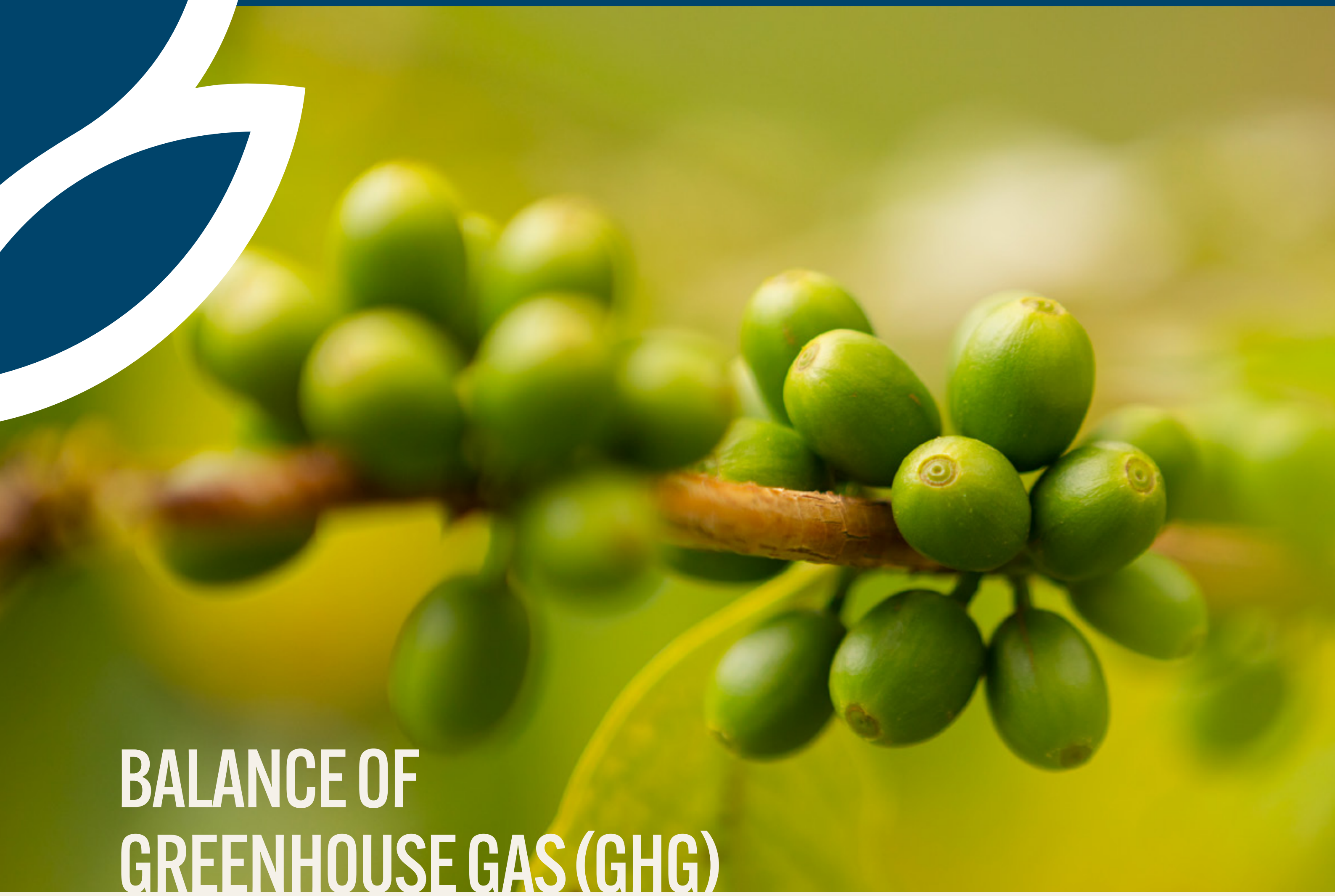
imaflora®



BALANCE OF GREENHOUSE GAS (GHG) EMISSIONS FROM COFFEE PRODUCTION ON DATERRA COFFEE FARMS

INDEX

SUMMARY

This study shows the estimates of the balance of greenhouse gas (GHG) emissions from coffee production on Daterra Coffee farms, located in the municipalities of Franca in São Paulo State and Patrocínio in Minas Gerais State. The GHG emissions of the analysed farms ranged from 3.05 to 3.95 tCO_2e ha^{-1} $year^{-1}$ and averaged 3.09 tCO_2e ha^{-1} $year^{-1}$. The main source of emissions was the use of synthetic nitrogen fertilisers, which accounted for about 45.2% of the total emitted by the farms - followed by soil liming (23,9%), fossil fuel use (23,3%), decomposition of crop pruning waste (7,4%) and electricity (0,2%). However, soil and plant carbon sequestration was able to offset more than 100% of the emissions, resulting in an average emission balance (GHG emissions + soil carbon sequestration + plant carbon sequestration) of -2.27 tCO_2e ha^{-1} $year^{-1}$. With yields ranging from 22 to 40 sacks of coffee per hectare per year (average of high- and low-yield harvests), the average GHG emissions balance of the Daterra Coffee farms was -0.07 tCO_2e per sack. This level of emission intensity per hectare shows that Daterra Coffee ranks among the top 5% most efficient coffee production systems in the world. The results also show that seeking an increase in the efficiency of nitrogen fertiliser use with the intention of reducing the amount applied without reducing productivity, and implementing soil conservation practices are important actions capable of mitigating GHG emissions from coffee growing - especially with the advancing age of the plots, which tend to require a greater amount of input. However, continued monitoring of the GHG emissions balance is recommended to support the evidence found and to more accurately identify the correlation between coffee management and GHG mitigation opportunities in order to positively influence other players in the sector to incorporate sustainable practices, be recognized by the market due to their role in preventing climate change and in meeting food demands.

INTRODUCTION

Coffee farming stands out as one of the main productive systems in Brazil. The state of Minas Gerais accounts for 55% of the planted area in the country, with an estimated harvest of 34.6 million sacks in 2020 (processed coffee) (CONAB, 2020).

Studies, however, show that the coffee crop is one of the most vulnerable to climate change. Therefore, assessing the risks and opportunities of this crop within the context of the current climate crisis will be essential for the competitiveness of this product in the medium and long term and for the national economy as a whole.

The climate resilience of agricultural crops depends on the implementation of more sustainable production practices. In the past decade, international agreements, public policies and the behaviour of consumers and investors have led to pressure for changes in production practices and conservation of natural resources in Brazil, leading to significant improvements in these areas. In the scope of this new farming, the following stands out:

- Compliance with the Brazilian Forest Code;
- Multilateral negotiations for the mitigation of global GHG emissions, which led to the creation of the National Climate Change Policy and its Low Carbon Agriculture Plan;
- Procurement policies of large companies in the food chain, driven by sectoral agreements;
- Restrictive criteria for the granting of rural credit by public and private banks;
- Consumer pressure for food traceability and sustainability.

