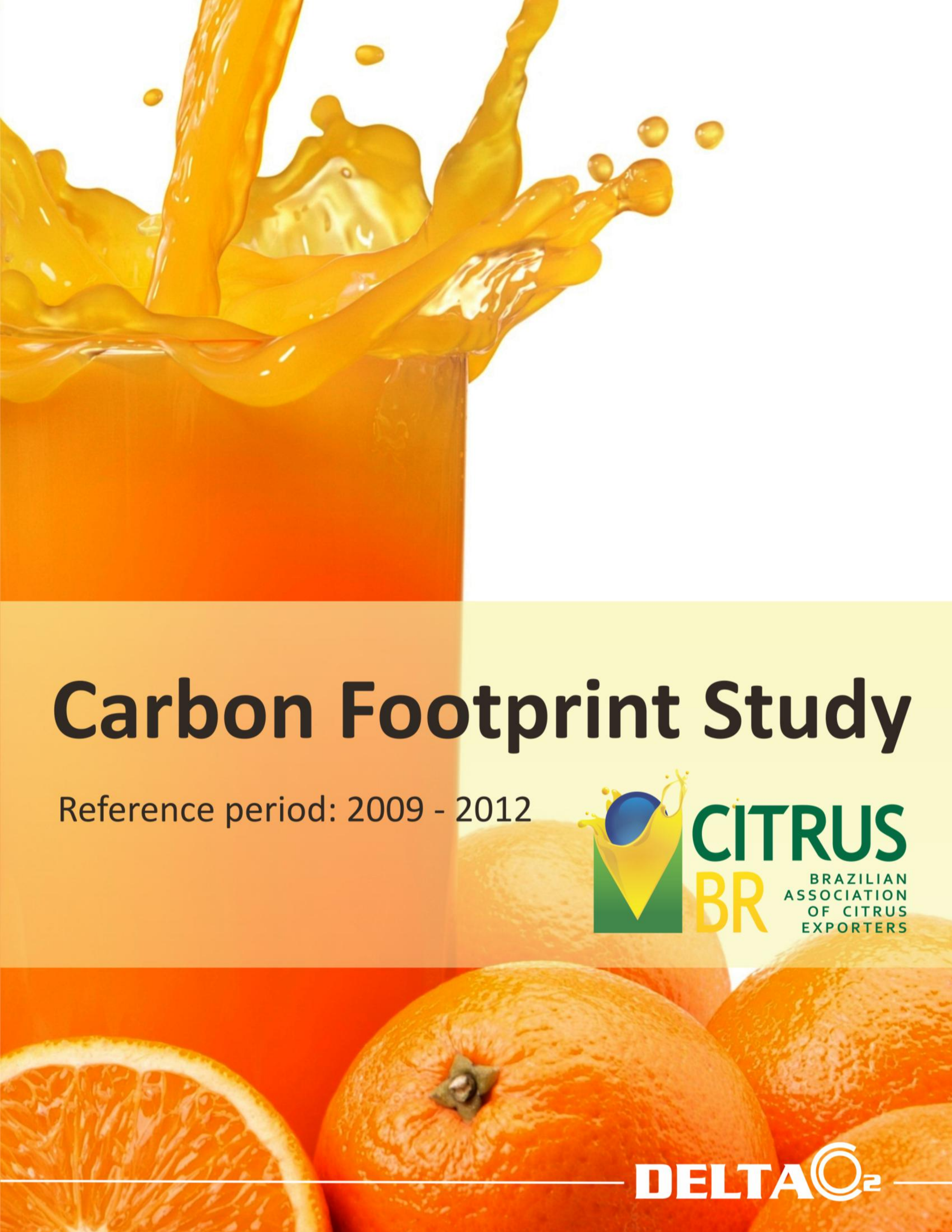

Carbon Footprint Study

Reference period: 2009 - 2012

CITRUS BR
BRAZILIAN ASSOCIATION OF CITRUS EXPORTERS

DELTA CO2

Report for

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DeltaCO2 started its activities in 2008 as a spin-off environmental consultancy from University of São Paulo, in the city of Piracicaba/SP.

