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ORIGINAL ARTICLE

Carbon footprint of Brazilian cocoa produced in Pará state

Pegada de carbono do cacau brasileiro produzido no estado do Pará

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Abstract

Pará is the main cocoa producing state in Brazil. To provide a comprehensive picture of the carbon cootprint from cocoa production (conventional and organic cultivation systems in Brazilian Trans-Amazon and Xingu regions), the Greenhouse Gas (GHG) Protocol methodology was used to calculate greenhouse gas emissions with a focus on the impact of climate changes. The carbon footprint was calculated based on original data collected in the conventional and organic cocoa cultivation of the Trans-Amazon and Xingu regions in the State of Pará. The harvesting, fermentation and drying steps were analyzed, with data collection in nine farms, three of each type of agricultural production: conventional; organic; and organic-fairtrade. The fruit is harvested manually, the husk is left at the field for natural fertilization without composting. The small amount of inputs, such as herbicides, insecticides and fertilizers, are used only on farms with cocoa conventional production. Eliminating the use of nitrogen fertilizers and implementing an efficient method of composting without the emission of methane in the air, the carbon footprint will be only 2.01 kg CO_2 eq./kg cocoa, i.e., total reduction of 81%.

Keywords: Sustainability; Organic; Greenhouse gases; Fairtrade; Composting; Certification.

Resumo

Pará é o principal estado produtor de cacau do Brasil. Para fornecer uma imagem abrangente da Pegada de Carbono do cacau produzido nas regiões Transamazônica e Xingu do estado do Pará, foi utilizada a metodologia do protocolo Green House Gas para calcular as emissões de gases de efeito estufa, com enfoque no impacto das mudanças climáticas. A Pegada de Carbono foi calculada com base em dados originais coletados nos cultivos de cacau convencional e orgânico nessas regiões. Foram analisadas as etapas de colheita, fermentação e secagem, com coleta de dados em nove fazendas, três de cada tipo de produção agrícola: convencional, orgânica e orgânica-fairtrade. A fruta é colhida manualmente, sendo a casca deixada no campo para fertilização natural, sem compostagem. A pequena quantidade de insumos, como herbicidas, inseticidas e fertilizantes, é usada apenas em fazendas com produção convencional de cacau. Eliminando o uso de fertilizantes nitrogenados e implementando um método eficiente de compostagem sem emissão de metano no ar, a Pegada de Carbono seria de apenas 2,01 kg CO_2 eq./kg de cacau, uma redução total de 81%.

Palavras-chave: Sustentabilidade; Orgânico; Gases de efeito estufa; Comércio justo; Compostagem; Certificação.

1 Introduction

Cocoa cultivation is an agricultural activity of great economic and social importance for the tropical climate, which is hot and humid, and according to Franco et al. (2019) and Reay (2019), the climatic needs and also its changes limit the expansion of the area cultivated with this crop worldwide.

According to the International Cocoa Organization (International Cocoa Organization, 2019), Brazil is the seventh largest producer of cocoa and ranks fifth in processing/cocoa grinding to obtain the main derivatives used by the chocolate industry (liquor/cocoa mass and cocoa butter).

Brazil is a country that has the entire production of the cocoa-chocolate chain, with projects to address cocoa sustainability, such as the CocoaAction (that is an initiative of the World Cocoa Foundation) and the implementation of labels/certifications (such as the Organic and Fairtrade) for sustainable cultivation (Chiapetti et al., 2020; Silva et al., 2017; Queiroz, 2014).

Figure 1 shows the world production of cocoa beans from 2003/2004 to 2016/2017 (in 1,000 tons, Y axis), with approximately 4,552.000 tons of total world production in 2016/2017 (Statista, 2018).

