STUDY ON CARBON AND WATERFOOTPRINT FOR SUSTAINABLE ORANGE PRODUCTION FOR ORANGE JUICE IN FAIRTRADE COOPERATIVES IN BRAZIL

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Please note: *This baseline study looks into carbon footprints of the same crop (oranges) from different sites with different soils and production approaches. Due to site-specific and often differing soil types, physical/chemical parameters (e.g. water regime, temperatures, porosity, degrees of acidity or salinity and others) as well as site-specific crops grown under a specific production approach (e.g. organic or conventional), carbon footprints of agricultural crops cannot easily be compared. Only if at least most of the above mentioned parameters are much alike, carbon footprints of the same agricultural crop from different sites could to some extent be comparable. Furthermore, to the best of our knowledge, there are no existing comparable studies on the carbon footprints of orange production one could relate to. Due to this, results have to be interpreted with caution and within the respective contexts.*

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1. Introduction

In Brazil, significant efforts are underway to combat climate change through comprehensive decarbonization initiatives. A key focus involves implementing rigorous measures to control deforestation, recognizing its pivotal role in carbon emissions and the broader ecological balance. The country emphasizes sustainable forest management and preservation, acknowledging the importance of biodiversity and aiming to curtail its carbon footprint.

A critical aspect of Brazil's decarbonization strategy involves transforming consolidated forests thoughtfully. Rather than allowing these areas to succumb to destructive practices like deforestation for pasture conversion, the country is exploring sustainable alternatives. The objective is to strike a delicate balance between accommodating agricultural activities and preserving the environment, ensuring a harmonious coexistence between human needs and ecological health.

The transformative period had started lightly in mid-60th and hardened in the early 80ths. This period had marked a significant shift in Brazil's agricultural landscape, primarily driven by emphasis on modernization of processes inputs, as biotechnology research acceleration, more intensively use of fertilizers and pesticides and new technologies for farming. The resulting improvements in efficiency and output contributed to elevated living standards and increased life expectancy[1] by one hand, but as a contradictory process, also brought meaningful changes to the rural space, as the reduction of the sources of food diversification squeezed by the monoculture production of commodities, and consequently contamination and exhaustion of natural resources, at the point of the expulsion of small holders from their spots to sum up the army of minimum wage worker around the industrialized cities. The modernization of agriculture in Brazil (academically called as "green revolution") conducted a symbiotic relationship with giant food production chains (the agrifood system[2]) financed exclusively by public-State revenue. The increased efficiency in farming processes generated higher yields, meeting the demands of a burgeoning food production industry. This interdependence between technological progress in agriculture and the food supply chain played a pivotal role in shaping Brazil's agricultural landscape nowadays.

Globally, the pursuit of nutrition is intricately linked to agricultural activities, guided by specific strategies that reflect an ongoing pressure to commit with adopt sustainability practices. Protein and carbohydrates stand out as the cornerstone of global nutrition, shaping the foundation for nourishing a growing global population. Agricultural endeavors worldwide are strategically aligned to produce these essential components, recognizing the paramount importance of meeting nutritional needs while mitigating environmental impact.

The mainstream of agriculture in the world are – at the start point - considered as environmentally unsustainable systems, as they present several factors that threaten the reproduction of ecosystems and natural resources, contributing to increasing environmental deterioration, loss of biodiversity and contamination of soil and water. In general, the impacts of Agri-food Systems on natural resources are worrying, from the point of view of sustainability and resilience, as these activities contribute to 29% of greenhouse gas emissions, 80% of forest deforestation, with 70% of fresh water used and 80% of the

[1] for further information about the importance of endogenous forces which boosted Brazil in the generation and improvement of varieties of plants and animals, (in relationship between the regime of appropriation of genetic technology and the Brazilian institutional tradition of research in this area) see: Shiki, S.,1991

[2] for agrifood system and agro-industrialization, distribution, storage and marketing, and, finally, consumption of food generated within the different value chains. To integrate these complex gears, different types of services are mobilized: teaching, research and knowledge, agricultural innovation and technology, financing and technical assistance and rural extension, agricultural certification, infrastructure and logistics, communication, and information, etc. For further information see: Friedmann, H.,1982.

loss of biodiversity across the planet (United Nations, 2023). From a social and cultural point of view, its effects have caused the deepening of social inequalities and rural and urban poverty, since there is a profound asymmetry within populations in being able to equitably acquire the food that reaches the markets.

In the Brazilian hegemonic agrifood system, this global nutritional effort pursues three key strategies which steer the course towards a more sustainable and abundant supply of essential nutrients. Firstly, biotechnology plays a crucial role by contributing to the development of high-yield varieties, enhancing the efficiency and productivity of agricultural processes. Secondly, the continuous expansion of cultivated areas remains a driving force, responding to the ever-growing demand for food resources. Thirdly, a pivotal aspect is the control of deforestation and the repurposing of already deforested lands, transforming them into croplands that serve as vital feedstock for global nutrition. That set of strategies are shaped overall by the “ethic and esthetic[3]” given by the increasing critics against the scaled way of food production and how much this system controls the diet of population in wide world.

These three interwoven strategies collectively form a comprehensive approach to address global nutrition challenges. By integrating technological advancements, sustainable land use practices, and environmental conservation efforts, the global community strives to ensure that agricultural activities not only meet the nutritional demands of the present but also contribute to the long-term health of the planet.

Brief Hindsight into Environmental Dilemmas

Deforestation played a pivotal role during the historical process of colonization and emancipation in Brazil, with economic expansions in the late 19th and early 20th centuries further fueling it. The 1960s saw the construction of Brasília, accelerating colonization in Brazil's Midwest and prompting regulatory frameworks for environmental protection. The military regime (1964-1985) intensified Amazon occupation, despite the enactment of environmental protection laws.

The Agroindustrial Complexes (AC) in the late 1960s integrated rural areas into the national and global food industry, receiving substantial government investments. This marked the "green revolution" in Brazilian agriculture, enhancing food security but contributing to large-scale deforestation. Extensive investments in science, technology, and institutions like EMBRAPA - Brazilian Agricultural Research Public Corporation - played a crucial role.

The Brazilian economic integration and commodity production expansion has been seen as the cornerstone of Brazil's economy. The rapid shift from a predominantly rural to an urban society within a decade was driven by increased agricultural productivity, expanded cultivation areas, and intensive agrochemical use. However, this transformation brought environmental, social, and public health challenges, including deforestation, pollution, rural migration, increased poverty, slum growth, and a surge in processed food consumption.

Over the past 30 years, about 80% of Brazil's emissions were attributed to deforestation and land use for cattle ranching, emphasizing the need to address these issues in greenhouse gas reduction strategies. The article concludes by highlighting the crucial challenge of balancing economic development with environmental preservation in Brazil's fight against climate change.

[3] See: Boltanski & Chiapello (2018). In this book it is discussed the importance of the upward movement given by the new and alternatives markets of food. The aesthetic critics took an important rule in the development of healthier food like organic, short circuit of food and all the package of sustainable practices like the Slow Food movement in urban spots. The target of this aesthetic and ethic critics have been placed by the global food chain, which are runned by the dominant drivers of the food system.

Holistic Approach to Sustainable Land Use

The intricate relationship between deforestation and CO_{2eq} emissions is closely linked to the disruption of vital life cycles in nature. Historically practiced in Brazil, deforestation continually impacts ecosystems and disrupts delicate balances. Phenolic compounds, crucial components of soil organic matter, play a pivotal role in carbon sequestration. When plants perish, their organic matter, rich in phenolic compounds, contributes to the formation of soil organic matter. This becomes essential in capturing carbon within the soil, preventing its release into the atmosphere as carbon dioxide (CO_2). The significance of agricultural practices cannot be overstated, as responsible management promotes soil quality, indirectly fostering carbon sequestration. Therefore, understanding and addressing the relationship between deforestation and these ecological elements are dominant for sustainable land use and effective climate change mitigation strategies.