Since its foundation the company has made calculations of the carbon footprint of agricultural products and greenhouse gas (GHG) inventories based on internationally recognized methodologies and protocols.

Pioneer in Brazil DeltaCO2 also designs detailed inventories for companies that need to quantify GHG emissions of their products and services. It also develops specific emission factors by direct measurements in situ, providing greater reliability to the results.

DeltaCO2 aims to quantify indicators of environmental sustainability, soil quality, GHG emissions, water use and quality and biological diversity.

DeltaCO2 inspires confidence and provides its customers with transparency, visibility and greater competitive advantage.

REPORT CONTENTS

EXECUTIVE SUMMARY

This report presents the chronology of actions, main results and lessons learned from the assessment of greenhouse gas (GHG) emissions and the carbon footprint of the orange juice produced and exported by companies associated with CitrusBR (Cutrale, Citrosuco/Citrovita and Louis Dreyfus) in the period 2009 - 2012. The functional units evaluated by companies were one liter of pasteurized orange juice not from concentrate (NFC) and one liter of frozen concentrated juice (FCOJ), both 11.5º Brix, delivered at the ports of Ghent, Belgium, and Rotterdam, Netherlands. The verification procedures of the calculations were performed using the latest versions of PAS 2050, GHG Protocol and ISO 14040/44, internationally accepted standards and protocols for studies of the life cycle of products with focus on GHG emissions. Emissions of carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) were expressed in CO_2 equivalents (CO_2e) according to their global warming potential. The methodology used by companies to estimate emissions considered collection of activity data, followed by multiplying these by specific GHG emission factors. We evaluated emissions related to the production of raw material, industrial processes and external logistics. Additionally, an extensive literature review compiled the major strategies for reducing GHG emissions in the citrus sector.

I. International standards

The establishment of the boundaries of the study, calculation of GHG emissions and verification procedures were performed in accordance with the main international protocols and standards used today:

- 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Intergovernmental Panel on Climate Change (IPCC), United Nations Framework Convention for Climate Change (UNFCCC).
- ISO 14040:2006 Environmental management - Life cycle assessment - Principles and framework.
- ISO 14044:2006 Environmental management - Life cycle assessment - Requirements and guidelines.
- PAS 2050:2011. Publicly Available Specification (PAS) 2050. Specification for the assessment of the life cycle greenhouse gas emissions of goods and services. BSI – British Standards.
- ISO 14064-1:2006, Greenhouse gases – Part 1: Specification with guidance at the organization level for the quantification and reporting of greenhouse gas emissions and removals.
- 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).
- GHG Protocol Product Life Cycle Accounting & Reporting Standard, 2011. World Resources Institute (WRI) e World Business Council for Sustainable Development (WBCSD).

II. Goal of the study

The study of the greenhouse gas (GHG) emissions and the carbon footprint of the orange juice produced and exported by CitrusBR arose as a demand from the AIJN (European Fruit Juice Association). In 2010, companies associated with CitrusBR (Cutrale, Citrosuco/Citrovita and Louis Dreyfus) worked together with expert advice of the consultancy *DeltaCO2 - Environmental Sustainability* for calculating the carbon footprint of the orange juice produced in the year of 2009.

The pioneering study in Brazil and the pursuit of CitrusBR of a better understanding of issues related to the sustainability of the production of orange juice exported to Europe, has made the study an annual commitment, with the last results presented for the year of 2012.

During the process, the results were reported annually to AIJN and were continuously evaluated by the Sustainability Team of CitrusBR. Since orange juice is a product of agricultural origin GHG emissions were evaluated by a minimum of four years in order to neutralize variations related to climate and market conditions. Thus, CitrusBR reaches the year 2013 with one of the most comprehensive studies of emissions associated with the orange juice production in Brazil.

Finally, we performed extensive literature review and compiled the main strategies for mitigation of GHG emissions in the citrus sector.

III. Scope of the study

The functional units evaluated by companies were one liter of pasteurized orange juice not from concentrate (NFC) and one liter of frozen concentrated juice (FCOJ), both 11.5º Brix, delivered at the ports of Ghent, Belgium, and Rotterdam, Netherlands.