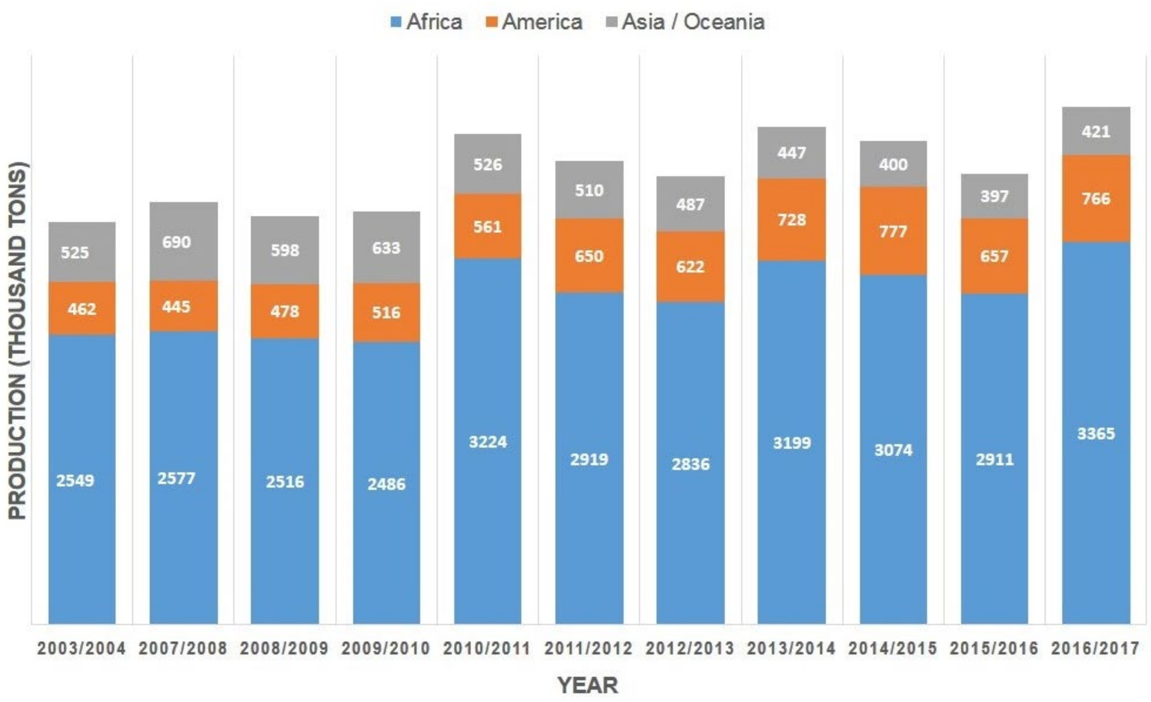

Figure 1. World production of cocoa beans from 2003/2004 to 2016/2017 (in 1,000 tons). Source: Statista (2018).

Figure 2 shows how cocoa production has increased in Brazil over the years, mainly due to the state of Pará, which became the first national cocoa producer owing to its increased productivity in recent years (Nunes, 2021; Mercado do Cacau, 2015).

Figure 2. Cocoa production in Brazil over the years 2006-2020 (in 1,000 tons). Source: Nunes (2021); Mercado do Cacau (2015).

More than 90% of the cocoa extracted from Pará comes from family farming, small and medium sized crops of 10 to 50 hectares, and performance is associated with the preservation characteristics of cocoa production in agroforestry systems (Globo Rural, 2019; Mendes, 2014). Albrecht & Kandji (2003) could define "agroforestry as any land-use system that involves the deliberate retention, introduction or mixture of trees on other woody perennials with agricultural crops, pastures and/or livestock to exploit the ecological and economic interactions of the different components".

The state of Pará has about 30,000 producers distributed in 29 municipalities, which produce cocoa in conventional and organic cropping systems. Four cooperatives operate in the organic system, with approximately 150 families involved in the production of organic cocoa (Nunes, 2021, Globo Rural, 2019).

A survey carried out in 2019 by the Brazilian Council for Organic and Sustainable Production pointed out that the main reason cited for the consumption of organic products was health (84%), followed by the environment (9%), thus highlighting the consumer's relationship with the organic product not using chemical products and, therefore, presenting less possibility of risks to their health and the environment (ORGANIS, 2019).

Ecologically sustainable, economically viable and socially fair production foods is the definition associated with the Organic system, i.e., capable of integrating man into the environment (Santos & Monteiro, 2008).

Some farms in Pará produce cocoa under Organic and Fairtrade certified systems. Fairtrade is an organized social movement that assists producers in developing countries to promote sustainability through fair trading practices and fair price payments, following environmental standards and improving social and social conditions, local economic infrastructure Gruenwald (2009 as cited in Queiroz, 2014).