The sum of all these factors, together with a constant evolution of technology and knowledge about agricultural practices in the tropics, has been the engine of a new revolution in the field, evidenced by increasing rates of productivity and carbon removal from soils, and decreasing rates of deforestation and GHG emissions.

This revolution still needs to overcome several obstacles to gain scale though. As such, the confirmation of social, environmental and economic benefits is essential for a greater cooperation among players aimed at the adoption of good agricultural and livestock production practices.

The scenario for the agricultural and livestock sector is changing and generating new risks, as well as opportunities. One of the first steps towards the establishment of a management process for the risks and opportunities represented by climate change is the preparation of an inventory of GHG emissions and removals. By knowing the GHG balance, as well as to map weaknesses, a property or economic sector will be able to outline strategies, plans and targets for climate change mitigation and adaptation, and operate in a developing environmental asset market.

TARGET

This study shows the estimates of the balance of greenhouse gas (GHG) emissions from coffee production at two Daterra Coffee farms located in the municipalities of Franca in São Paulo state (Fazenda São João) and Patrocínio in Minas Gerais state (Fazenda Boa Vista).

PROJECT CHALLENGES

The project has a number of innovative features. GHG emissions are normally assessed within the agricultural activity. This practice alone does not denote the environmental benefits of coffee farms pursuing sustainable farming practices. Estimating the balance of GHG emissions is the most assertive way because, besides demonstrating the environmental impact caused by climate change, it also accounts for environmental benefits related to the carbon sequestered in the soil, the biomass area of coffee plants and also to the maintenance of native areas on the farm.

METHODOLOGY

PRODUCTION SYSTEMS

Two coffee farms were assessed in this study. These farms are part of Daterra Coffee and are located in the municipalities of **Franca** (São Paulo state) and **Patrocínio** (Minas Gerais state), one of the main coffee producing regions in Brazil (Figure 1).

Figure 1. Location of the municipalities of Franca-SP and Patrocínio-MG.

The climate in this region is humid subtropical with dry winters and hot summers, classified as Aw (Köppen classification). The temperature reaches 30°C in summer and drops to approximately 12°C in winter, making for an average temperature of 20°C. The average rainfall in the region is 1,500.00 millimetres per year (Pereira & Souza, 2015).

The coffee farms analysed in this study were established decades ago in the region and today total an area of approximately 6,940 hectares (ha), of which around 2,924 hectares are dedicated to coffee farming.

ANALYSIS OF THE GREENHOUSE GAS BALANCE

The analytical framework for assessing the balance of Daterra Coffee's GHG emissions was based on IPCC guidelines (IPCC, 2006), facilitated by the GHG calculation framework and GHG emission and removal factors from the GHG-Agricultural Protocol (WRI, 2014), together with data on coffee management required for this assessment. This coffee management data is included in Table 1 and represents the average management values for the last two years (high- and low-yield coffee harvests) and were collected by the Daterra Coffee team.

The scope of this paper focuses on emissions and removals from agricultural management of coffee production within the farm scale ("inside the farm"). Therefore, emissions from the transport of soil input manufacture from outside the farm area were not considered. In addition, we assumed a 20-year temporal dependence of the soil and the sequestration of carbon in the soil and coffee trees (Henry et al., 2009). The main sources of farm-scale GHG emissions and removals were considered along with the data in Table 1 (IPCC, 2006; Figure 2):

- Emissions of nitrous oxide (N_2O) and carbon dioxide (CO_2) from the use of nitrogen fertilisers in the soil;
- Emissions of nitrous oxide (N_2O) deriving from the decomposition of pruning waste in the soil;
- Emissions of CO_2 deriving from soil liming;

- Emissions of CO_2 deriving from the burning of fossil fuels (diesel) in machinery;
- Emissions of CO_2 deriving from the soil of degraded areas;
- Removal of CO_2 deriving from the sequestration of carbon in soil in improved areas;
- Removal of CO_2 deriving from the above-ground biomass of coffee plants.

Additionally, the results will demonstrate the biogenic emissions of CO2 resulting from the burning of biofuels and biomass. The recommendation of the GHG Protocol Brazil is that CO2 emissions from this combustion be reported separately.

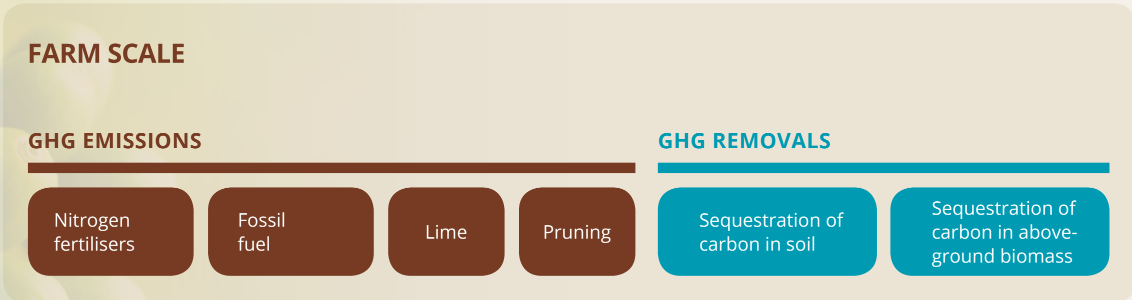


Figure 2. Scope of the assessment of the greenhouse gas emissions balance (emissions + removals) of coffee production from Daterra Coffee farms.

The estimated GHG emission and removal values for each agricultural practice listed above were converted into CO_2 equivalents (CO_2e) using the Global Warming Potential (GWP) factors provided by the IPCC 5th Assessment Report ($CO_2 = 1$, $CH_4 = 28$ and $N_2O = 265$) (IPCC, 2014) as shown in the equation below:

$$GHG_{\text{Balance Emissions}} = GHG_{\text{Nitrogen Fert}} + GHG_{\text{Fossil fuel}} + GHG_{\text{Limestone}} + GHG_{\text{Decomposition of pruning}} + GHG_{\text{Soil carbon stock}} + GHG_{\text{Above-ground biomass}}$$

Lastly, the results were correlated with the production variables described in Table 1, such as area and productivity of coffee farms, resulting in GHG emission intensity metrics for the production systems.