The survey of activity data conducted by the companies included the various stages of the production chain, with the production of oranges in the orchards, as well as the juice industrial processing stage. The study also covered emissions related to the transport of oranges from orchards to factories, the orange juice to the port of Santos in Brazil, and the shipping of juice to the ports of Ghent and Rotterdam.

To calculate the carbon footprint we considered the following GHGs: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). In the case of fossil fuels, we considered emissions of CO_2, CH_4 and N_2O. For biomass fuels (bagasse, ethanol and biodiesel), were included only emissions of CH_4 and N_2O, taking into account that the biogenic CO_2 is absorbed by the next crop through the process of photosynthesis.

The methodology used by companies to estimate emissions considered collection of activity data, followed by multiplying these by specific GHG emission factors. The results for the gases CH_4 and N_2O were converted into CO_2 equivalent, considering the Global Warming Potential (GWP) of each gas, following the Fourth Assessment Report (AR4) of the IPCC (2007).

A description of each of the major steps considered by the companies in the production and distribution of orange juice, detailing the sources evaluated, is presented bellow:

Production and transportation of oranges

- Fuels used in farm vehicles;
- Fuels used in vehicles to transport workers to harvest orange;
- Nitrogen fertilizer application;
- Lime application;
- Application of organic fertilizers;
- Electricity consumed on farms;
- Fuels in vehicles to transport oranges to processing factories;
- Indirect emissions in the production and transportation of agricultural inputs and fuels.

Processing and transportation of orange juice – Brazil

- Stationary combustion in boilers and generators;
- Electricity consumed in factories and storage terminals in Santos;
- Fuel used to transport juice from factories to the port of Santos;
- Indirect emissions in the production and transportation of industrial raw materials and fuels.

Transportation of orange juice - Europe

- Fuels used on ships that transport orange juice to Europe;
- Electricity used to storage the orange juice in Europe.

IV. Life cycle stages

The various steps of the production chain evaluated by companies were later compiled into three main phases, described below:

1. **Raw Material** - Includes seedling production, planting, cultivation, fertilization, harvesting and transport of fruit to the industrial plants.
2. **Industrial Processes** - Includes receiving the fruit, processing, pasteurization or pasteurization + concentration, storage at the plant, road transport to and storage at the Brazilian port (Santos).
3. **External Logistics** - Includes the transport of juice to European ports in Belgium and the Netherlands, and the storage of juice at the port of destination.

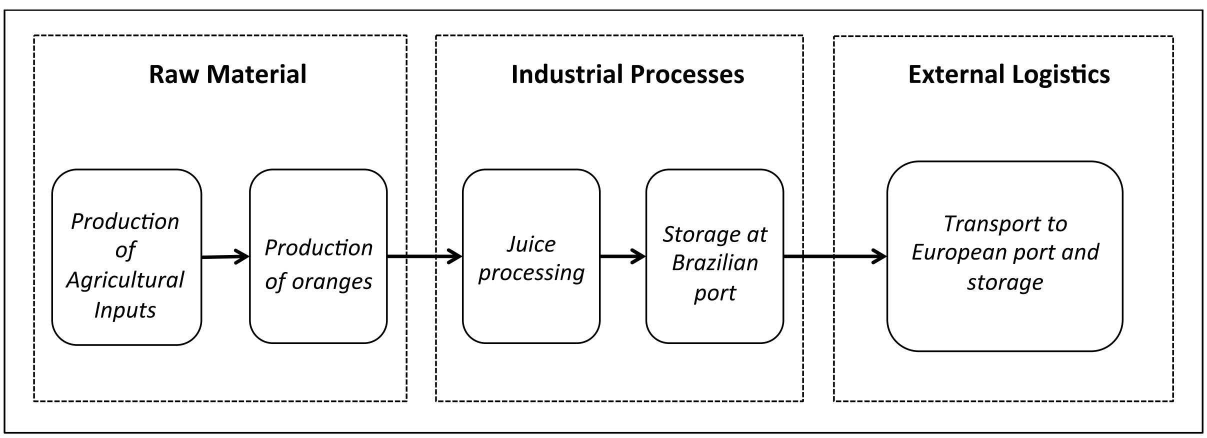

Figure 1. Involved processes, systems boundaries and life cycle stages in the carbon footprint of the orange juice produced in Brazil and exported to Europe.