To provide a comprehensive picture of the Carbon Footprint from cocoa produced in the state of Pará (conventional and organic cultivation systems in Brazilian Trans-Amazon and Xingu regions) the GHG Protocol methodology was used to calculate greenhouse gases emissions (GHG) with a focus on impact of climate changes. The Carbon Footprint is a measure of the amount of carbon dioxide and other greenhouse gases emitted over the life cycle of a process or product. Emissions equivalent of carbon dioxide (CO_2 eq.) is the unity of measurement of Carbon Footprint (Wiedmann & Minx, 2008).

Some studies have shown similarity to the subject of analyze the environmental impacts in different cultivation systems. Ortiz-R et al. (2014) studied the Colombian cocoa production and aimed to assess and implement sustainability in agriculture, recommending agricultural practices based on Von Wirén-Lehr (2001 as cited in Ortiz-R et al., 2014). Ntiamoah & Afrane (2008) studied the production and processing of Ghanaian cocoa, with the aim of providing comprehensive view of the environmental impacts associated with cocoa production and processing through the application of Life Cycle Assessment (LCA) methodology. Gateau et al. (2012) aimed to adapt the LCA methodology to the production chain of cocoa from Bahia (Brazil) exported to a chocolatier in France, evaluating and comparing the environmental impact by LCA in four cultivation systems.

Figure 3 shows the comparison of the Carbon Footprint (emissions of Greenhouse Gas – GHG) of food products (Miah et al., 2018).

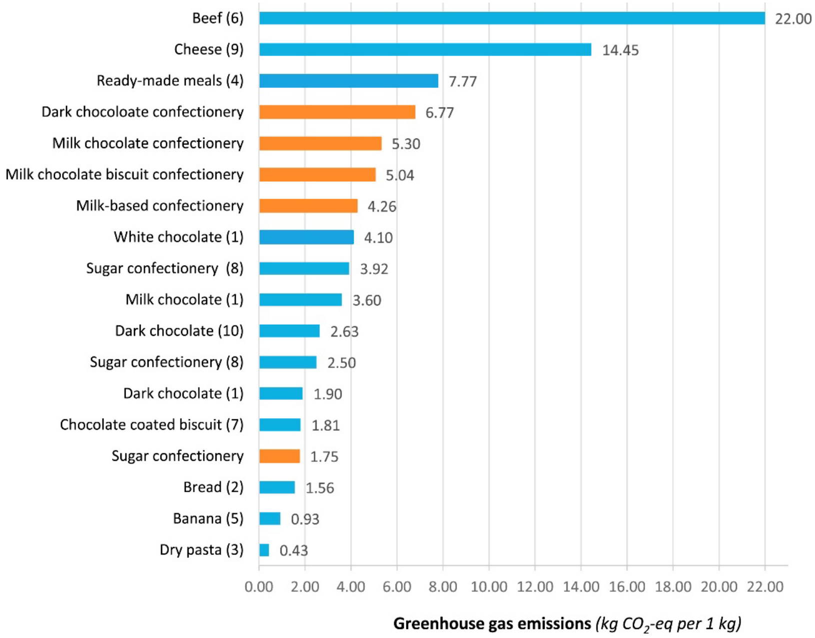

Figure 3. Carbon Footprint of food products. Source: (1) = Jungbluth & Konig (2014), (2) = Espinoza-Orias et al. (2011), (3) = Fusi et al. (2016), (4) = Rivera et al. (2014), (5) = Lescot (2012), (6) = Beauchemin et al. (2010), (7) = Konstantas et al. (2019), (8) = Nilsson et al. (2011), (9) = Santos Junior et al. (2017), (10) = Recanati et al. (2018 as cited in Miah et al., 2018).

Miah et al. (2018) calculated a Carbon Footprint of 5.30 and 6.77 kg CO_2 eq./kg milk and dark chocolate confectionery, respectively. Cocoa production is the most important phase of chocolate life cycle, as Konstantas et al. (2018) stated: "all the studies also found that the cultivation of cocoa beans was the main environmental hotspot followed by chocolate manufacturing and packaging". The contribution analysis shows that production of raw materials is the main hotspot, accounting for 67% to 81% of the total impact (the Carbon Footprint varies between 2.91 and 4.15 kg CO_2 eq./kg chocolate) (Konstantas et al., 2018). Recanati et al. (2018) calculated 2.62 kg CO_2 eq./kg chocolate with 60% of this emission due to the cocoa production (1.55 kg CO_2 eq. / 590 g cocoa). Neira (2016) calculated 2.49 – 2.82 kg CO_2 eq./kg chocolate (pure, 100% cocoa), with 66% of this emission due to the cocoa production (1.63 – 1.96 kg CO_2 eq./kg cocoa).

