmcti agricultural soils in the Cerrado region of the Brazilian Amazon. Soil And Tillage Research, [S.L.], v. 103, n. 2, p. 342-349, maio 2009. Elsevier BV. http://dx.doi.org/10.1016/j.still.2008.10.022.

■ CERRI, Carlos EP; FEIGL, B.; CERRI, Carlos Clemente. Dinâmica da matéria orgânica do solo na Amazônia. SANTOS, G. de A.; SILVA, LS da; CANELLAS, LP, p. 325-358, 2008.

■ CONAB. Acompanhamento da Safra Brasileira. 20121. Available at: https://www.conab.gov.br/info-agro/safras. Retrieved in 09/2021.

■ COSTA, André da et al. Propriedades físicas do solo em sistemas de manejo na integração agricultura-pecuária. Revista Brasileira de Ciência do Solo, [S.L.], v. 33, n. 2, p. 235-244, abr. 2009. FapUNIFESP (SciELO). http://dx.doi.org/10.1590/s0100-06832009000200001.

■ COSTA JUNIOR, C. et al. Assessing soil carbon storage rates under no-tillage: comparing the synchronic and diachronic approaches. Soil And Tillage Research, [S.L.], v. 134, p. 207-212, nov. 2013. Elsevier BV. http://dx.doi.org/10.1016/j.still.2013.08.010.

■ DEFRA. Department for Environment Food and Rural Affairs. The DA GHGI Improvement Programme 2009-2010: EU ETS Task. Available at: <https:// uk-air.defra.gov.uk/assets/documents/reports/cat07/1005251111_DA_ GHGI_Improvement_Report_EUETS_May2010r.pdf>. Retrieved in 12/2021.

REFERENCES

■ DENARDIN, José Eloir et al. Diretrizes do sistema plantio direto no contexto da agricultura conservacionista. Passo Fundo: Embrapa Trigo, v. 15, 2012.

■ FEARNSIDE, P. M. Fogo e emissão de gases de efeito estufa dos ecossistemas florestais da Amazônia brasileira. Estud. av. vol.16 no.44 São Paulo Jan./Apr. 2002. Available at:<http://www.scielo.br/scielo.php?script=sci_arttext&pid=S0103-40142002000100007>. Retrieved in 12/2021.

■ HUNGRIA, M.; NOGUEIRA, M. A.; ARAUJO, R. S. Tecnologia de coinoculação da soja com Bradyrhizobium e Azospirillum: incrementos no rendimento com sustentabilidade e baixo custo. In: Embrapa Soja-Artigo em anais de congresso (ALICE). In: REUNIÃO DE PESQUISA DE SOJA DA REGIÃO CENTRAL DO BRASIL, 33., 2013, Londrina. Resumos expandidos... Brasília, DF: Embrapa, 2013., 2013.

■ INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE – IPCC, 2006. Guidelines for National Greenhouse Gas Inventories. IGES, Hayama, Japan.

■ INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE – IPCC, 2006. IPCC Guidelines for National Greenhouse Gas Inventories, v. 4: Agriculture, Forestry and Other Land Use. Available at: https://www.ipcc-nggip.iges.or.jp/public/2006gl/vol4.html.

■ INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE – IPCC, 2013. Climate Change 2013: The Physical Science Basis.

■ INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE – IPCC, 2014. Intergovernmental Panel on Climate Change. Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Available at: https://www.ipcc.ch/working-group/wg1/

■ INTERGOVERNMENTAL PANEL ON CLIMATE CHANGE – IPCC, 2019. Guidelines for National Greenhouse Gas Inventories – Agriculture, Forestry and Other Land Use In: EGGLESTON,S., BUENDIA, L., MIWA, K., NGARA, T., TANABE, K (Ed.). Hayama: Intergovernmental Panel on Climate Change / IGES, v.4, 2006.

■ JOHNSON, Richard A. et al. Statistics Principles and Methods. 6. ed. John Wiley & Sons, Inc, 2009. 706 p. Available at: https://parsmodir.com/wp-content/uploads/2013/02/bhattacharyya.pdf. Retrieved in 12/2021.