FARM	TOTAL AREA	COFFEE AREA	PLANTATION DENSITY	AVERAGE YIELD	UREA	OTHER FERTILISERS	AGRICULTURAL CORRECTIVE	USE OF DIESEL
	(ha)		Plants ha^{-1}	sc ha^{-1} year^{-1}	Tons year^{-1}			L year^{-1}
Boa Vista Farm	*6,395.13*	*2,741.52*	*3,994*	*35*	*-*	*3,895*	*4,240*	*571,500*
São João Farm	*543.85*	*152.00*	*3,990*	*25*	*-*	*165,75*	*448*	*60,000*

***Table 1.** Description of both Daterra Coffee farms.*

It is important to point out that the emission estimates of the GHG emissions balance for the culture of coffee on both farms was based on the following assumptions:

- In general, it was considered that the growth of coffee trees occurs linearly and that the coffee plantation is renovated every 20 years; therefore, the values found were annualised for the purpose of calculation.
- The dynamics of coffee tree management considered in the study followed three different types of pruning techniques ("*recepa*" - stumping or cutting off all plagiotropic branches at 20-30 cm from the orthotropic branch, "*decote*" - cutting off the orthotropic branch at 1.5 m and 2.0 m aboveground and "*esqueletamento*" - cutting off all plagiotropic branches at 20-30 cm from the orthotropic branch) and the following schedule of activities:

Recepa

- Year 1 - planting (base year);
- Year 12 - stumping of coffee crop, with 95% loss of aboveground biomass;
- Year 20 - renovation with full pruning of the trees (100% loss of aboveground biomass) followed by replanting.

Decote

- Year 1 - planting (base year)
- Year 12 - 1st cut of coffee crop, with 30% loss of aboveground biomass;
- Year 16 - 2nd cut of coffee crop, with 30% loss of aboveground biomass;

- Year 20 - renovation with full pruning of the trees (100% loss of aboveground biomass) followed by replanting.

Esqueletamento

- Year 1 - planting (base year);
- Year 12 - 1st cut of coffee crop, with 50% loss of aboveground biomass;
- Year 16 - 2nd cut of coffee crop, with 50% loss of aboveground biomass;
- Year 20 - renovation with full pruning of the trees (100% loss of aboveground biomass) followed by replanting.

- In crop pruning, the removed biomass left on the field was considered as green fertiliser, and its N_2O emissions were included in the respective balance of GHG emissions;

- In the renovation, it was considered that 100% of the biomass left on the soil over the period of 20 years as a result of falling plant material and roots will be maintained in the properties;

- The data collected on input, management and yield for each farm refer to the year the data was collected and do not represent average data over the years.

RESULTS

The GHG emission estimates of both Daterra Coffee farms ranged from 3.05 a 3.95 $tCO_2e\ ha^{-1}\ year^{-1}$ and averaged 3.09 $tCO_2e\ ha^{-1}\ year^{-1}$ (Table 2). Of these emissions, the main source was the application of nitrogen fertilisers (45.2%), followed by soil liming (23.9%), fossil fuel use (23.3%), decomposition of crop pruning waste (7.4%), and electricity (0.2%) (Figure 3). Additionally, Figures 4 and 5 present this information for the two farms evaluated in this study.

GHG EMISSIONS

FARM	N-FERTILISER	LIME	DIESEL	ELETRICITY	PRUNING	TOTAL
	(tCO_2e/ha/year)					
Boa Vista Farm	*1.42*	*0.71*	*0.69*	*0.23*	*0.0046*	*3.05*
São João Farm	*1.04*	*1.35*	*1.26*	*0.23*	*0.061*	*3.95*
Total	**2.46**	**2.06**	**1.95**	**0.46**	**0.066**	**7.00**
Average	**1.40**	**0.74**	**0.72**	**0.23**	**0.008**	**3.09**

Table 2. ***GHG emissions per hectare per year for Daterra Coffee farms.***

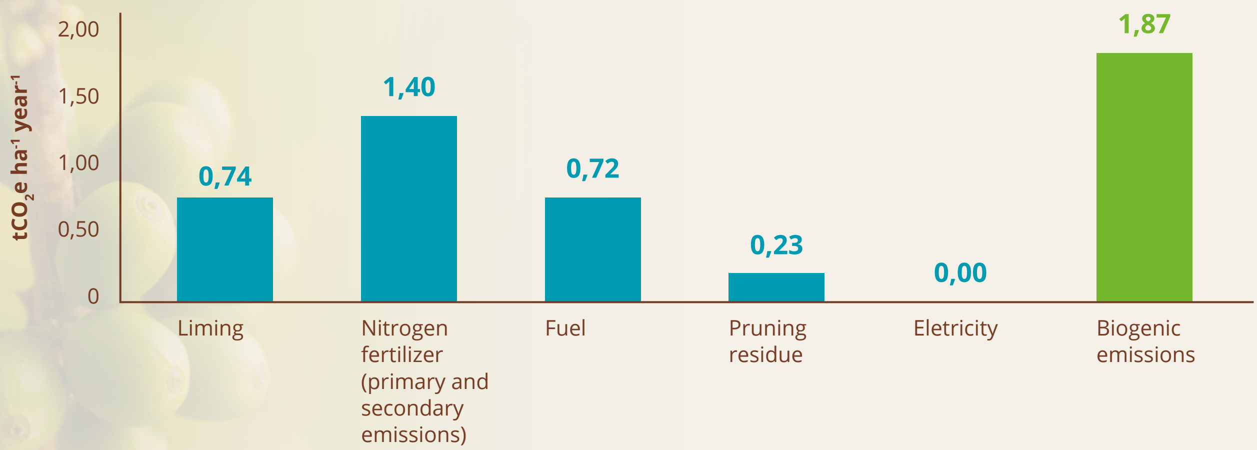


Figure 3. ***Average GHG emissions from the main emitting sources at Daterra Coffee Farms.***