V. Verification procedures

The verification process for the calculation of GHG emissions and carbon footprint of the orange juice produced by companies associated with CitrusBR was based on the analysis of Excel spreadsheets sent by representatives of the companies to DeltaCO2 or through physical meetings in the between the parts.

DeltaCO2 consultants verified the spreadsheets with focus on the procedures of calculations and accordance with the standards and methodologies mentioned above. The emission factors used were also checked and, when necessary, were updated and reported to the companies.

DeltaCO2 was not responsible for checking the quality of the activity data collected and reported by the companies, being the verification process restricted to the GHG calculation, allocation procedures and emission factors used.

Nevertheless, since DeltaCO2 worked directly with each of the companies, there was a continuous feedback between the parts with regard to the principles employed for the calculations in each study. Thus, it was possible to ensure better homogeneity in the inventories and more reliable results.

VI. Challenges and opportunities for GHG mitigation in the orange juice industry

The four-year study on the carbon footprint of the orange juice produced and exported to Europe by companies associated with CitrusBR allowed the identification of several hotspots regarding greenhouse gas emissions in the production chain. Therefore, we performed an extensive literature review to identify the main challenges and opportunities for GHG mitigation in the orange juice industry.

1. Nitrogen fertilizers

The application of nitrogen fertilizers is essential for increasing productivity in citrus orchards. In adequate amounts, nitrogen applied to orange plants favors growth and fruiting. However, nitrogen fertilizers also contribute to the emission of large quantities of nitrous oxide (N_2O) into the atmosphere.

N_2O is an important greenhouse gas (GHG) because of its high global warming potential (GWP), about 300 times greater than carbon dioxide (CO_2), this enhances the degree of importance of the issue in agricultural systems.

To provide greater environmental sustainability to production systems, some actions should be considered in order to mitigate GHG emission and still meet nutritional requirements and maintain good levels of productivity in the orchards:

1.1. Type of fertilizer

Preliminary studies indicate that the application of urea, which has a high concentration of nitrogen (45%), results in greater N_2O emissions when compared to other synthetic nitrogen sources - such as ammonium nitrate and ammonium sulfate (Matson et al. 1996). Urea also contains carbon in its composition and, after the reaction in the soil, this carbon is emitted as CO_2 (Serrano-Silva et al., 2011). The substitution of urea by other nitrogen sources can thus contribute to the reduction of GHG emissions.

Pepsico has developed research in Florida on the agronomic efficiency of nitrogen fertilizers called "low carbon", produced by processes with lower energy use and use of renewable energy. These inputs will have lower upstream emission factors, which can result in lower GHG emissions.

1.2. Application methods

The recommendation of surface distribution of fertilizers is based on several studies that tested various types of fertilizers and concluded that it is preferable to apply the fertilizer on the soil surface and under the plant canopy.

From the environmental point of view, studies have shown that surface application of nitrogen in the soil results in higher N_2O emissions to the atmosphere. Therefore, when possible this method of application should be avoided. An alternative would be application in furrows, injected or drip, which can significantly reduce N_2O emissions.

1.3. Doses

The fertilizer recommendation for citrus orchards should be made taking into account that there is always need for adjustments of the quantities of fertilizers used according climate, soil, plant varieties, plant age, the presence of pests and the management systems used in each orchard.

Knowledge of these aspects is very important because if the actual needs of each orchard are not respected, the indiscriminate use of fertilizers can cause problems such as unnecessary expenses, nutritional imbalances and phytotoxicity of nutrients applied in excess for one or more years (Koller, 2008).