Deforestation, a historical practice in Brazil, disrupts vital life cycles in nature, profoundly impacting ecosystems. In this context, the role of phenolic compounds in soil organic matter and carbon sequestration becomes pivotal, emphasizing the need for a nuanced understanding of ecological dynamics.

Conservation agriculture practices, ranging from promoting ground cover and tannin-rich materials to composting with agricultural residue and embracing agroforestry systems, emerge as proactive measures to counteract the adverse effects of deforestation. These practices not only enhance soil quality but also contribute to carbon sequestration, forming a crucial part of sustainable land use strategies.

Simultaneously, minimizing pesticide use and fostering soil microbial life play significant roles in mitigating the ecological impact of deforestation. Reducing broad-spectrum pesticide use positively influences soil microbial life, promoting plant residue decomposition and enriching the soil. Responsible pesticide management becomes integral to maintaining a healthy soil ecosystem, indirectly contributing to carbon sequestration.

Furthermore, recognizing the importance of native vegetation and ecosystem restoration is crucial in the battle against deforestation and its associated emissions. Legally protected areas act as crucial carbon sinks, preserving biodiversity and supporting sustainable land use. Restoration efforts in water ecosystems, including wetlands and riverbanks, not only contribute to carbon sequestration but also play a vital role in water purification and aquifer replenishment. Therefore, the synergy between these diverse elements -from conservation agriculture to reduced pesticide use and ecosystem restoration - forms the foundation for a holistic approach to address the challenges posed by deforestation and promote sustainable land use practices.

In navigating the transition toward a low-carbon agriculture sector, the commitment and determination of producers are paramount. The market mechanism, evaluating ecosystem benefits and carbon sequestration, operates as a pivotal incentive for producers, offering both direct benefits for them and indirect advantages for society and the planet. This journey requires a comprehensive plan and effective tools, with organic and sustainable certification programs emerging as key solutions to guide producers in adopting sustainable land use practices. By intertwining proactive measures against deforestation, the promotion of soil health, and the evaluation of ecosystem benefits through market mechanisms, we pave the way for a harmonious coexistence between agricultural productivity and environmental preservation.

Sustainability certifications

Sustainability certifications, encompassing organic and environmental certifications, promote eco-friendly farming practices like crop rotation, soil conservation, and tree cultivation, enhancing soil's carbon sequestration capacity. They mandate efficient plant residue use, cover crop cultivation, and conservation of native vegetation. Certifications set limits on fertilizers and pesticides, mitigating soil degradation and greenhouse gas emissions. Monitoring and traceability track practices' impact on carbon sequestration, with educational components promoting sustainable agriculture.

These certifications create market opportunities for certified products, encouraging farmers to adopt carbon sequestration practices. Functioning as guidelines and incentives, agricultural certification plays a pivotal role in climate change mitigation and resource conservation, shaping sustainable agricultural and industrial practices through governance structures that define criteria, conduct audits, and ensure system integrity and reliability.

The Water Footprint

The synergy between sustainability certification and water footprint calculation lies in their shared objective of ensuring adherence to stringent environmental and social standards in agricultural practices. While certification sets the overall framework for sustainable practices, water footprint calculation quantifies the water use associated with a product, process, or activity, aiding in the assessment of its impact on water resources. Estimating the water footprint provides an indicator for enhancing both natural and artificial water systems, influencing restoration strategies and improvements in irrigation processes and technologies.

The Water Footprint, expressed in terms of *volume per year* and *produced unit of agricultural crop*, encompasses various forms of freshwater use, consumption, and pollution. It considers both **direct and indirect** consumption, including rainwater, soil moisture, and contaminated water during the analyzed process. The three components of the Water Footprint—Green, Blue, and Grey[4]— provide a comprehensive perspective on water usage and pollution. This combined approach empowers producers and companies to measure, monitor, and enhance their environmental performance, promoting sustainable agricultural practices, reducing water resource wastage, and minimizing impacts on aquatic ecosystems. In essence, it contributes to responsible water management and fosters the long-term sustainability of agricultural production.

- [4]**Green Water Footprint:** This component represents water from rainfall or soil moisture and is particularly significant in agricultural products. It reflects the amount of water that is naturally available in the soil and contributes to the growth of crops without additional irrigation.
- **Blue Water Footprint:** This consists of surface or groundwater and includes water extracted from freshwater sources for irrigation or other purposes. It represents the direct consumption of freshwater resources.
- **Grey Water Footprint:** This component reflects the amount of water required to dilute pollutants to acceptable levels in water bodies. It accounts for the water needed to assimilate pollutants released during the production process, helping to measure the environmental impact on water quality.

The Cool Farm Tool

This study aims to present the results of carbon emissions and water footprint estimates in the production of oranges for orange juice by a group of producers, including both organic and conventional, from four Fairtrade certified cooperatives.

The methodology employed for these estimates utilizes the Cool Farm Tool, which simultaneously considers three widely recognized "scopes" concerning greenhouse gas emissions. The specific scopes addressed by the tool are elaborated upon below:

- Scope 1 encompasses direct emissions and emissions removal (sequestration) occurring within the farm boundaries or under the ownership and control of the farmer. This scope covers various aspects, including fuel and energy consumption (both on-farm and contracted), soil management practices, incorporated crop residues, fertility and biomass inputs, and land use changes. The tool also addresses enteric fermentation of livestock, livestock manure management and storage and carbon sequestration by forests, not relevant for this study who refers to tree crops (orange trees).
- Scope 2 involves emissions associated with the acquisition and use of on-farm electricity, which also encompasses the production of purchased electricity.
- Scope 3 addresses indirect emissions linked to the production, processing, and distribution of inputs within the agricultural system. This level includes embodied emissions from machinery, construction materials, and agricultural infrastructure, such as fertilizer production, primary processing, and primary distribution.

Greenhouse Gas Emissions

Table 1 outlines the greenhouse gas emissions considered in the Cool Farm Tool methodology. These emissions encompass the three primary greenhouse gases associated with agricultural product production: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

Table 1 – Greenhouse gas emissions covered by Cool Farm Tool

Emission Source	Description	Greenhouse Gas
Conversion of land use	Changes in soil and biomass carbon stocks due to conversion of other land to agriculture	CO_2
Change of tillage	Changes in soil carbon due to tillage practice	CO_2
Use of fertilizers	Emissions from the fertilizer production process, and processes such as volatilization and leaching of applied fertilizers	CO_2, N_2O
Use of pesticides	Emissions resulting from the use of machinery to apply pesticides	CO_2
Residue management	Emissions due to the way crop residues are treated	N_2O, CH_4
Cover cropping	Changes in soil carbon due to the growing of cover crops, and incorporating the residues into the soil	CO_2
Rice cultivation	Methane emissions due to organic matter decomposition in waterlogged rice cultivation	CH_4
Manure management	Emissions due to the application of manure	N_2O, CH_4
Livestock feed	Emissions from the production of livestock feed	CO_2
Enteric fermentation	Emissions from enteric fermentation in ruminants	CH_4
Manure management	Emissions due to the way animal manure is treated	N_2O, CH_4

Emission Source	Description	Greenhouse Gas
Energy use	Emissions from energy used in field operations, e.g., tillage, spreading, etc.	CO_2
	Emissions from energy used in primary processing	CO_2
	Emissions from energy used in irrigation	CO_2
	Emissions from energy used in transporting inputs to and products from the farm	CO_2
Wastewater	Emissions due to the decomposition of organic matter in wastewater	CH_4

Apart from considerations pertaining to agricultural practices, the Cool Farm Tool also encompasses aspects related to "Soil Organic Carbon." This term refers to carbon found within the organic components of the soil, which includes deceased plant and animal materials, byproducts generated during their decay, and soil microbial biomass. These are called "carbon sinks[5]".

This study is focused on specific objectives related to carbon credits:

I. **Assess Potentials for Carbon Emission Reductions:** The primary goal was to evaluate the potential and possibilities for reducing carbon emissions within the studied context;

II. **Explore Carbon Sequestration Opportunities:** Another key objective was to assess opportunities for carbon sequestration and to determine the feasibility of utilizing carbon sequestration as a means for generating carbon credits;

III. **Investigate Alternative Ways for Carbon Credit Generation**: The study aimed to determine whether alternative methods for generating Carbon Credits could be viable for income diversification. This involved exploring diverse avenues beyond traditional approaches to carbon credit generation.