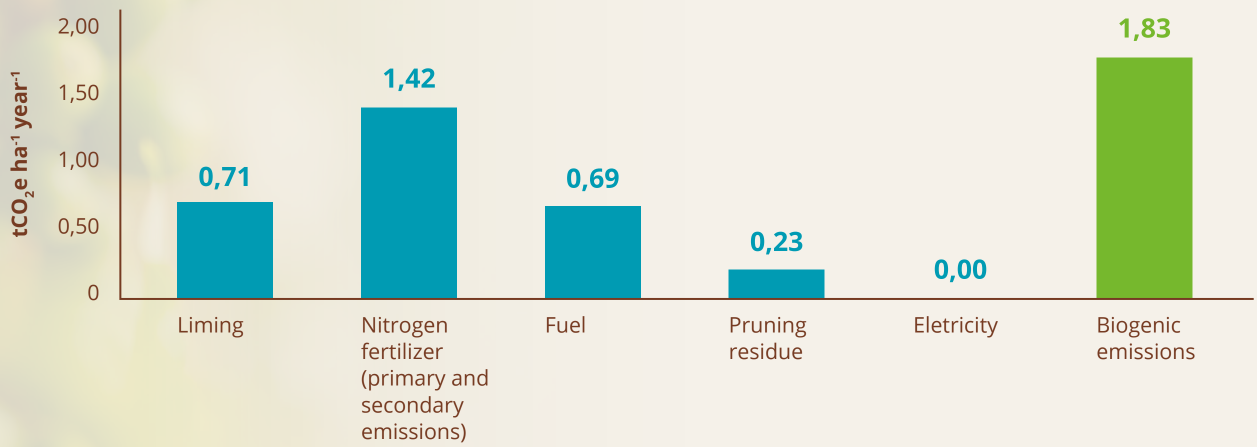


Figure 4. ***GHG emissions from the main emitting sources at Boa Vista Farm (Patrocínio/MG).***

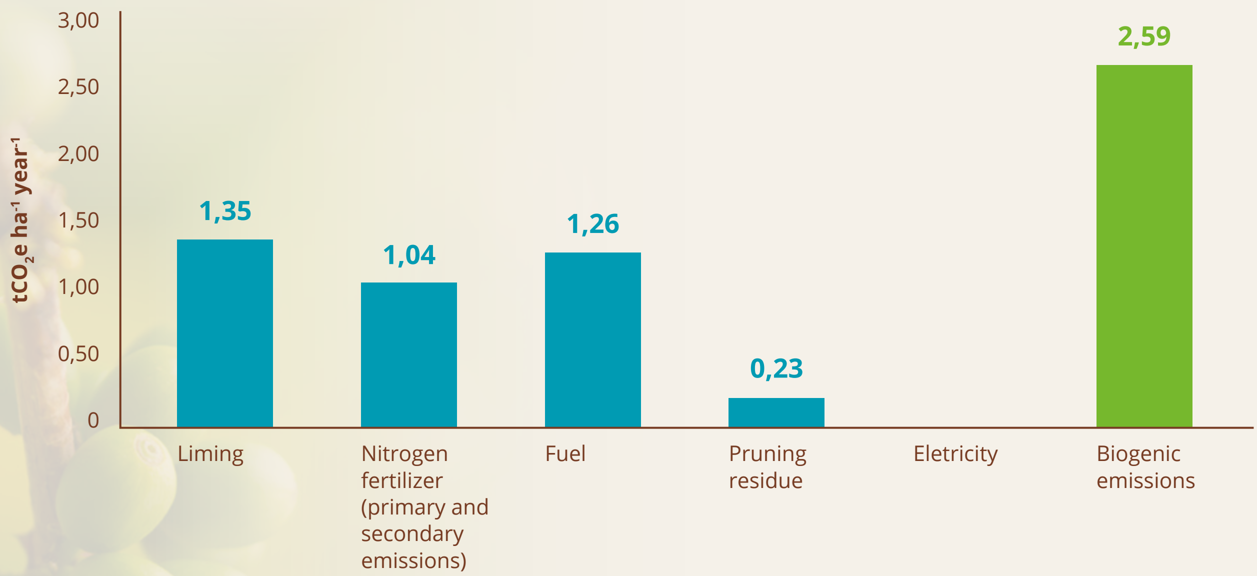


***Figure 5**. GHG emissions from the main emitting sources at São João Farm (Franca/SP).*

The use of inputs, especially nitrogen fertilisers, is a significant source of GHG emissions (IPCC, 2006; Davidson, 2009). GHG emissions from the use of nitrogen fertilisers are a consequence of the formation of nitrous oxide gas (N_2O) during the nitrification and denitrification reactions that occur during the application of this input to the soil.

Studies conducted on coffee plantations in Central America also report the use of nitrogen fertilisers as the main contributor to GHG emissions from the production system (Van Rikxxoort et al., 2014; Noponen et al., 2012). In Brazil, the use of this input is one of the main sources of GHG emissions, accounting for about 5% of national GHG emissions (SEEG, 2019).

On the other hand, due to the constant coverage and contribution of organic matter to the soil from the roots, leaves and prunings from coffee plantations, it is estimated that the soil in these locations accumulates carbon (organic matter) at an average rate of -1.95 $tCO_2e\ ha^{-1}\ year^{-1}$. This soil carbon accumulation, in turn, was able to offset 63% of GHG emissions (Figure 6).

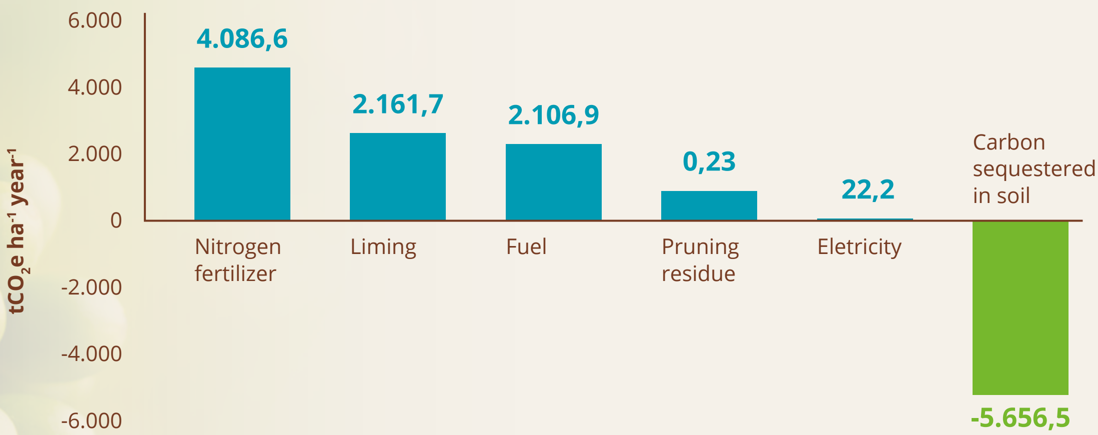


***Figure 6.** Greenhouse gas (GHG) total emissions and removals of Daterra Coffee Farms.*

Furthermore, since it is a perennial crop, coffee also causes additional carbon sequestration in the aboveground biomass of the plants, calculated at approximately - 65.5 $tCO_2\ ha^{-1}$ over 20 years or -3.42 $tCO_2e\ ha^{-1}\ year^{-1}$. These values are consistent with the scientific literature, which shows that carbon sequestration in the aboveground biomass of coffee plantations reaches up to -3.0 $tCO_2e\ ha^{-1}\ year^{-1}$ (Silva et al., 2013; Coltri et al., 2011).