■ LAL, R. Soil processes and the greenhouse effect. In: Methods for assessment of soil degradation Boca Raton: CRC Press, 1998. p. 199-212

■ MAIA, Stoécio Malta Ferreira et al. Contrasting approaches for estimating soil carbon changes in Amazon and Cerrado biomes. Soil And Tillage Research, [S.L.], v. 133, p. 75-84, out. 2013. Elsevier BV. http://dx.doi.org/10.1016/j.still.2013.06.002.

■ MORAES, J.F.L.; VOLKOFF, B.; CERRI, C.C.; BERNOUX, M. Soil properties under Amazon forest and changes due to pasture installation in Rondônia, Brazil. Geoderma, v.70, p.63-81, 1996.

■ PAUSTIAN, K. et al. Management options for reducing CO2 emissions from agricultural soils. Camada arável estoca mais carbono que vegetação e atmosfera Biogeochemistry, v. 48, p. 147-163, 2000.

■ PBGHGP - PROGRAMA BRASILEIRO GHG PROTOCOL. Especificações do Programa Brasileiro GHG Protocol: contabilização, quantificação e publicação de inventários corporativos de emissões de gases de efeito estufa.

■ POORE, Joseph; NEMECEK, Thomas. Reducing food's environmental impacts through producers and consumers. Science, v. 360, n. 6392, p. 987-992, 2018.

■ REIS, Layara Campelo dos et al. Caracterização da variabilidade da precipitação no MATOPIBA, região produtora de soja. Revista Brasileira de Geografia Física, [S.L.], v. 13, n. 4, p. 1425, 11 jun. 2020. Revista Brasileira de Geografia Fisica. http://dx.doi.org/10.26848/rbgf.v13.4.p1425-1441.

■ REIS JUNIOR, F.B. Fixação biológica de nitrogênio: uma revolução na agricultura. In: FALEIRO, F.B.; ANDRADE, S.R.M.; REIS JUNIOR, F.B. dos (Ed.). Biotecnologia: estado da arte e aplicações na agropecuária. Planaltina: Embrapa Cerrados, 2011. Cap. 9. p. 247-281.

■ ROBERTSON, G. Philip et al. Greenhouse Gas Fluxes in Tropical and Temperate Agriculture: the need for a full-cost accounting of global warming potentials. Environment, Development And Sustainability, [S.L.], v. 6, n. 1/2, p. 51-63, 2004. Springer Science and Business Media LLC. http://dx.doi.org/10.1023/b:envi.0000003629.32997.9e.

REFERENCES

- RUDORFF, B.; Risso, J. et al. Análise Geoespacial da Soja no Bioma Amazônia associada com mudança de uso e cobertura do solo e aptidão agrícola: 2000 a 2017. Florianópolis, 2018.

- SILVA, Vanderlei Rodrigues da et al. Variabilidade espacial da resistência do solo à penetração em plantio direto. Ciência Rural, [S.L.], v. 34, n. 2, p. 399-406, abr. 2004. FapUNIFESP (SciELO). http://dx.doi.org/10.1590/s0103-84782004000200010.

- SISTEMA DE ESTIMATIVA DE EMISSÕES DE GASES DE EFEITO ESTUFA - SEEG. Análise da evolução das emissões de GEE no Brasil (1990-2020). Observatório do Clima, 2021.

- SPAROVEK, Gerd, Bastiaan Philip Reydon, Luís Fernando Guedes Pinto, Vinicius Faria, Flavio Luiz Mazzaro de Freitas, Claudia Azevedo-Ramos, Toby Gardner et al. "Who owns Brazilian lands?" Land Use Police 87 (2019): 104062.

- THE GREENHOUSE GAS PROTOCOL – A Corporate Accounting and Reporting Standard, 2008 (Revised Edition). World Resources Institute (WRI) e World Business Council for Sustainable Development (WBCSD).

- UNFCCC (Alemanha). Kyoto Protocol Reference Manual: on accounting of emissions and assigned amount. Bonn, 2008. 130 p. Available at: https://unfccc.int/resource/docs/publications/08_unfccc_kp_ref_manual.pdf. Retrieved in 04/2022.

- USDA. Foreing Agricultural Service: data and analyses. Data and Analyses. 2021. Available at: https://www.fas.usda.gov/data. Retrieved in 09/2021.

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