By addressing these objectives, the study aimed to contribute valuable insights to the field of carbon credit generation and sustainable practices. Below, in summary, we present the context of this study and its probable outcome, which implies supporting the orange producers, participants of the study in the estimation of the greenhouse gas emissions, and initiating a process of emission reduction and monitoring, based on a baseline that will be given by this estimation:

- ***STEP 1*** *– Identify and validate the baseline scenario: In this initial stage, the primary focus is on identifying and validating the baseline scenario. This involves comprehending the current state of carbon emissions and existing practices, which will establish a robust foundation for evaluating future reductions.*
- ***STEP 2*** *– Define the project system boundaries: The second step entails defining the boundaries of the project system. This step precisely outlines the scope of activities that will be considered when estimating carbon emissions and removals. A clear delineation is critical to ensure that all relevant sources of emissions and removals are adequately accounted for.*
- ***STEP 3*** *– Estimate baseline emissions and removals: Lastly, the third step involves estimating baseline emissions and removals. This process includes accurately and reliably quantifying existing carbon emissions and removals. This data will serve as the basis for future comparisons, enabling the assessment of emission reduction success and the potential for carbon credit certification. The latter means that when a producer or a*

[5] In the context of "Soil Organic Carbon," it refers to the organic components of the soil that act as carbon sinks. These components include deceased plant and animal materials, byproducts generated during their decay, and soil microbial biomass. The soil, in this case, serves as a reservoir that absorbs and retains carbon, preventing it from being released into the atmosphere. Soil organic carbon is an essential aspect of maintaining soil fertility, structure, and overall health.

cooperative decides for a credit certification, it will be necessary to follow all the methodology steps of the adopted standard, as "Golden Standard" for example.

By successfully completing these initial steps, this work will establish a solid foundation for the adoption of more sustainable agricultural practices and in the future evaluate a possibility for certification of carbon credits. Understanding the baseline scenario, defining relevant activities clearly, and accurately measuring emissions and removals are essential steps toward a more environmentally conscious and climate-friendly future.

2. Objectives and hypotheses

The primary objective of this study is to conduct a comprehensive assessment of orange juice production in the southern and southeastern regions of Brazil, with a specific focus on three distinct clusters. Within the realm of **"economic aspects,"** our study aims to achieve the following:

Estimate the costs associated with adhering to Fairtrade standards and legal requirements.

- Investigate the potential benefits of implementing agroecological practices, biodiversity criteria, and the utilization of the Cool Farm Tool for emission estimations.
- Explore the readiness of farmers and cooperatives to engage in carbon reduction initiatives, including the exploration of carbon credit production and trade opportunities.

In the context of **"decarbonization,"** our research endeavors to:

- Estimate carbon emissions utilizing the Cool Farm Tool.
- Identify and assess opportunities for emission reduction and carbon sequestration.
- Estimate the expenses linked to agroecological interventions.

Lastly, under the umbrella of the **"Cool Farm Tool,"** our hypotheses are geared towards:

- Identifying strategies for minimizing carbon emissions.
- Investigating potential avenues for carbon sequestration.
- Analyzing water management and drought mitigation strategies, particularly in response to the frequent droughts experienced in Brazil.

These investigations promise to provide a more profound understanding of the challenges and opportunities inherent in the orange-to-orange juice production sector in the southern and southeastern regions of Brazil.

Table 2 - Study objectives and working hypotheses

	OBJECTIVES OF THE STUDY	WORKING HYPOTHESES
ECONOMIC ASPECTS	Estimate the costs of compliance (with FT standards and legal requirements) and the advantages of scaling up and extending agroecological practices, biodiversity criteria, and the use of the Cool Farm Tool or other appropriate tools for local farmers to improve livelihoods.	The implementation of agroecological practices and biodiversity criteria can result in reduced costs and increased profitability for farmers.
	Is there a provision at the Producer Organization (PO) or farmers level to address carbon reductions or evaluate the option of producing carbon credits, for example, to diversify income? If not, what are the reasons?	The willingness of producers to participate in carbon reduction initiatives may depend on economic incentives and technical support.

	OBJECTIVES OF THE STUDY	WORKING HYPOTHESES
DECARBONISATION	What is the amount of carbon emissions estimated with the Cool Farm Tool?	Using the Cool Farm Tool can reveal the amount of carbon emissions associated with orange production in southern Brazil.
	Are there possibilities for carbon reduction and sequestration in the selected cooperatives and in what quantity?	Producer cooperatives can implement measures to reduce carbon emissions and sequester carbon, contributing to climate change mitigation.
	What would be the estimated costs of all the interventions/instruments mentioned above for smallholder farmers/cooperatives?	Implementing carbon reduction and water management practices may involve costs that need to be estimated to assess economic viability.
COOL FARM TOOL	Evaluate potential and possibilities for reducing carbon emissions.	Using the Cool Farm Tool can identify opportunities to reduce carbon emissions in orange production.
	Evaluate carbon sequestration opportunities and whether it would be possible to use carbon sequestration as a carbon credit generation opportunity.	Identifying carbon sequestration opportunities can pave the way for the generation of carbon credits and create a source of extra income for producers.
	Analyze the water footprint and opportunities for water management, water retention, and other opportunities to mitigate the effects of frequent droughts in Brazil.	Water footprint analysis can reveal ways to better manage water and cope with the challenges of frequent droughts.
	What is the estimated water footprint and what opportunities for water management, water retention or other ways to mitigate the effects of frequent droughts in Brazil exist?	Estimating the water footprint will provide valuable information for effective water management and mitigating the impacts of droughts.

3. Context of the Study

Brazil holds a leading position in orange juice production, playing a crucial role in the global supply of this commodity, accounting for an impressive 79% of the worldwide consumption of conventional orange juice (CitrusBR, 2023). This prominence not only influences the global citrus market but also carries substantial environmental implications, particularly concerning carbon emissions and water consumption. A detailed examination of these aspects embedded in the life cycle of agro-industrial products, such as orange juice, points towards possible sustainable paths to contribute to efforts in reducing atmospheric carbon emissions.

Simultaneously, transitioning to a paradigm of sustainable production requires adaptive strategies in the face of a critical climate change scenario. Climate change affects not only agricultural practices but also has a significant impact on the economy, where agriculture plays a crucial role in the Gross Domestic Product (GDP). Challenges imposed by climate change, such as unpredictable weather conditions, erratic rainfall patterns, and extreme climatic events, directly impact agricultural productivity. This direct influence on agricultural productivity can adversely affect the economic contribution of the agricultural sector to the GDP.

Addressing the challenges of climate change necessitates promoting sustainable agricultural practices from an integrated perspective that encompasses all aspects related to orange juice production, focusing not only on production efficiency but also on natural resource preservation.

In simple terms, this means that producers must strike a balance between efficient and sustainable production. This is part of a broader adaptation process involving emission reduction and changes in production methods. These changes include transitioning from conventional methods to practices that preserve soil fertility, promote water conservation, enhance biodiversity, and provide ecosystem services. In summary, producers aim to operate in a way that is efficient in terms of production while adopting environmentally friendly and sustainable practices in the long term.

The 2030 Agenda for Sustainable Development and the commitments of the Fairtrade initiative

In September 2015, global leaders from 193 United Nations Member States, along with civil society representatives, convened at the UN headquarters in New York for a General Assembly. Their collective goal was to devise a comprehensive strategy aimed at eradicating poverty, safeguarding the planet, and securing peace and prosperity for all. This momentous plan, titled "Transforming Our World: The 2030 Agenda for Sustainable Development," led to the establishment of 17 Sustainable Development Goals (SDGs), which represent an evolution of the earlier Millennium Development Goals (MDGs).