Therefore, considering the coffee trees and the coverage and input of organic matter in the soil, the coffee production areas of the farms analysed in this study remove on average -5.37 $tCO_2e\ ha^{-1}\ year^{-1}$ (Figure 7).

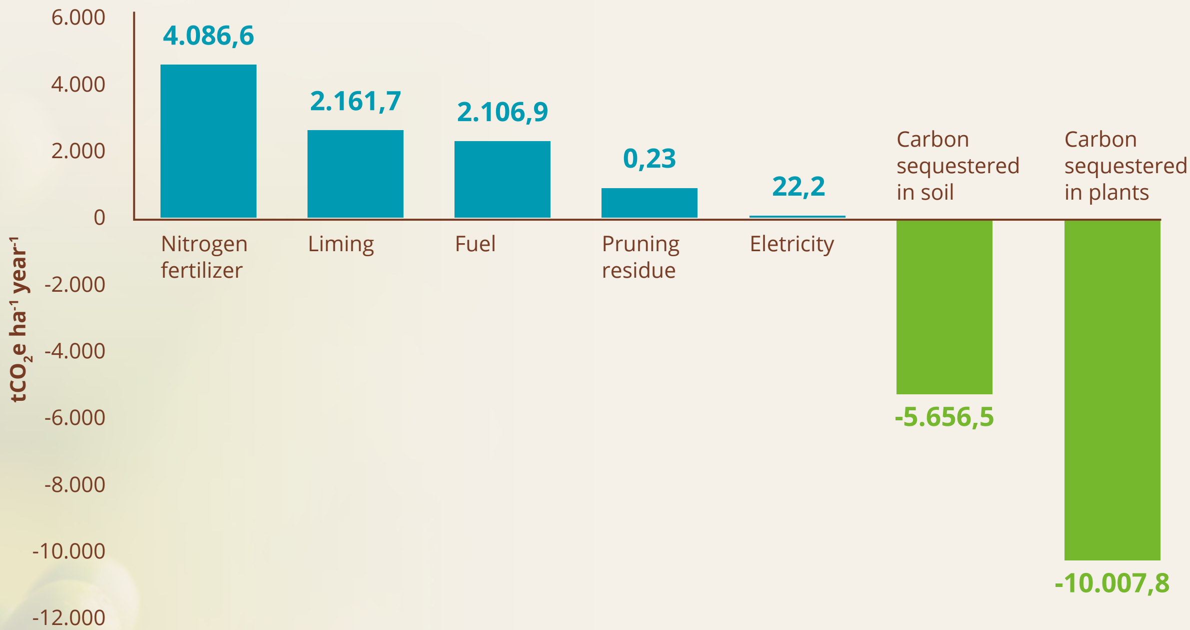


Figure 7. Greenhouse gas (GHG) total emissions and removals of Daterra Coffee Farms.

It is important to remember, however, that due to the renovation of the coffee plantation (here considered after a period of 20 years), a part of the carbon sequestered in the aboveground biomass may be lost, i.e., is not permanent. As such, after the 20-year period, it is necessary to reassess these carbon sequestration rates and the permanence of coffee growing in these areas.

The average coffee yields of the properties ranged from 22 - 40 sacks of coffee per hectare (considering the average of the high- and low-yield harvests) and showed an average of approximately 25 sacks per hectare at São João Farm and 35 sacks per hectare at Boa Vista Farm. By associating the respective estimated values of the GHG emission balance, we conclude that the Boa vista Farm removed approximately 2.32 $tCO_2e\ ha^{-1}$ and the São João Farm emitted around 1.42 $tCO_2e\ ha^{-1}$, which sets the GHD balance of Daterra Coffee at -2.27 $tCO_2e\ ha^{-1}$.

The differences between the GHG emissions of these farms are mainly due to the size of the properties, which makes their needs in relation to production management different.

Globally, it is estimated that an average of 44.6 tCO_2e ha^{-1} $year^{-1}$ is emitted per hectare of coffee produced (considering a yield of 80% including raw: roasted coffee beans and not including carbon sequestration in soil and/or aboveground biomass), of which 63%, or 28.1 tCO_2e tCO_2e ha^{-1} $year^{-1}$ derives from the farm. Compared to these emission values without including soil carbon sequestration and/or aboveground biomass (Table 2), the farms assessed in this study are potentially in the group of the 5% least intensive in emitting GHGs per ha of coffee produced at the farm scale, i.e. in the group that emits up to 4.25 tCO_2e per ha of coffee produced (roasted) (Figure 8) (Poore et al., 2018).

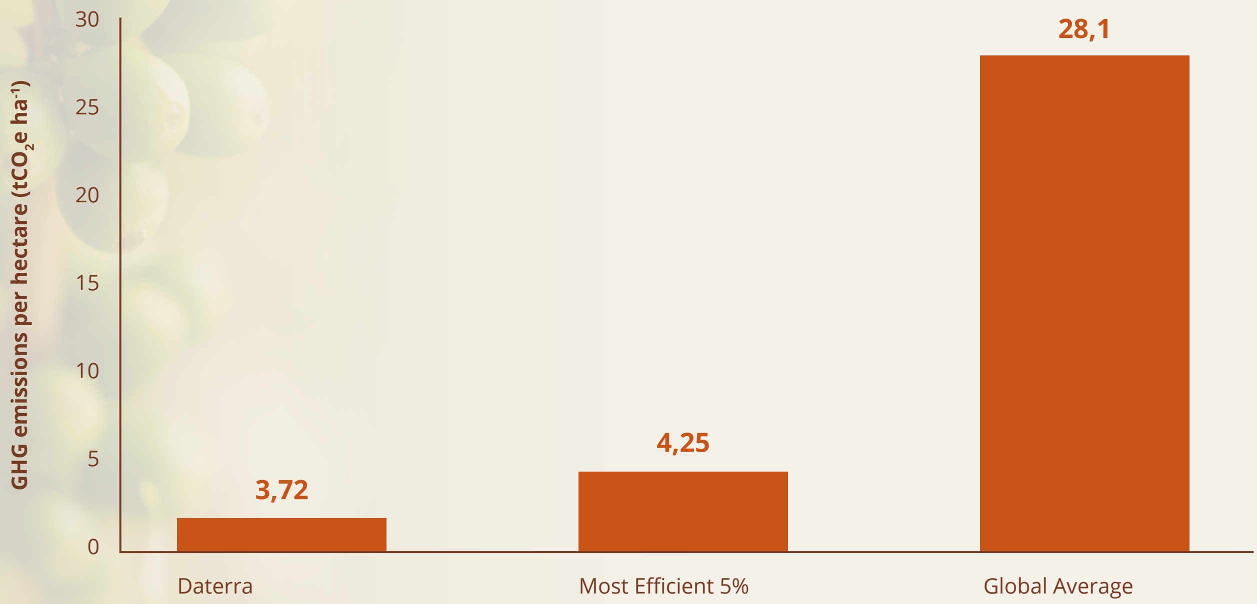


***Figure 8.** GHG emissions per kilogram of roasted coffee from Daterra Coffee Farms as compared with the global average and the group of the most efficient 5%.*

Additionally, emissions from land transport (road) to the Port of Santos for the outflow of coffee production were calculated.