So, this study aimed to calculate the Carbon Footprint, based on data collected during the growing, fermentation and drying of cocoa in the Trans-Amazon and Xingu regions in the state of Pará, as well as the potential that each types of cultivation system (conventional and organic) contributes to the reduction of the Carbon Footprint.

2 Materials and methods

To calculate the Carbon Footprint, the study was based on the 2006 IPCC – Intergovernmental Panel on Climate Change (Riitta et al., 2006, Riitta & Svardal, 2006, Queiroz & Garcia, 2010, Yokote, 2003, GHG Protocol, 2016). The GHG Protocol (2006) Corporate Standard provides standards and guidance for companies and other organizations to prepare an inventory of greenhouse gases emissions. It covers the accounting and reporting of the six greenhouse gases covered by the Kyoto Protocol — carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6).

Climate Change Impact Method - CML 2000 (Global Warming Potential - GPW 100) is the reference to calculate the emissions of carbon dioxide equivalent (CO_2 eq.). Conversions of CO_2 released into the atmosphere have the following ratios: CH_4:CO_2 (25:1); CO_2:CO_2 (1:1); N_2O:CO_2 (298:1).

Data collected from nine farms in Brazilian Amazon were the basis to all calculations and tables were generated using Microsoft Excel. Not all the questions asked in the survey applied to the nine farms were answered (such as liters of water and electricity for washing recipients), because the farmers could not provide some of the data, however, the lack of this data did not prevent calculations for the Carbon Footprint. It is noteworthy that despite the nine farms do not use water for irrigation, this is a wish of the majority of farmers visited.

In addition to the data collected on the farms, some "conversions" in the mass balances of cocoa growing, fermentation and drying were calculated. To calculate the percentage of mass losses and emissions released during the fermentation, drying and growing steps, the averages based on 10 cocoa varieties studied by Efraim (2009) were used.

The scope is the calculation of the Carbon Footprint, within the system boundary (which are the fermentation, drying and growing steps) and with the following functional unit: results expressed in 1,000 kg of cocoa ready for commercialization.

Data were calculated for 1,000 kg (1 t is the functional unit) of cocoa produced, equivalent to 16 bags of 60 kg for the year 2014. For 1,000 kg of cocoa, 19.233 units (un) of cocoa pod were harvested, containing 2,959 kg of soft cacao (808 seeds × 3.663 g / seed ≈ 1,681 kg of fermented beans) (Efraim, 2009). The cocoa pod was harvested manually and broken open with machetes. During harvest, the husk and the placenta were separated. The placenta was manually separated from the cocoa seeds surrounded by pulp. The fermentation used the cocoa seeds surrounded by pulp. The husk was left in the field as fertilizer.

The ideal would be to implement composting of the husk (rich in potassium) to allow the reduction of methane emission, which has a negative impact on global warming (climate changes). In relation to methane (CH_4) emissions, 2006 IPCC is the reference to estimate the emissions of this gas from the disposal of the husk in the field (Riitta et al., 2006; Riitta & Svardal, 2006; Queiroz & Garcia, 2010) - see Equation 1.

$$Lo = W * DOC * DOCf * MCF * F * (16/12) \qquad (1)$$

Where:

Lo - CH_4 generation potential, kg CH_4

W – mass of waste deposited, kg

DOC - Degradable Organic Carbon (content in % of wet waste = 20%);

DOCf – Fraction of DOC that can decompose (50% IPCC recommended default value);

MCF – Methane (CH_4) Correction Factor for aerobic decomposition (50% - semi aerobic management);

F – Fraction of CH_4 (50% IPCC default);

16/12 – molecular weight ratio – methane/carbon.

Then (Equation 2):

$$Lo = W * 0.2 x 0.5 x 0.5 x 0.5 x (16/12) = 0.033 kg CH_4 / kg waste * W (kg waste) \quad (2)$$

Regarding the nitrogen fertilizer, GHG Protocol (2016) is the reference to calculate the emission of N_2O (E_{N2O}) – see Equation 3.

$$E_{N2O}(kg of N_2O) = N_{FERT} * FE \quad (3)$$

Where:

NFERT – mass of Nitrogen fertilizer, kg

EF– Emission Factor = 0.0275 Ministério da Ciência, Tecnologia e Inovação (2010 as cited in GHG Protocol, 2016)

Moreover, according to Yokote (2003) the emission factor for the diesel is 3.39 CO_2 eq./L of diesel.