Figure 1 - Sustainable Development Goals

Source: Fairtrade International (2023)

Fairtrade International aligns all its endeavors and initiatives with the 2030 Agenda and its associated goals and targets. These contributions occur through various means, such as adhering to established Fairtrade Criteria, utilizing Fairtrade Premium funds to support SDG targets, forging partnerships and initiatives that provide additional resources to producers, and collaborating with companies to address development challenges. This includes addressing human rights risks within global supply chains (Fairtrade International, 2023).

Throughout this study, these SDGs will be presented whenever an action or conclusion is linked to its content, with emphasis on:

- Socioeconomic questionnaire,
- Objectives of the study
- Results of the study and
- KS Recommendations

Figure 2- SDGs included in this study

Brief Overview on Brazilian Cooperatives

Cooperatives in Brazil exhibit diverse characteristics, deeply rooted in regional nuances. In the Northern Region, historical challenges of vast distances and sparse population have shaped extractive cooperatives, with recent efforts focusing on indigenous community support. The Northeast Region sees agricultural cooperatives as integral to global food supply chains, impacted by the quality of the institutional framework and organizational culture. In the Central-western Region, resurgence post-gold exploration, coupled with initiatives like the Japanese-Brazilian Cooperation Program – PRODECER[6], has fostered growth in both rural and urban cooperatives. The Southeast Region stands as a pioneer, with strategic utilization of cooperativism for agricultural modernization since the 1920s. The far Southern Region boasts a rich history, evolving through phases driven by immigrant influences.

Statistics and Impact of Cooperatives in Brazil

A holistic view of cooperatives in Brazil reveals their significant presence, with statistics indicating 1,185 agricultural cooperatives uniting approximately one million cooperative farmers (Anuário Coop, 2023). Family farming cooperatives, comprising around 80% small-scale producers, play a crucial role, contributing half of Brazil's total production. These cooperatives generate employment for about 249,000 individuals and are pivotal in global production chains of grains, coffee, and animal protein.

Empowerment of Family Farming Cooperatives

The empowerment of family farming cooperatives is a key narrative in Brazil's agricultural story. Public policies and programs, such as the Food Acquisition Program - PAA (Brasil, 2003) and the National Program for the Production and Use of Biodiesel - PNPB (Brasil, 2023), have elevated the status of family farming cooperatives. Social movements like the National Confederation of Agricultural Workers (CONTAG) and the Landless Rural Workers Movement (MST) have played a significant role.

[6] PRODECER, the Japanese-Brazilian Cooperation Program for the Development of the Cerrados, emerges as a prominent geopolitical initiative and program implemented across the extensive cerrado regions in the Midwest Region of Brazil, as well as in the states of Minas Gerais, Mato Grosso, Mato Grosso do Sul, Bahia, Tocantins, and Maranhão. For further information, see: Caribé (2016).

The present scenario, as highlighted by the 2017 Census of Agriculture, underscores the indispensability of cooperatives for family farming, contributing to sustainable development and inclusive productivity.

Presentation of the cooperatives in this study

All four cooperatives involved in this study share a commonality—they are part of a broader movement of cooperation and solidarity economy that gained momentum in the early 21st century. Notably, these cooperatives were established relatively recently, reflecting the renewed interest in family farming and solidarity economy globally, including Brazil.

These cooperatives, all focused on family farming and certified Fairtrade, exhibit several key similarities in their approach. Firstly, their commitment lies in enhancing the quality of life for family farmers by promoting sustainable agricultural practices and upholding workers' rights. Beyond securing fair prices for their members' products, these cooperatives invest in projects that benefit the communities in which they operate, addressing aspects such as education, health, and environmental conservation.

The Fairtrade Premium, also known as the Community Development Premium, is an integral component of Fairtrade certification. This premium, paid additionally by companies purchasing certified products, directly benefits the producers' community. It is designed to finance projects aimed at improving the quality of life for farmers and their families. These projects can include investments in infrastructure, education, health services, environmental sustainability, and more. The Fairtrade Premium serves as a significant tool for empowering farming communities and fostering sustainable development in regions where access to resources and opportunities is often limited.

Operational Scope of Cooperatives

Cooperative A

Cooperative A – The cooperative is based in Paraná, Brazil. Initially comprising 13 members, the cooperative has since grown to 68 members, with 52 engaged in orange production and 16 involved in the cultivation of vegetables, cassava, fruits, and fish farming. Cooperative A's primary objectives include market expansion and diversification.

In the 2000s, Cooperative A achieved Fairtrade certification, enabling access to improved market prices and exports to European countries such as Germany, Austria, Finland, Norway, and Switzerland. This certification has contributed to enhancing the quality of life for cooperative members. Cooperative A's mission is centered on facilitating market access, adding value to products, and fostering the socioeconomic development of its members. The cooperative aspires to be recognized for its effective services, grounded in values such as unity, transparency, credibility, ethics, and sustainability. Among its key goals is the continued expansion and diversification of operations, including the export of orange juice to five European countries.

Cooperative A actively works towards improving the living conditions of its members, their families, and communities. The cooperative initiates projects that focus on promoting favorable working conditions, education, and sustainable practices. Additionally, it provides technical assistance to reduce production costs and champions the production of biofertilizers to enhance soil quality and diminish the Carbon Footprint.

Cooperative A actively participates in government public procurement programs, supplying whole juice and cassava flour across the state of Paraná. The cooperative prioritizes the well-being of its workers by providing training in occupational health and safety, along with Personal Protective Equipment (PPE).

Furthermore, Cooperative A invests in partnerships with government programs aimed at providing healthy food to schools and public institutions. A portion of the resources is dedicated to combating hunger, diversifying incomes, fostering food production, and promoting decent work and economic growth, with a special emphasis on ensuring the health and safety of its workers. The cooperative is deeply committed to sustainability and the overall well-being of communities, reflecting an investment in a shared future for everyone involved.

Cooperative B

Cooperative B - The cooperative originated in Rio Grande do Sul, Brazil. Currently, the cooperative has a total of 107 members, including 10% women, and manages a combined property area of 11.10 hectares per member, operating at altitudes ranging from 300 to 500 meters.

For over a decade, Cooperative B has proudly held Fairtrade certification, signifying its dedication to fair business practices. The cooperative's production encompasses oranges destined for juice production, with a total volume of 5,000 tons of fruits. This includes 500 tons of Frozen Concentrated Orange Juice
- FCOJ - and 1,000 tons of fruits, with 400 tons representing Not From Concentrate - NFC - orange juice. Operating on a total area of 1,200 hectares, Cooperative B allocates 300 hectares to conventional citrus production and 100 hectares to organic production.

Cooperative B's mission is to unite member producers to access higher value-added markets, enhance the quality of life, and promote socio-environmental development for members and the communities in which they operate. Comprising small family producers, the cooperative aims to expand its services to reach a larger number of small producers in the region, benefiting over 1,500 families involved in orange production.in the region.

Cooperative B prioritizes the well-being of its members and their families by developing projects in key areas identified by the members themselves. These priority areas include health, education, sustainable production, and environmental conservation. Projects like provide essential health services, such as medical and dental care, laboratory tests, and the acquisition of medicines.

The cooperative actively collaborates with regional institutions and schools to promote cooperative concepts and values, fostering leadership and collaboration through projects. Another noteworthy initiative was developed in partnership with a local school. This project aims to implement a model agroforestry system for food production without the use of chemicals, contributing to soil regeneration.

Cooperative B allocates significant resources, including 28% of the Fairtrade Premium and its own funds, to initiatives related to responsible production and consumption, community sustainability, partnership development, environmental conservation, education, and health services. Emphasizing cooperation, the cooperative actively seeks partnerships with municipal governments, schools, philanthropic entities, financial institutions, and the local community to enhance the quality of life and foster sustainable development in their communities.

Cooperative C

Cooperative C - The Cooperative was established in São Paulo, Brazil. The cooperative's inception was prompted by the citrus price crisis that peaked between 2011/12 and 2014/15, driven by a surplus of oranges and a surge in international juice stocks. Faced with this challenging scenario and the resultant decline in profitability, SEBRAE in Barretos, São Paulo, intervened by organizing groups of small citrus producers from neighboring cities. The goal was to provide training and explore marketing alternatives to mitigate losses and ensure the continued involvement of these citrus growers in the industry.