Emissions from transport and distribution (downstream) are those arising from the transport or storage of products sold in vehicles and/or facilities not belonging to the reporting company. For example:

- Warehouses and distribution centers
- Retail facilities
- Air Transport
- Rail transport
- Road transport
- Maritime transport

The calculation of transmission and distribution emissions can be done according to the following methods:

- **Method based on fuel consumption:** it is determined by the amount of fuel consumed and applying the appropriate emission factor for that fuel;

- **Distance-based method:** in this case, the emission factor is related to the distance traveled (in km) and the amount of cargo transported (in tons).

It is important to highlight that for the estimates of GHG emissions from coffee transport, the following assumptions were made:

- For the calculation of GHG emissions from transport, the method based on fuel consumption will be used;

- GHG emissions from coffee transport and distribution are divided into two stages. In the first stage, the road modal is used to transport the production from the São João farm (Franca-SP) to the Boa Vista Farm (Patrocínio-MG) and then the entire production is transported to the port of Santos-SP.

Transport emissions were calculated by functional unit, that is, GHG emissions for the transport of 1 ton of coffee were evaluated. The emission results are shown in Figure 9.

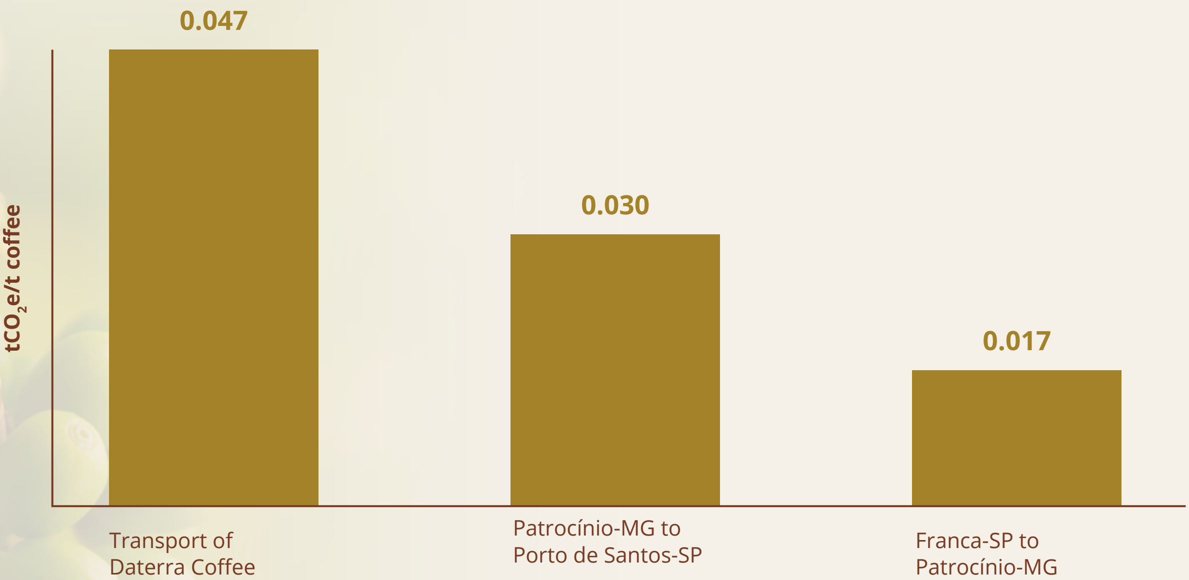


Figura 9. Emissions of greenhouse gases (GHG) by road transport to transport coffee production.

The total emission for transporting 1 ton of coffee is approximately 0.05 t CO_2e. About 99.5% of transport emissions correspond to CO_2 emissions from the burning of fossil fuels. CH_4 and N_2O emissions are not very representative, that is, they are responsible for just under 0.5% of emissions.

Based on Daterra Coffee's carbon balance results and considering an average productivity of 34,5 bags of 60 kg of coffee per hectare, we can conclude that the GHG emissions intensity of the farms evaluated is 1.54 t CO_2e per ton of coffee. Thus, we can infer that transport emissions correspond to approximately 3% of total emissions.

OPPORTUNITY TO REDUCE GHG EMISSIONS AND IMPROVE THE EFFICIENCY OF THE PRODUCTION SYSTEM

These results show that increasing the efficiency of nitrogen fertiliser use and implementing soil conservation practices are important actions capable of mitigating GHG emissions caused by coffee growing.

The application of nitrogen fertilisers added to the GHG emissions of the farms assessed in this study by more than 50% on average (Table 2; Figure 3). Nitrogen fertilisers, which are energy-intensive to produce, cause N_2O emissions from soils on application and are easily leached even in systems where trees predominate if such is not quickly absorbed by them (Babbar; Zak, 1995; Schroth et al., 1999, 2000). Efficient fertiliser use is, therefore, an important component in minimising the impact of GHG emissions on coffee production. Fertilisers should be applied based on the recommendations of local services for extending and using precision farming in regular soil and leaf analysis. The method and time of application should also be taken into account.

The diversification of coffee production systems with trees may also help mitigate GHG emissions. Enriching the coffee plantation with shade trees or even wind breakers may increase the carbon storage of the system by about 10 $tCO_2e\ ha^{-1}\ year^{-1}$ (Feliciano et al., 2018). Some species, such as Erythrina spp. or Gliricidia sepium, for example, besides increasing the carbon stocks of the system can also help reduce the need for nitrogen fertilisers through nitrogen fixation and nitrogen-rich pruning (Nygren et al. 2012). Another opportunity to mitigate GHG emissions in coffee production is to replace fossil fuel with biofuel in farm machinery.

ESTIMATE OF CARBON STOCKS IN THE ABOVEGROUND BIOMASS OF NATIVE VEGETATION

The plant biomass in the native vegetation areas of rural properties stores a large amount of carbon. This study quantified the carbon stored in the aboveground phytomass of the native vegetation areas in the Daterra Coffee farms.