3 Results and discussion

Figure 4 shows the flowchart of the system boundary, separated by the steps of growing, fermentation and drying, with the values of mass losses and emissions (Efraim, 2009).

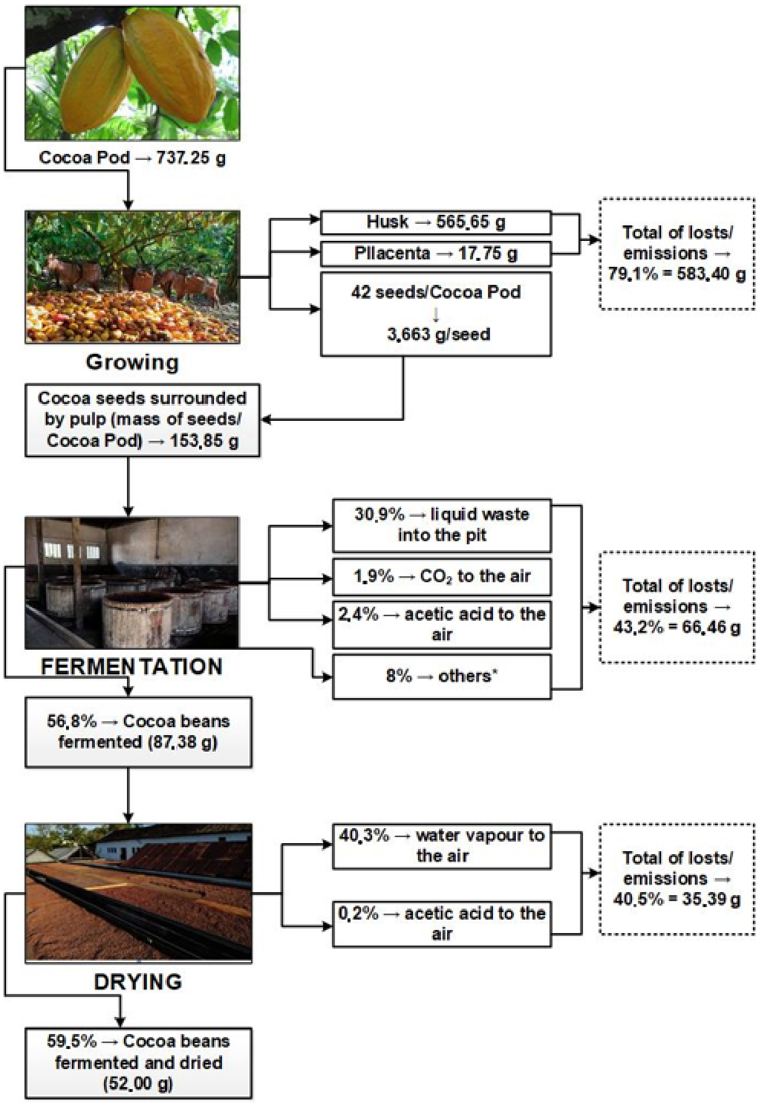

Figure 4. Flowchart of the system boundary, based on data collected in 2014, in the state of Pará, Brazil. Others* - mass reduction due to biochemical reactions that occur during fermentation.

Table 1 shows the raw data collected from the survey model applied in the three conventional farms from the state of Pará - Brazil. It is worth noting that these farms do not have certified organic or Fairtrade cocoa production.

Table 1. Raw data collected in three conventional cocoa farms from the state of Pará - Brazil.

RAW DATA	Cocoa farms (Conventional Production)		
	Farm 1	Farm 2	Farm 3
Farm area (ha)	100	270	55
Cultivation area (ha)	72	60	32
kg/ha produced	666	1167	723
Herbicide (kg)	0	40	30
Inseticide (kg)	0	10	0
Fertilizer (kg)	3000	0	20000
Diesel (L)	100	600	0
Cocoa produced (kg)	48000	70000	35000
Bags produced (60 kg)	800	1167	583
Cocoa sold as Organic or Organic-Fairtrade certified (kg)	0	0	0
Organic or Organic-Fairtrade cocoa sold as conventional (kg)	0	0	0

Analyzing the raw data collected (Table 1), the average productivity was 852 kg/ha, ranging from 666 to 1,167 kg/ha.