About a decade ago, Cooperative C achieved Fairtrade certification, marking a significant milestone in its journey. Currently comprising 96 members, including 10% women, with an average landholding of 16 hectares per member and operating at an altitude of 573 meters, the cooperative is dedicated to supporting and strengthening small producers. Cooperative C aims to provide opportunities and innovative solutions to address the challenges faced by the agricultural sector.

Cooperative C is actively involved in several projects aimed at enhancing the well-being and prosperity of its members. One notable initiative is the Weather Station, providing valuable information for strategic planning of agricultural activities. The cooperative also prioritizes the purchase and maintenance of implements, offering technical assistance and production control, while incentivizing goal attainment through bonuses. Small producers benefit from a crop subsidy, ensuring financial security.

Committed to community and environmental welfare, Cooperative C engages in projects like constructing septic tanks and providing spray Personal Protective Equipment (PPE) kits, showcasing dedication to sustainability. The cooperative's hail crop premium protects crops, and soil coverage with grasses contributes to more sustainable farming practices.

In 2022, Cooperative C demonstrated its unwavering commitment to the well-being of workers and producers by investing 48% of the Fairtrade Premium in initiatives focused on this objective. Furthermore, 25% of the premium was allocated to infrastructure and administration improvements, enhancing operational efficiency. Additionally, 18% went towards producers' bonuses, with a focus on increasing income and promoting good agricultural practices. The cooperative also invested 9% in initiatives promoting the inclusion of youth and women, monitoring, and mitigating climate conditions, and advancing basic sanitation efforts.

Cooperative D

Cooperative D – The cooperative is based in Paraná, Brazil and unites 38 citrus growers, mostly small-scale, with areas up to four fiscal modules. A pivotal moment for Cooperative D transpired in the last decade, marked by the attainment of Fairtrade certification, affirming the production of socially and environmentally responsible orange juice.

This certification serves as a testament to the cooperative's commitment to labor rights, the elimination of child labor, and the provision of optimal working conditions, including transportation, rest facilities, and personal protective equipment. Furthermore, it underscores Cooperative D's dedication to environmentally respectful practices.

The Fairtrade seal carries an additional premium of US$ 250 per ton of juice exported to the international solidarity market, with this surplus directly benefiting the producer community. These funds empower investments in enhancing the production base, increasing orchard productivity, and supporting initiatives to prevent greening, the primary disease affecting citrus crops.

Cooperative D's mission is to deliver quality products that not only satisfy consumers but also enhance the lives of the farmers behind these products. The cooperative strives to achieve this objective by harmonizing sustainable agricultural practices with environmental protection, while simultaneously contributing to closing the income gap among its members. This is facilitated through technical support, providing access to equipment and machinery at low or zero cost, and fostering strong partnerships with buyers, as well as government and private institutions.

Dedicated to upholding human rights and implementing good practices for both permanent and temporary workers, Cooperative D actively promotes the inclusion of women and youth, monitors and mitigates climate conditions, and advances basic sanitation. The cooperative allocates significant investments to support workers, enhance infrastructure, promote sustainable practices, and facilitate the inclusion of youth and women.

Cooperative D extends beyond the production of certified orange juice. Specific Initiatives empower women to establish small businesses, diversifying family income. Another project encourages beekeeping and orange honey production, promoting sustainable cultivation practices. Additionally, a further initiative focuses on optimizing soil fertility, enhancing the productivity and profitability of cooperative members.

In 2022, Cooperative D strategically utilized the Fairtrade Premium cross various areas, including worker well-being, infrastructure and administration improvements, the promotion of good agricultural practices, and the inclusion of youth and women. Moreover, the cooperative actively works to mitigate environmental impacts, underscoring its commitment to a better future for all involved.

4. Sampling Methodology and Data Collection Techniques

Table 3 - Description of activities carried out (2023)

Description	Cooperatives	Date
Approval of the proposal with Fairtrade	-	June 09
Kick-off meeting with Fairtrade - Inception meeting for the study on carbon and water footprint in orange cooperatives in Brazil	-	June 19
CLAC E-mail – Invitation to the engagement meeting with the cooperatives	-	June 19
Presentation of engagement with cooperatives	COOPERATIVE C COOPERATIVE B COOPERATIVE D COOPERATIVE A	June 23
Email KS Consulting to the cooperatives – sending the material of the engagement presentation and request for confirmation regarding the interest in participating in the study.	-	June 26
Responses from the cooperatives on the invitation to participate in the study – (Accepted the invitation)	COOPERATIVE D COOPERATIVE B COOPERATIVE C COOPERATIVE A	June 26 June 27 June 27 June 28 July 17
Delivery of the Study Concept		June 30
Feedback Fairtrade – Study Concept		July 7
Delivery of the Revised Study Concept		July 14
Fairtrade's Acceptance of the Study Concept		July 17
Invitation to the first 1st alignment meeting on the study with the participating cooperatives	COOPERATIVE C COOPERATIVE B COOPERATIVE A COOPERATIVE D	July 18
1st Meeting – Presentation of the study and planning of the field visit for data collection	COOPERATIVE C COOPERATIVE B COOPERATIVE A COOPERATIVE D	July 20 July 24 July 25 July 31
KS Consulting sends documentation to cooperatives with requests for information and terms for conducting the study. (List of orange-producing properties, Term of Ethical Commitment for Data Collection and Consent Form for Data Use.	COOPERATIVE C COOPERATIVE D COOPERATIVE B COOPERATIVE A	July 20 July 21 July 21 July 21
Cooperatives sent their lists of orange producers for selection of samples of rural properties for the study.	COOPERATIVE B COOPERATIVE A COOPERATIVE D COOPERATIVE C	July 28 July 31 August 14 August 15

Cooperative D - Field data collection: 1st option: period from 14 to 08/18/2023 or 21 to 25/08/2023 2nd option: period from 25 to 09/29/2023	COOPERATIVE D	No Response August 04 (Scheduled)
1st - Progress Meeting CO2 Footprint Study on FT oranges in Brazil	-	August 3
KS consulting sends list of selected producers for study (Field data collection) - Cooperative A	COOPERATIVE A	August 3
Cooperative A – Data Collection (Field Visits)	COOPERATIVE A	August 7 to 11
Cooperative A - 1st request for additional information	COOPERATIVE A	August 21
Cooperative A - 2nd request for additional information	COOPERATIVE A	August 24

KS consultancy sends list of selected producers for study (Field data collection)	COOPERATIVE B COOPERATIVE D	August 16 August 30
Delivery of the Product 4 - Intermediate Report - Study on Carbon and Water Footprint	-	August 25
Cooperative A – Meeting to request additional information	COOPERATIVE A	August 25
Feedback - Intermediate Report - Study on Carbon and Water Footprint	-	August 28
Cooperative B – Data collection (Field visits)	COOPERATIVE B	August 28 to September 1
Cooperative D – Request from the cooperative to postpone a field visit scheduled for the period from 25 to 09/29/2023.	COOPERATIVE D	September 8
Cooperative A - 4th request for additional information	COOPERATIVE A	September 11
2nd meeting – Organization of field visits for data collection.	COOPERAT IVE C COOPERA TIVE D	September 12
2nd - Progress Meeting CO2 Footprint Study on FT oranges in Brazil	-	September 14
Cooperative C – Data collection (Field visits)	-	September 25-28
Cooperative A - 5th request for additional information	COOPERATIVE A	September 25
Cooperative D – New date for field data collection, from 10/23 to 10/25/2023.	COOPERATIVE D	Scheduled on October 11
Cooperative D – 2nd Meeting – Organization of field visits for data collection.	COOPERATIVE D	October 16
Cooperative D – Data Collection (Field Visits)	-	October 23 to 25
3rd - Progress Meeting CO2 Footprint Study on FT oranges in Brazil		October 26
Delivery of the Deliverable 6 – Detailed narrative report		November 10
Handover Manual Delivery		November 24
Holding the workshop	COOPERATIVE C	November 27
Holding the workshop	COOPERATIVE B	November 28
4th – Final Progress Meeting CO2 Footprint Study on FT oranges in Brazil		December 01
Holding the workshop	COOPERATIVE A	December 05
Holding the workshop	COOPERATIVE D	December 06
Delivery of the Deliverable 6 – Detailed narrative report Revised and supplemented		December 20
Delivery of the ppt disclosure		December 20

This study began after the approval of the proposal by Fairtrade Germany on June 9. An initial meeting took place on June 19 to coordinate the start of the study with the Fairtrade orange cooperatives in Brazil. Subsequently, CLAC (Latin American and Caribbean Coordinator of Small Producers and Workers of Fairtrade) invited the cooperatives to participate in an engagement meeting.