To estimate the amount of carbon stored in these areas the following steps were taken:

- Collection of geo-referenced data of native vegetation areas identified as permanent preservation areas (PPAs) and legal reserves (LRs);
- Overlap of the native vegetation polygons of the farms with the vegetation map of the states of São Paulo and Minas Gerais;
- Finding in the literature the average values of carbon stored in the phytomass in each of the main types of native vegetation identified in the farms under analysis;
- Estimate of carbon and CO_2 stored in the phytomass of the areas under native vegetation.

The amount of carbon stored in the forest areas around coffee plantations was also calculated, as shown above, according to the carbon stock levels in the respective biomes of the countries provided by the Global Ecological Zones (FAO, 2013; IPCC, 2006).

From the point of view of carbon fixation, forests play a fundamental role, as they store more carbon in their trees and in the soil than what currently exists in the atmosphere (IPCC, 2000). The Brazilian Cerrado region represents a significant portion of the planet's tropical ecosystems and, therefore, has a huge role in the global carbon cycle, acting as a great assimilator and accumulator of carbon. In recent decades, the replacement of extensive areas of the original Cerrado cover for other uses that require deforestation and slash-and-burning has been occurring at a fast pace and this whole process of vegetation replacement has certainly contributed to increasing the amount of CO_2 in the atmosphere.

The assessed properties totalled 1,506,888 tCO_2e stored in the aboveground biomass of the native vegetation and in the soil of the conservation areas. Of this total, about 300,000 t CO_2e is stored in an additional forest area maintained by Daterra Coffee. Figure 10 shows carbon stored above and below ground in the PPA, LR and preserved forest reserve areas for each property under analysis.

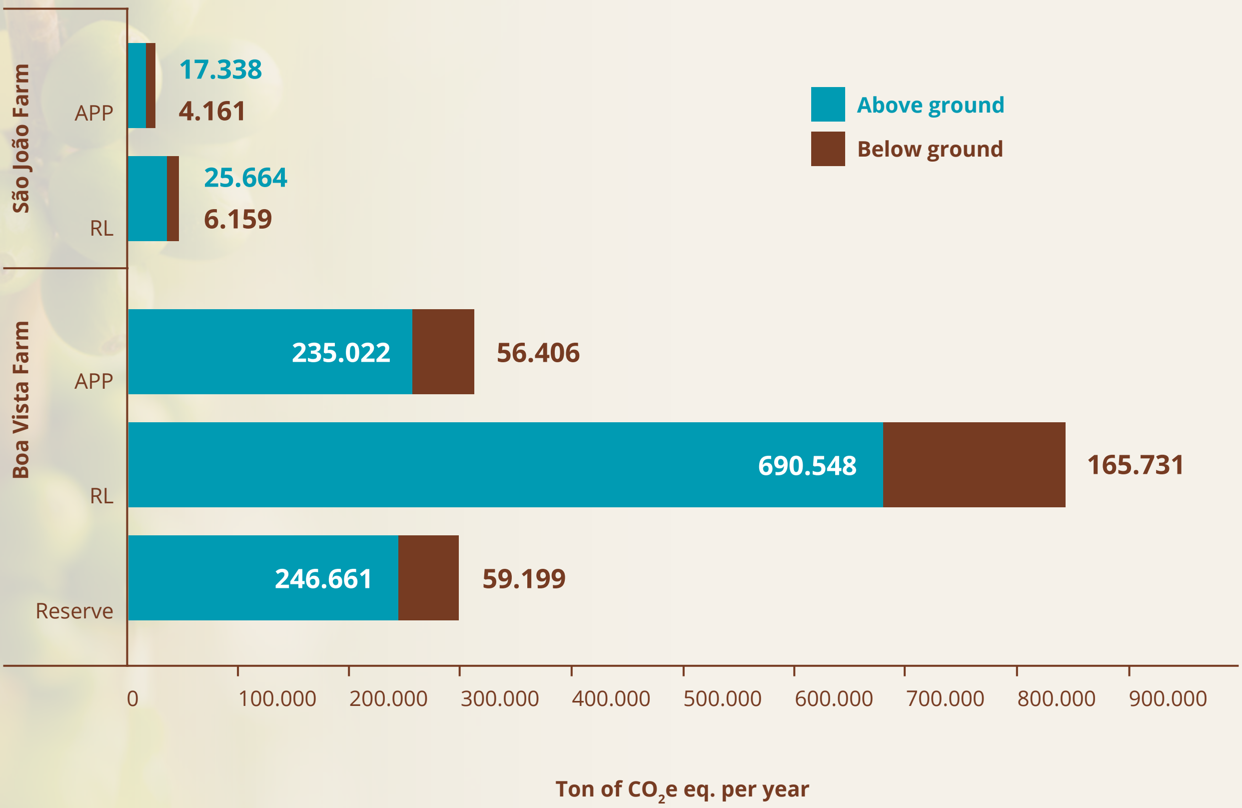


***Figure 10.** Carbon stored in the preserved areas on Daterra Coffee farms.*

CONCLUSION

The average GHG balance of both Daterra Coffee farms was -2.27 tCO_2e ha-1 year-1 or -0.07 tCO_2e per sack of coffee produced. The average GHG emission of the farms was 3.09 tCO_2e ha^{-1} $year^{-1}$, with the main source of emission being the use of synthetic nitrogen fertilisers, which represented around 45.2% of the total emitted.

On the other hand, soil carbon sequestration was able to offset more than 63% of these emissions, removing carbon at an average rate of -1.95 tCO_2e ha^{-1} $year^{-1}$. Furthermore, it is important to mention that it has been estimated that the coffee plantation has a carbon stock in the tree biomass of approximately -68.5 tCO_2e ha^{-1} over the 20 years or -3.42 tCO_2e ha^{-1} $year^{-1}$. With this, it is estimated that Daterra Coffee farms, are responsible for carbon sequestration at an average rate of -5.37 tCO_2e ha^{-1} $year^{-1}$.

These results show that increasing the efficiency of nitrogen fertiliser to reduce the amount applied without reducing yield and implementing soil conservation practices are important actions capable of mitigating GHG emissions caused by coffee growing.

Global comparisons suggest that Daterra Coffee has coffee production systems that are potentially among the 5% most efficient in terms of GHG emissions per hectare. Therefore, Daterra Coffee provides society and the market not only with quality coffee, but also with the environmental services of soil regeneration and support for climate regulation, a fact that can be used as a product differentiation.

The findings indicate the potential for alignment between coffee production and the removal of carbon from the atmosphere. As such, carbon becomes a potential indicator of good property management, underscoring the presence of a low climate impact and highly productive system.