Table 2 shows the raw data collected in the three organic farms from the state of Pará – Brazil where there is no use of herbicides, insecticides and fertilizers.

Table 2. Raw data collected in three organic cocoa farms from the state of Pará – Brazil.

RAW DATA	Cocoa farms (Organic Production)		
	Farm 4	Farm 5	Farm 6
Farm area (ha)	97	85	20
Cultivation area (ha)	45	9	12
kg/ha produced	777	611	1250
Herbicide (kg)	0	0	0
Inseticide (kg)	0	0	0
Fertilizer (kg)	0	0	0
Diesel (L)	150	Uses carriole	No data
Cocoa produced (kg)	35000	5500	15000
Bags produced (60 kg)	583	92	250
Cocoa sold as Organic or Organic-Fairtrade certified (kg)	15000 (42.8%)	2500 (45.5%)	7000 (46.7%)
Organic or Organic-Fairtrade cocoa sold as conventional (kg)	20000 (57.2%)	3000 (54.5%)	8000 (53.3%)

Analyzing the raw data collected (Table 2), the average productivity was 879 kg/ha, ranging from 611 to 1,250 kg/ha.

Table 3 shows the raw data collected in the three organic and Fairtrade certified farms from the state of Pará – Brazil where there is no use of herbicides, insecticides and fertilizers.

Table 3. Raw data collected in three Organic-Fairtrade cocoa farms from the state of Pará - Brazil.

RAW DATA	Cocoa farms (Organic and Fairtrade Production)		
	Farm 7	Farm 8	Farm 9
Farm area (ha)	50	115	96
Cultivation area (ha)	25	30	30
kg/ha produced	600	1000	666
Herbicide (kg)	0	0	0
Inseticide (kg)	0	0	0
Fertilizer (kg)	0	0	0
Diesel (L)	Uses motorcycle	Animal traction	No data
Cocoa produced (kg)	15000	30000	20000
Bags produced (60 kg)	250	500	333
Cocoa sold as Organic or Organic-Fairtrade certified (kg)	12000 (80.0%)	25000 (83.3%)	10000 (50.0%)
Cocoa Organic or Organic-Fairtrade sold as conventional (kg)	3000 (20.0%)	5000 (16.7%)	10000 (50.0%)

Analyzing the raw data collected (Table 3), the average productivity was 755 kg/ha, ranging from 600 to 1,000 kg/ha.

Analyzing the raw data collected (Tables 1-3), the average productivity was 830 kg/ha, ranging from 600 to 1,250 kg/ha (Pará – Brazil). This coincides with the variation in average Colombian cocoa productivity (Ortiz-R et al., 2014) where the productivity ranged from 671 to 1,000 kg/ha. Gateau et al. (2012) found productivity from 177 to 909 kg/ha for cocoa (Bahia – Brazil). Gockowski & Sonwa (2011) could report a productivity of 214 kg/ha for Côte d'Ivoire and 456 kg/ha for Ghana. Considering differences in region, climate, and the incidence of diseases like "Witches' Broom" for example, this variation is expected (Efraim, 2009). It is interesting to note a good productivity in both organic and conventional production in this study.

Conventional cocoa farms use small amounts of herbicides, insecticides and fertilizers (organic cocoa does not use them). Nitrogen fertilizers contribute to the greenhouse effect due to N_2O emissions. In a study of LCA cocoa in Ghana, these fertilizers are the main contributors to the impact on cocoa production (Ntiamoah & Afrane, 2008). On the other hand, the use of organic fertilizers significantly contributes to the reducing of environmental impacts such as CO_2 eq emissions (Ortiz-R et al., 2014). In this context, the importance of organic cultivation for the environment is clear. Studies have shown that nitrogen fertilizers can also cause dependence on the soil, as they kill organisms and micro-flora that contribute to soil richness and plant development (Ecycle, 2015).

Regarding the transportation of cocoa in the field, the means used were tractor, motorcycle, animal traction and carriole, each with little or no fossil fuel.

It is also worth noting that the farms that produce cocoa with the Organic or Organic-Fairtrade labels do not sell all their products using these certifications. This makes them less profitable because they sell a part of their products as conventional cocoa. Although the value of certified products is higher, cocoa producers cannot always sell all their entire production with certification, since the sale can take longer and producers sometimes need quick cash to "pay the bills for the day".