On June 23, 2023, a broad meeting took place to present the proposed study, its challenges, and objectives, highlighting its relevance to the producers themselves. This meeting was attended by representatives of prominent organizations, including Fairtrade Germany, CLAC (Latin American and Caribbean Coordination of Small Producers and Fairtrade Workers), KS Consulting and Training, as well as several notable Cooperatives,

After this meeting, an e-mail was sent to the cooperatives, inviting them to participate in this study. A deadline for manifestation was set, with the deadline of June 29, 2023, for them to confirm their interest in joining the project. After the conclusion of this period, and based on the responses received, there was a consensus between Fairtrade Germany, CLAC and KS to carry out the study together with four cooperatives:

- COOPERATIVE C - located in São Paulo.
- COOPERATIVE A - located in Paraná.
- COOPERATIVE B - located in Rio Grande do Sul.
- COOPERATIVE D - located in Paraná.

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Based on this definition, remote meetings were scheduled with each of the four selected cooperatives, with the purpose of detailing the methodology of the study, clarifying doubts, requesting complementary information about the cooperative members, and establishing the logistic plans for the fieldwork and data collection phase.

Each cooperative went through the following stages: initial remote meeting, request for information about cooperative members (Appendix 1), signing a consent form for data usage (Appendix 2), sampling, field data collection, and requesting missing information.

The sampling process began with a thorough examination upon receiving lists containing information about cooperative members who are orange producers. This involved a meticulous definition of demographic parameters, including age group and gender, in alignment with data from the 2017 Agricultural Census conducted by the Brazilian Institute of Geography and Statistics (IBGE). The purpose of this census was to gather comprehensive information on national agriculture.

The selection of producers to be visited incorporated a random approach, applying a standard formula to calculate the minimum sample size required for reliable results that accurately represent the characteristics of producers in general. The details of this process were crucial in ensuring a genuinely representative and impartial sample. The outcomes of this sampling strategy are outlined below.

Table 4 - Demographic parameters for the State of Paraná

State of Brazil	Age class	Producer´s gender				
		Total	Men	Men (%)	Women	Women (%)
Paraná	Total	305.154	262.895	100%	40.646	100%
	Under 25 years old	5.101	3.929	1%	1.172	3%
	From 25 to less than 35 years	23.124	19.344	7%	3.780	9%
	From 35 to less than 45 years	50.070	43.313	16%	6.757	17%
	From 45 to less than 55 years old	81.345	71.010	27%	10.335	25%
	From 55 to less than 65 years	78.393	68.643	26%	9.750	24%
	From 65 to less than 75 years old	46.750	40.630	15%	6.120	15%
	75 years old and over	18.758	16.026	6%	2.732	7%
	% Total	**100%***	**86%**	**-**	**13%**	**-**

Source: IBGE, 2017

Table 5 - Demographic parameters for the State of São Paulo

State of Brazil	Age class	Producer´s gender				
		Total	Men	Men (%)	Women	Women (%)
São Paulo	Total	188.620	160.917	100%	23.881	100%
	Under 25 years old	1.634	1.344	0,84%	290	1%
	From 25 to less than 35 years	9.731	8.211	5%	1.520	6%
	From 35 to less than 45 years	24.067	20.665	12%	3.402	14%
	From 45 to less than 55 years old	42.945	37.347	23%	5.598	23%
	From 55 to less than 65 years	50.773	44.462	27%	6.311	26%
	From 65 to less than 75 years old	36.260	32.080	19%	4.180	18%
	75 years old and over	19.388	16.808	10%	2.580	11%
	% Total	**100%***	**85%**	**-**	**13%**	**-**

Source: IBGE, 2017

Table 6 - Demographic parameters for the State of Rio Grande do Sul

State of Brazil	Age class	Producer´s gender				
		Total	Men	Men (%)	Women	Women (%)
Rio Grande do Sul	Total	365.094	319.691	100%	43.933	100%
	Under 25 years old	4.386	3.558	1%	828	2%
	From 25 to less than 35 years	24.416	21.008	7%	3.408	8%
	From 35 to less than 45 years	50.990	45.106	14%	5.884	13%
	From 45 to less than 55 years old	89.873	80.264	25%	9.609	22%
	From 55 to less than 65 years	100.618	89.844	28%	10.774	25%
	From 65 to less than 75 years old	65.757	57.409	18%	8.348	19%
	75 years old and over	27.584	22.502	7%	5.082	12%
	% Total	**100%***	**87,6%**	**-**	**12%**	**-**

* The sum of percentages of men and women does not result in 100%, due to the percentage of properties whose responsibility for the management of the establishment is the responsibility of an administrator.

Source: IBGE, 2017

To calculate the optimal sample size, we use the following formula:

$$n = (Z^2 * \sigma^2 * N) / ((Z^2 * \sigma^2) + (E^2 * (N-1)))$$

Where: N = Population size; E= Margin of error; σ = Standard deviation or population variance; Z = Z score.

To this study the adopted values were N = 223; E = 0,1; σ = 0,5 and Z = 1,65

After analyzing the lists provided by the cooperatives, it was determined that the total number of orange growers participating in this study was 223. Utilizing the prescribed calculation formula, a sample size of 54 producers was established for visitation and interviews. This number was distributed proportionally among the cooperatives, as illustrated in the table below. In essence, this section outlines the intricacies of the orange grower sampling process, meticulously considering specific demographic and mathematical criteria to ensure a representative selection. To determine the sample, producers were assigned numbers, and the selection was conducted randomly, respecting the sex and age groups of the producers, as detailed in the following tables.

Table 7 - Sample distribution by cooperatives

Cooperative Name	Location	Total number of orange producers	Distribution among cooperatives	Number of producers to be visited
COOPERATIVE C	SP	60	27%	15
COOPERATIVE D	PR	37	17%	9
COOPERATIVE B	RS	87	39%	21
COOPERATIVE A	PR	39	17%	9
Total	**-**	**223**	**100%**	**54**

Table 8 - Sample distribution by sex and age (Males)

		Men (Sample by age)						
Cooperative	**Male**	**< 25**	**≥25 to 35**	**≥35 to 45**	**≥45 to 55**	**≥55 to 65**	**≥65 to 75**	**≥ 75**
COOPERATIVE C	13	0	1	1	3	4	3	1
COOPERATIVE D	8	0	1	1	3	2	1	0
COOPERATIVE B	19	0	1	3	5	6	3	1
COOPERATIVE A	8	0	1	1	3	2	1	0

Table 9 - Sample distribution by sex and age (Women)

		Women (Sample by age)						
Cooperative	**Female**	**< 25**	**≥25 to 35**	**≥35 to 45**	**≥45 to 55**	**≥55 to 65**	**≥65 to 75**	**≥ 75**
COOPERATIVE C	2	0	0	0	1	1	0	0
COOPERATIVE D	1	0	0	0	0*	1	0	0
COOPERATIVE B	2	0	0	0	1	1	0	0
COOPERATIVE A	1	0	0	0	1	0	0	0

*For Cooperative D, the age range was changed to the next most representative range (From 55 to less than 65 years) because there were no female producers in the previously selected range (From 45 to less than 55 years old).

A random draw was performed within each of the age groups and gender groups using this method.