Continuity in monitoring the balance of emissions, mainly in the capacity of the soil to sequester carbon, is recommended to support this evidence, to identify with greater precision the correlation between management decisions and the GHG emission balance, to positively influence other players in the sector to incorporate these practices, to be recognized by the market for the sustainability differential and to benefit from financial arrangements based on carbon indicators.

REFERENCES

Babbar, L.I.; Zak, D.R. Nitrogen loss from coffee agroecosystems in Costa Rica: leaching and denitrification in the presence and absence of shade trees. **Journal of Environmental Quality**, v. 24, p. 227–233, 1995. doi:10.2134/jeq1995.00472425002400020003x.

Coltri, P.P.; Lazarim, C.; Dias, R.; Zullo Junior, J.; Pinto, H.S. Estoque de carbono em sistemas cafeeiros a pleno sol e cultivado com macadâmia no sul de Minas Gerais, Brasil. In: **SIMPÓSIO DE PESQUISA DOS CAFÉS DO BRASIL**, 7., 2011, Araxá. Anais... Brasília, DF: Embrapa Café, 2011.

CONAB - Companhia Nacional de Abastecimento. Boletim da Safra de Grãos. 2019. Disponível em: <*https://www.conab.gov.br/info-agro/safras/graos/boletim-da-safra-de-graos*>.

Davidson, E.A. The contribution of manure and fertilizer nitrogen to atmospheric nitrous oxide since 1860. **Nature Geoscience**, v. 2, p. 659-662, 2009.

Feliciano, D.; Ledo, A.; Hillier, J.; et al. Wich agroforestry options give the greatest soil and above ground carbon benefits in different world regions? **Agriculture, Ecosystems and Environment**, v. 254, p. 117-129, 2018.

Henry, M.; Tittonell, P.; Manlay, R.J.; Bernoux, M.; Albrecht, A.; Vanlauwe, B. Biodiversity, carbon stocks and sequestration potential in aboveground biomass in smallholder farming systems of western Kenya. **Agriculture, Ecosystems and Environment**, v. 129, p. 238–252, 2009.

IPCC - Intergovernmental Panel on Climate Change, 2006. In: Eggleston, H.S., Buendia, L., Miwa, K., Ngara, T., Tanabe, K. (Eds.). **IPCC Guidelines for National Greenhouse Gas Inventories**, Prepared by the National Greenhouse Gas Inventories Programme. Institute for Global Environmental Strategies, Tokyo, Japan, 2006.
Disponível em: <*http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html*>.

IPCC - Intergovernmental Panel on Climate Change: **Climate Change 2014: Impacts, Adaptation, and Vulnerability**. Summaries, Frequently Asked Questions, and Cross Chapter Boxes. A Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.

BARROS, V.R.; FIELD; C.B.; DOKKEN, D.J.; MASTRANDREA, M.D.; MACH, K.J.; BILIR, T.E.; CHATTERJEEE, M.; EBI, K.L.; ESTRADA, Y.O. GENOVA, R.C.; GIRMA, B.; KISSEL, E.S.; LEVY, A.N.; MACCRACKEN, S.; MASTRANDREA, P.R.; WHITE, L.L. (eds.). United Kingdom and New York: Cambridge University. 2014 Nygren, P.; Fernández, M.P.; Harmand, J.M.; Leblanc, H.A. Symbiotic dinitrogen fixation by trees: an underestimated resource in agroforestry systems? **Nutrient Cycling in Agroecosystems**, v. 94, p. 123–160, 2012. doi:10.1007/s10705-012-9542-9.

Noponen, M.; Jones, E.; et al. Greenhouse gas emissions in coffee grown with differing input levels under conventional and organic management. **Agriculture, Ecosystems & Environment**, v. 151, p. 6-15, 2012. doi: 10.1016/j.agee.2012.01.019.

Poore, J.; Nemecek, T. Reducing food's environmental impacts through producers and consumers. Science, v. 360, p. 987-992, 2018. SEEG - Sistema de Estimativas de Emissões de Gases de Efeito Estufa, 2018. Emissões do setor de agropecuária - Período de 1970 a 2016. Disponível em: *<https://www.imaflora.org/downloads/biblioteca/Relatorios_SEEG_2018-Agro_Final_v1.pdf>.*

Schroth, G.; Rodrigues, M.R.L.; D'Angelo, S.A. Spatial patterns of nitrogen mineralization, fertilizer distribution and roots explain nitrate leaching from mature Amazonian oil palm plantation. **Soil Use Management**, v. 16, p. 222-229, 2000. doi:10.1111/j.1475-2743.2000.tb00197.x

Schroth, G.; Silva, L.F.; Seixas, R.; Teixeira, W.G.; Macêdo, J.L.V.; Zech, W. Subsoil accumulation of mineral nitrogen under polyculture and monoculture plantations, fallow and primary forest in a ferralitic Amazonian upland soil. **Agriculture, Ecosystems & Environment**, v. 75, p. 109-120, 1999. doi:10.1016/S0167-8809(99)00068-7.

SILVA, A. B, da; MANTOVANI, J. R.; MOREIRA, A. L.; REIS, R. L. N. Estoques de carbono no solo e em plantas de cafeeiro (*Coffea arabica L.*). **Interciencia**, v. 38, n. 4, p. 286, 2013.

Van Rikxoort, H.; Schroth, G., Läderach, P. et al. **Agronomy for Sustainable Development**, v. 34, n. 4, p. 887-897, 2014. doi: https://doi.org/10.1007/s13593-014-0223-8.

WRI - WORLD RESOURCES INSTITUTE, 2014. GHG **Protocol Agricultural Guidance: Interpreting the Corporate Accounting and Reporting Standard for the agricultural sector.** 2014. Disponível em: *<https://ghgprotocol.org/agriculture-guidance>.*

EMISSIONS BALANCE
OF GREENHOUSE GASES (GHG)
FOR THE PRODUCTION OF COFFEE ON THE FARMS
FROM DATERRA COFFEE

Realization:
Imaflora, Instituto de Manejo e
Certificação Florestal e Agrícola

Coordination and text production:
Bruno de Almeida Castigioni

Revision:
Renata Potenza
Marina Jordão

Design Graphic:
Thiago Olbrich

About Imaflora:

Imaflora (Institute of Forestry and Agricultural Management and Certification) is a Brazilian non-profit organization created in 1995 to promote conservation, sustainable use of natural resources and to generate social benefits in the forestry and agricultural sectors.

imaflora®

www.imaflora.org

instagram.com/imaflorabrasil
youtube.com/imaflora
twitter.com/imaflora
facebook.com/imaflora
imaflora.org/noticias
linkedin.com/in/imaflora

DOE IMAFLORA

doe.imaflora.org