It is also important to note that analyzed farms with Fairtrade-Organic certification sell 71% of their cocoa with certification, but farms with single Organic certification only sell 45% with certification. It can be said that the cocoa producers can sell a greater amount of cocoa using the Fairtrade system, which is mindful of economically sustainable trade and has an interest in the export market, than the single organic certification system, which has a lower commercial value in comparison.

It is noted that the farms have a total area greater than the area destined to cocoa cultivation, as shown in Tables 1-3. These farms are located in the regions of Trans-Amazon and Xingu in the state of Pará, in the middle of the Amazon rainforest, and the area that is not used for planting cocoa is associated with a preserved forest or a reforestation area with native forest.

Table 4 presents the Environmental Parameters collected of the Brazilian Cocoa produced in the state of Pará, calculated for 1,000 kg (1 ton is the functional unit) of cocoa ready for commercialization in 2014.

Table 4. Environmental Parameters - 1,000 kg of Brazilian Cocoa produced in Pará state (2014).

Environmental Parameters	Unit	Average/1t
Inputs		
Energy		
Diesel	l	1.66
Natural Resources		
Harvested cocoa pod	un	19,233.00
Herbicide	kg	0.16
Inseticide	kg	0.02
Fertilizer	kg	70.44
Land Use		
Area of the farm	ha	4.34
Cultivation area	ha	1.24
Outputs		
Solid Waste		
Husk	kg	10,618.93
Placenta	kg	333.20
Emissions to Air		
Carbon dioxide, in air/unspecified (husk)	kg CO_2 eq	973.40
Methane, in air/unspecified (husk)	kg CO_2 eq	8,849.00
Dinitrogen monoxide (fertilizer)	kg CO_2 eq	578.12
Carbon dioxide, in air/unspecified (diesel)	kg CO_2 eq	5.63
Lactic acid	kg	236.71
Acetic acid	kg	74.37
Carbon dioxide, in air/unspecified (fermentation)	kg CO_2 eq	56.22
Water vapour	kg	677.30
Emissions to Water		
Liquid waste into the pit	kg	914.31

Table 5 shows the Carbon Footprint (GHG emissions in CO_2 eq.) for the Environmental Parameters collected (Table 4).

Table 5. Carbon Footprint for the Brazilian Cocoa produced in Pará state (2014).

Emissions to Air	Unit	Average/1ton	CML 2000 (GWP100)	CO_2 eq (kg)
Carbon dioxide, in air/unspecified (husk)	kg	973.40	x 1	973.40
Methane, in air/unspecified (husk)	kg	353.96	x 25	8,849.00
Dinitrogen monoxide (fertilizer)	kg	1.94	x 298	578.12
Carbon dioxide, in air/unspecified (diesel)	kg	5.63	x 1	5.63
Carbon dioxide, in air/unspecified (fermentation)	kg	56.22	x 1	56.22
Carbon Footprint (total)				**10,462.37**
With composting of the husk (conversion of methane to carbon dioxide)				973.40 (-8,849)
Carbon Footprint (total – with husk composting)				**2,586.77**
Organic - without fertilizer (dinitrogen monoxide)	kg			(-578.12)
Carbon Footprint (total – organic and with composting)				**2,008.65**

The Carbon Footprint results in 10,462.37 kg CO_2 eq /t cocoa produced in Pará (Brazil) and, after carrying out a suitable composting process and eliminating the emission of methane, the amount of CO_2 released into the atmosphere decreased to 2.59 kg CO_2 eq/kg cocoa (a reduction of approximately 75%). Vervuurt (2019) found, on average, 3.6 kg CO_2 eq./kg cocoa (Côte d'Ivoire); Neira (2016) reported 1.63 - 1.96 kg CO_2 eq/kg cocoa (Ecuador); Ortiz-R et al. (2016) calculated 2.89 kg CO_2 eq./kg cocoa (Colombia); Ntiamoah & Afrane (2008 as cited in Ortiz-R et al., 2016) found 3.22 kg CO_2 eq./kg cocoa (Ghana). Ortiz-R et al. (2016) could report that, without an adequate composting process of the husk, the Carbon Footprint rises to 8.89 kg CO_2 eq./kg cocoa (Colombia), very close to 10.46 kg CO_2 eq./kg cocoa calculated in the present study. Bockel et al. (2021) highlighted the importance to the Food and Agriculture Organization (FAO) of the United Nations for agroforestry and sustainable Research & Development projects to decrease the Carbon Footprint. In addition, Myers (2020) reported that Barry Callebaut, an important player in the cocoa processing sector, reduced its Carbon Footprint from 3.93 to 3.65 kg CO_2 eq./kg cocoa from 2019 to 2020 linked to sustainability targets.