Sample of participants

The producers chosen for visits and data collection in each cooperative are listed below. In order to uphold data confidentiality, each producer has been assigned a unique identification (ID) that will be used throughout the duration of the study.

Table 10 - Selected Sample – Cooperative A (Paraná)

Producer	Genre	age	Total Area (ha)	Crop area (ha)	Production (ton)	Crop System
ID1_1	F	45	12,1	10,64	212,80	conventional farming system
ID1_2	M	47	9,68	7,35	147,00	conventional farming system
ID1_3	M	44	50	50,00	1.760,80	conventional farming system
ID1_4	M	50	9,68	5,50	194,00	conventional farming system
ID1_5	M	66	38,72	37,51	1.500,40	conventional farming system
ID1_6	M	61	21,00	13,60	446,40	conventional farming system
ID1_7	M	26	16,00	15,00	300,00	conventional farming system
ID1_8	M	55	5,46	5,46	218,40	conventional farming system
ID1_9	M	51	5,54	5,54	80,00	conventional farming system

Table 11 – Selected Sample - Cooperative B (Rio Grande do Sul)

Producer	Genre	age	Total Area (ha)	Crop area (ha)	Production (ton)	Crop System
ID2_1	M	53	40,00	14,00	90,00	organic
ID2_2	M	56	5,00	4,00	35,00	conventional farming system
ID2_3	M	50	20,00	4,00	120,00	conventional farming system
ID2_4	M	84	12,50	2,00	40,00	conventional farming system
ID2_5	M	60	9,00	3,00	50,00	conventional farming system
ID2_6	M	61	15,00	5,00	48,00	conventional farming system
ID2_7	F	53	12,80	1,50	72,89	conventional farming system
ID2_8	M	54	12,00	12,00	340,00	conventional farming system
ID2_9	M	51	8,00	8,00	260,00	conventional farming system
ID2_10	M	61	34,00	5,00	24,00	Organic
ID2_11	M	63	10,80	2,00	30,00	conventional farming system

Producer	Genre	age	Total Area (ha)	Crop area (ha)	Production (ton)	Crop System
ID2_12	M	69	32,00	12,00	200,00	conventional farming system
ID2_13	F	47	16,60	7,50	70,00	Organic
ID2_14	M	66	11,80	4,70	24,00	conventional farming system
ID2_15	M	39	18,50	10,00	60,00	Organic
ID2_16	M	36	6,25	4,00	41,00	conventional farming system
ID2_17	M	62	10,80	2,50	25,00	conventional farming system
ID2_18	M	37	31,00	8,00	150,00	conventional farming system
ID2_19	M	32	15,00	1,00	0,00	conventional farming system
ID2_20	M	65	7,50	5,00	29,00	Organic
ID2_21	M	49	12,50	6,00	70,00	conventional farming system

Table 12 – Selected sample - Cooperative C (São Paulo)

Producer	Genre	age	Total Area (ha)	Crop area (ha)	Production (ton)	Crop System
ID3_1	F	63	35,57	12,10	21,44	conventional farming system
ID3_2	M	46	12,60	12,60	84,42	conventional farming system
ID3_3	M	83	8,71	5,70	239,31	conventional farming system
ID3_4	F	54	62,92	21,00	460,06	conventional farming system
ID3_5	M	54	98,00	10,00	382,63	conventional farming system
ID3_6	M	56	13,00	9,20	209,76	conventional farming system
ID3_7	M	50	21,00	8,87	161,74	conventional farming system
ID3_8	M	73	41,00	35,00	424,19	conventional farming system
ID3_9	M	56	26,50	20,00	387,52	conventional farming system
ID3_10	M	67	29,00	14,00	754,80	conventional farming system
ID3_11	M	74	18,15	16,94	759,92	conventional farming system
ID3_12	M	32	17,00	8,00	336,35	conventional farming system
ID3_13	M	40	10,40	8,60	407,58	conventional farming system
ID3_14	M	63	16,94	9,00	296,92	conventional farming system
ID3_15	M	56	12,76	10,00	365,20	conventional farming system

Table 13 – Selected sample - Cooperative D (Paraná)

Producer	Genre	age	Total Area (ha)	Crop area (ha)	Production (ton)	Crop System
ID4_1	F	59	23,19	10	339,11	conventional farming system
ID4_2	M	50	24,2	5,11	154,99	conventional farming system
ID4_3	M	32	9,68	7,93	267,52	conventional farming system
ID4_4	M	60	54,4	32	250,02	conventional farming system
ID4_5	M	42	24,2	10	414,05	conventional farming system
ID4_6	M	73	27,1	24,55	800,3	conventional farming system
ID4_7	M	60	18,15	9,43	657,13	conventional farming system
ID4_8	M	51	70,24	41	1.000,61	conventional farming system
ID4_9	M	47	65,34	40,68	1.092,87	conventional farming system

Cooperative D encountered delays in data collection due to internal issues. Initially scheduled for August 14, the visits were rescheduled to the week of September 25, and later shifted to October 23. Cooperative A faced challenges in providing data during the visit, possibly attributed to the field technician's limited responsibility for technical recommendations. However, they later assisted in gathering additional data after the field visit.

Following cooperative meetings, a socioeconomic questionnaire (Appendix 3) was developed for use in the research, covering topics such as income, education, and production diversity. The questionnaire results, along with the Cooperative Fairtrade Cool Farm Tool outcomes, informed decisions, and recommendations in the study. The collected data were tabulated and presented in the "Characterization of Cooperatives and Producers" section.

Data for emissions and water footprint calculations (Appendix 4) related to harvest, soil, agrochemicals, fuel and energy, irrigation, land use change, and orange transportation were collected using a spreadsheet aligned with the Cool Farm Tool. The data collection process was documented with a voice recorder, ensuring consent from producers or assistants. Geolocations were recorded during property visits, and photographs of orchards and agricultural facilities were taken (Appendix 5).

Validation of the Data Collection Source

Throughout the study, the challenge of collecting qualitative and quantitative data from small family farms, often lacking written or recorded documentation, became evident. This characteristic, common in small-scale productions with minimal external oversight, necessitated the establishment of a decision hierarchy for validating information. While notes, documents, and reports from interviews were considered, special attention was given to the insights shared by producers during interviews. Stimulated by the collecting agronomist, producers could provide specific metrics, such as tons, hectares, orange trees, spacing, dosages, etc., and calculate quantities on the spot, even if not formally recorded. This approach closely aligns with the producer's reality when translated into the language of the Cool Farm Tool.

When available, corroborating documents, including invoices, receipts, technical notes, recommendations, and field notebooks, were combined with the producer's reports to generate input. Cooperative records and documents from its members also contributed valuable information to the study.

Recognizing the limitations of human memory and the absence of annotations, a third source of data was introduced. In cases where producers couldn't recall specific indicators, default data was used, serving as a "penalized" indicator. This approach accounts for potential overestimation, ensuring that emissions are considered in a worst-case scenario. Despite potential inflation, having a baseline provides a starting point for future adjustments to improve accuracy.

Default data, obtained from official sources such as agronomic bulletins (Boletim 100), Agri annual Bulletin, and publications from EMBRAPA (Brazilian Agricultural Research Corporation), offered weighted information on consumption averages and agronomic recommendations in each territory.

There were few needs (3) to re-contact some producers after the visit (to correct or confirm any data or to complete any missing data).

Data Processing and Tabulation

The data gathered was organized in spreadsheets, grouped by cooperative. Each of the four cooperatives comprises varying numbers of producers, including men and women, distributed across different age groups (refer to the sampling rules):

- COOPERATIVE A: 9 producers
- COOPERATIVE C: 21 producers
- COOPERATIVE B: 15 producers
- COOPERATIVE D: 9 producers

The following rules were established for data processing:

- <u>Identification of outliers</u>: When outliers were detected (utilizing boxplots to observe the distribution), the anomalous value was substituted with the average of the values from other producers who provided data.
- <u>Missing data</u>: For sample elements with missing data (e.g., fertilizers), the average of the values from other producers who supplied data was utilized.