Besides the aspects mentioned above, several studies have reported that there is a direct relationship between the dose of fertilizer added to the soil and N_2O emissions to the atmosphere (Khalil et al., 2004, Liu et al., 2005; Ruser et al., 2006 Signor, 2010). Therefore, the application of the dose that matches the nutritional needs of the orchard, without excess, can contribute to reducing these emissions.

1.4. Urease and nitrification inhibitors

A potential practice for reducing GHG emissions from the soil is the use of chemical additives to temporarily inhibit the enzyme urease when urea is applied on the soil surface. The use of additives should be considered when urea cannot be incorporated, particularly when the soil pH is high or where residues remain on the soil surface (Barth, 2009).

Nitrification inhibitors can also be used with urea in areas where the potential for leaching and denitrification of nitrate are high (Cantarella, 2007). However, one must consider the effect of these additives still needs to be verified and validated by field experiments on Brazilian soil conditions and climate.

Some of the companies associated with CitrusBR began testing the use of fertilizers and inhibitors and some results have shown the potential of this practice on reducing GHG emissions. However, the economic viability of such practices must be evaluated, since these fertilizers could represent an increase in the production costs.

The table below presents an exercise on the potential reduction of GHG emissions from fertilizers with the use of inhibitors:

Table 1. Reduction of emissions with the use of fertilizers with inhibitors.

Fertilizer/Inhibitor	Dose (kg/ha)	%N	Total (kg CO_2eq)	% of reduction
Urea	100	45	352.55	
Urea (2.5%)[a]	100	45	290.17	**- 18%**
Urea (5%)[b]	100	45	275.74	**- 22%**

[a,b] Urea with 2.5% and 5% of urease inhibitor.

1.5. Organic fertilizers

Organic sources and biofertilizers have lower upstream emissions in their production, since synthetic fertilizers are energy intensive (high emissions per unit of product). The emissions for the transport of fertilizers are also reduced when nutrient sources are located on farms or in the vicinity, such as in organic residues composting.

In a study on the production and use of organic fertilizers in citrus orchards in Egypt, Luske (2010) found that when the crop is fertilized with organic compost the carbon footprint is 162 kg CO_2/ton. When nitrogen fertilization occurs with ammonium nitrate carbon footprint is about thirty times larger, with a value of 1813 kg CO2e/ton. Studies have reported that N_2O emissions are also lower when organic compost is applied, besides promoting carbon sequestration in the soil (Saft and Kortmann, 2004; Luske and Van der Kamp, 2009).

2. Diesel

Biofuels are seen by environmentalists and government leaders as one of the most promising alternatives to reduce our dependence on fossil fuels and GHG emissions to the atmosphere (Farrell et al., 2006; Ragauskas et al., 2006) . Thus, the replacement of fossil fuels with biofuels such as biodiesel, ethanol and biomass power generation in generators or use by agricultural machinery results in a viable alternative to reduce these emissions.

3. Lime

Liming is on of the first practices to be adopted in future orchards because of its effects in controlling acidity (decreasing nutrient leaching and aluminum toxicity, providing calcium and magnesiu, and improving soil structure and microbial activity). Besides the dose and type of lime, it is important to pay attention to other application factors – e.g. climate conditions.

This practice should be done after detailed soil analysis, applying only the recommended amount, thus reducing the CO_2 emissions to the atmosphere. Lime with higher reactivity is used in smaller quantities, also lowering CO_2 emissions.

4. Pesticides

The rational use of pesticides may contribute directly to the reduction of GHG upstream emissions associated with the production and distribution of these inputs. The Integrated Pest Management (IPM) allows for a more adequate use of pesticides, avoiding investments in excess or in inappropriate time. When pesticides are used inappropriately they can cause damage to the health of people and animals, and also cause serious environmental problems.

The use of alternative pesticides and natural products can in some cases replace products with higher GHG upstream emissions. Additionally, the use of biological pest control reduces the amount of pesticides used and the associated emissions.

5. Electricity

Of all the activities that generate greenhouse gases, the energy sector is one of the largest contributors to global warming in the world. However, this scenario is different in Brazil.