Based on the total world production 2016/2017 (Figure 1) and the CO_2 eq./t cocoa calculated in this study, the world Carbon Footprint of the cocoa beans production would be approximately 4.8×10^{10} kg CO_2 eq. By eliminating the emission of methane, after performing an appropriate composting process, the amount of CO_2 released into the atmosphere decreased to 1.2×10^{10} kg CO_2 eq (75% of reduction = 3.6×10^{10} kg CO_2 eq).

It is important to note that cocoa cultivation, in a production cycle of 40 years, fixes the carbon in the soil maintaining a stock of approximately 90 t C/ha from year 25 to 40 with a sequestration rate of approximately 3.6 t C/ha from year 1 to 25 (Gockowski & Sonwa, 2011).

Jacobi et al. (2014) could state that:

- total carbon stock in simple agroforestry systems was about 128 t C/ha (about 60 t C/ha in soil, 35 t C/ha in shade trees and the difference in biomass below ground);

- monoculture stored significantly less carbon (about 86 t C/ha with about 55 t C/ha in soil, 2 t C/ha in shade trees and the difference in biomass below ground);

- organic farming practices in general and agroforestry in particular were often seen as having greater potential for carbon sequestration than common agricultural practices and were also often seen as making positive contributions to agrobiodiversity and natural biodiversity.

Albrecht & Kandji (2003) concluded that perennial systems like agroforests can store and conserve considerable amounts of carbon in living biomass and in wood products. Carbon sequestration in soils is also relevant by implementing agroforestry practices (around 95 t C/ha in soil and biomass).

It is worth noting that the Carbon Footprint was calculated with a focus only on the data collected on the farms surveyed in that specific year, not considering other emissions or temporality (Bessou et al., 2014).

Other important fact is the possibility of obtaining carbon credits (1,2 U$/t CO_2 eq), which could even help to pay for "solar compost bins" to the "family farmers". Other source of funds to finance the development and availability of these "solar compost bins" for the small family farms would be the chocolate industry and/or industries that uses certified cocoa/chocolate and/or “reduced Carbon Footprint chocolate/cocoa” (Kimura et al., 2010).

If the chocolate industry e/or industries that uses chocolate started to use a Self-Declaration Environmental label indicating the Carbon Footprint reduction on their product package, they would add value to the product and promote Sustainable Development, and possibly increase sales to the "more sustainable consumers" who cares about a lower impact of the product in the environment (greenhouse effect), also improving the incomes of these family farmers.

4 Conclusions

Environmental impact assessment methods serve as a reference in environmental studies to determine more accurately the significance of an environmental change. There are some stages of harvesting, fermentation and drying that can be improved to lower the environmental impact, especially when looking at the CO_2 eq. released into the atmosphere (10.46 kg CO_2 eq./kg cocoa produced in Pará- Brazil). A planned composting method replacing the husk disposal procedure as fertilizer reduces methane emission and greenhouse effect to 2.59 kg CO_2 eq./kg cocoa (approximately 75% of reduction). The non-use of nitrogen fertilizers can contribute to the reduction of environmental impacts, being beneficial to the environment and improving the cultivation of organic products, as the removal of fertilizers in the process promotes a reduction in CO_2 emissions. Therefore, eliminating the use of nitrogen fertilizers and implementing an efficient composting method reduces the Carbon Footprint of cocoa produced in Pará (Brazil) to 2.01 kg CO_2 eq./kg cocoa (a total reduction of approximately 81%).

Another point of contention lies in the fact that the farms that have certified cocoa are not getting the profit due to difficulty selling 100% of their certified product. Therefore, is necessary the implementation of socio-economic policies for a better distribution and dissemination of cocoa certificates. This would ensure the return of aggregated value, because, as noted, products that generate lower environmental and social impacts benefit the producer, the consumer, and the environment.

It is important to remember that Carbon Footprint studies are dynamic and the data can always be refined, substituted or complemented with updated information to improve the representativeness of the analyzed sector. Based on this study, the cocoa sector in Brazil can quantify the benefits of future actions on sustainable (environmental and socio-economic aspects) improvement in cocoa production.

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