The world electricity matrix is composed mostly by fossil fuels, mainly petroleum, coal and natural gas (IEA, 2009). In Brazil, however, the high share of renewable energy in the electricity matrix – i.e. hydroelectricity, ethanol mixed in gasoline and bagasse from sugar cane - make the GHG emissions from this source relatively small.

There are a variety of opportunities to reduce greenhouse gas emissions associated with electricity generation, transmission, and distribution. The orange juice industry in Brazil is using a great share of bagasse from sugar cane as a renewable energy source rather than fossil fuels to generate electricity. This action has a great potential on reducing the GHG emissions in the processing stage of the orange juice production. However, it is possible that in the next years the industry will face a decrease in supply of bagasse with the increase in the second-generation ethanol production in Brazil.

6. Main GHG emission hotspots and mitigation strategies

Below we present a table that summarizes the main GHG emission hotspots identified and the potential mitigation strategies associated:

Table 2. Main GHG emission hotspots identified in the orange juice carbon footprint study and the potential mitigation strategies associated.

GHG emission hotspots	Mitigation strategies
Synthetic fertilizers	• Efficient use of agricultural inputs, adjusting the dose, time of application, type of fertilizer and application methods to obtain the maximum benefit, avoiding waste. • Reduce the use of synthetic inputs (which cause high upstream GHG emissions), favoring the use organic sources.
Urease and nitrification inhibitors	• Use of chemical additives that temporarily inhibit the enzyme urease when urea is applied on the soil surface.
Organic fertilizers	• Promote waste composting inside the orchards, taking advantage of organic matter and nutrients available, thus avoiding GHG emissions in the production and transport of inputs.
Electricity	• Use of renewable energy sources to generate electricity.
Fuels	• Replace fossil fuels with biofuels such as biodiesel, ethanol and biomass.
Pesticides	• Rational use of pesticides may contribute directly to the reduction of GHG upstream emissions.

VII. Opportunities for soil carbon sequestration

Farmlands, be they for annual crops or other agricultural vegetation such as orange plantations, cover vast quantities of the globe's land surface area and exist under a range of climatic conditions. As recognised by the IPCC, agricultural systems contain large carbon reserves and have considerable potential to support mitigation actions through soil carbon sequestration.

It is widely accepted that carbon storage (both in soils and standing biomass) holds a potentially significant mitigation opportunity for fruit crops. However, there are few data available for carbon sequestration in soils under different orange cultivation systems.

Thus, we encourage companies to calculate sequestration as part of their GHG quantification activities and report the results as recommended by the GHG Protocol Guidelines. Below we present two major strategies that can contribute with soil sequestration in orange orchards:

1. Soil management and tillage

Soil tillage operations such as plowing, harrowing and subsoiling result in reduction of soil carbon stocks and emissions of CO_2 to the atmosphere due to the process of mineralization of soil organic carbon (Reicosky et al., 1999). The magnitude of carbon losses as CO_2 is directly related to the intensity of soil disturbance by the implements used. Thus, depending on the type of management, soils can be an important source or sink of carbon to the atmosphere (Lal et al., 1995; Bernoux et al., 2005).

Reduced tillage and soil conservation management are considered good alternatives to conventional agricultural practices. These systems minimize soil disturbance, enabling the maintenance or increase of soil carbon stocks (Kern and Johnson, 1993; Reicosky and Linstrom, 1993, Silva-Olaya, 2010).

2. Cover crops

Maintaining ground cover with cover crops has a number of agronomic benefits such as improving physical, chemical and biological soil properties, erosion control and nutrient supply to the orchard (Matheis et al., 2006). Also, they can promote an increase in nitrogen and soil carbon through decomposition of biomass and roots.

VIII. Final considerations

CitrusBR supports transparent communication of important data related to indicators of sustainability, working to find solutions that include all stakeholders and promotes the adoption of scientific knowledge to support strategic decisions and face eventual barriers to international trade.

The carbon footprint study of the orange juice produced and exported by CitrusBR represent a pioneer initiative in the Brazilian industry and now, after 4 years, is one of the few long term studies in the orange juice sector.

CitrusBR has a commitment to increase transparency, seeking constant improvement in terms of environmental, economic and social sustainability.

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