Orange production, as a perennial crop, adheres to a cyclical pattern encompassing diverse cultural practices, including fertilization, crop protection, pruning, control of invasive plants, and more, alongside the harvesting process. This cycle establishes predictability in producers' actions, leading to proportional estimations of input and energy consumption corresponding to the farm's size.

*Note: Any alterations associated with the aforementioned scenarios are documented in an additional file titled **"Manual – Handover."***

Entering The Data Into The Cool Farm Tool

Following processing, the data was put into the Cool Farm Tool. To facilitate this process, a guide for completing the Cool Farm Tool was crafted to establish shared understanding regarding the tool's filling options, such as soil parameters, unit usage, fixed responses for specific cases, and more. Each producer put into the tool is identified by an alphanumeric acronym corresponding to the cooperative's identification:

- COOPERATIVE A – ID 1
- COOPERATIVE C – ID 2
- COOPERATIVE B – ID 3
- COOPERATIVE D – ID 4

The producer's identification appears as follows: ID_X_Y, where: "ID" signifies the cooperative's identification (ranging from 1 to 4). "X" is the number representing the specific cooperative. "Y" is the number signifying the producer within the sampling list. This nomenclature ensures data traceability and upholds the confidentiality of the producer's information. After data entry, a thorough review is conducted.

A checklist for review was developed to scrutinize control points, ensuring corrections and adjustments as needed. Finally, the calculation for each ID is encapsulated, and the results file (in PDF) is exported.

5. Socioeconomic Analysis of Cooperatives

The data represent a sample of 54 rural producers spanning all age groups and genders, with quotas distributed proportionally based on the 2017 Agricultural Census distributions for the states of Paraná and São Paulo[7]. Including producers from different age groups and genders allows for a more comprehensive analysis of agricultural and social dynamics, considering the specific challenges and opportunities faced by diverse demographic groups. The sample's diversity provides a robust foundation for assessing variations in production strategies, activity diversification, and reliance on specific crops across the agricultural population.

The interviews, scheduled in advance, were conducted in the presence of cooperative technicians/agronomists, and lasted an average of one hour. They were guided by the socioeconomic questionnaire and the Cool Farm Tool.

Socioeconomic Data Analysis Method

Orange growers' practices and insights encompass a broad spectrum of crucial topics that shape agriculture in the studied regions. From concerns about climate change, which directly impact crop production and management, to strategies for mitigating these effects, growers actively seek improvements post-certification as it can influence family income and orange-related earnings. Managing pests and diseases requires specific practices and investments in crop protection infrastructure.

Furthermore, factors such as the hiring of temporary workers, access to bank credit, and the education level of producers play pivotal roles in the dynamics of local agriculture. Therefore, delving

[7] See Chapter 4 which presents the logic of the composition of the samples by cooperative. ensures that the sample accurately represents the demographic characteristics of the regions of Paraná and São Paulo, making them applicable to the agricultural reality of these states.

into growers' perceptions and practices on these topics provides valuable insights into the intricate interplay between orange activity and the influencing factors.

The method employed in analyzing data related to the perception of climate change and practices in the four cooperatives (Cooperative A, Cooperative B, Cooperative C, and Cooperative D) followed a structured process. This process considered various categories of analysis for perceptions and practices, incorporating appropriate statistical calculations to interpret and validate the observed data, as illustrated in the table below.

Table 14 - Practices and Perceptions Analysis

Practices	Analysis	Perceptions	Analysis
Hiring temporary workers)	proportion measure	Climate change	standard deviation
Household income	proportion measure	Strategy for mitigating the effects of climate change	standard deviation
Production	proportion measure	Post-Certification Improvements	standard deviation
Family work	proportion measure	Income from orange production	standard deviation
Infrastructure investment	proportion measure	Presence of pests/diseases	standard deviation
Bank Credit	proportion measure		
Education level	proportion measure		

The process involved the following steps:

- Data Collection: Initially, data were gathered on climate change perceptions through a socioeconomic questionnaire and interviews with sampled producers from the four cooperatives. This comprehensive data collection covered various analytical categories, including the hiring of temporary workers, climate change mitigation strategies, household income, and improvements after certification.
- Standard Deviation (SD) Calculation: Standard deviation, a statistical measure reflecting data variability, was calculated for each analytical category within the four cooperatives. This calculation allowed an assessment of the diversity of responses within each cooperative for each topic.
- Identification of Influencing Factors: The factors contributing most to the increase in standard deviation in each category were identified for each cooperative. This involved pinpointing specific participant perceptions that significantly deviated from the average for each topic.
- Interpretation of the Results: Results were interpreted based on the standard deviation calculation and identification of influencing factors in each category. For instance, if a specific category (e.g., "Less rainfall" or "Higher temperatures") was predominantly chosen by participants in a cooperative, it indicated a prevailing concern within that cooperative regarding that aspect of climate change.

Below is the legend used to interpret the Standard Deviation (perception).

Table 15 - Standard Deviation (perception).

Standard deviation	Interpretation	Description
0 a 5	Very low	Low variability, indicating that most producers have very similar perceptions and are aligned on how to deal with climate change.
6 a 10	Low	Relatively low variability, suggesting that most producers share similar perceptions and agree on how to manage the effects of climate change.
11 a 15	Moderate	Moderate variability, indicating that there are some differences in producers' perceptions, but there is still some agreement in addressing the effects of climate change.
16 a 19	Moderate - High	Moderate to high variability, suggesting that producers' perceptions have significant differences, although there is still a degree of consensus on how to deal with climate change.
20 a 25	High	High variability, indicating that producers' perceptions are substantially different, and there may be a significant degree of disagreement regarding the management of the effects of climate change.
26 a 30	Excessively high	Excessively high variability, pointing to widely divergent perceptions among producers, with significant disagreements in addressing the effects of climate change.

Results Interpretation by Cooperatives – Practices and perceptions of sampled producers

Cooperative A

Farm Characterization

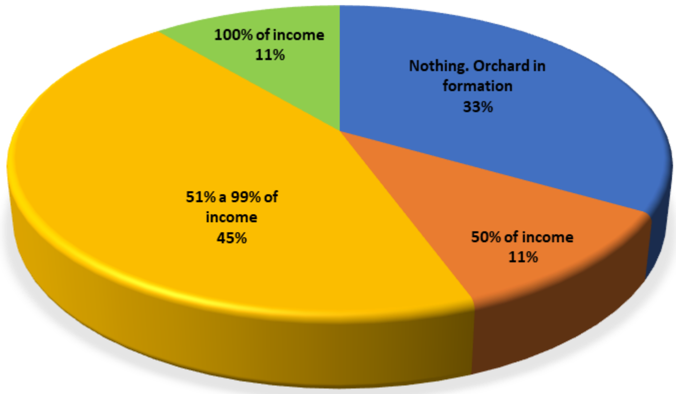
Most of the sampled producers are focused on the exclusive production of oranges, which represents 67% of the total, and also reflects the main crop produced by the cooperative. Other activities, such as the production of grass for silage, cassava and livestock, and beef cattle, are practiced – along with oranges – by a smaller portion of producers, each representing 11% of the total.

Table 16 - Other crops on the properties visited (Cooperative A)

Activities	Number of producers	% of Producers
Orange Only	6	67%
Silage grass	1	11%
Cassava and livestock	1	11%
Beef cattle	1	11%

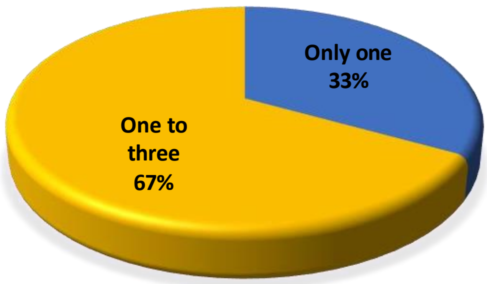
Orange production significantly contributes to the family income of cooperative growers. For a considerable portion (45%), the majority of their income is derived from orange production, ranging from 51% to 99% of their total income. Additionally, for a subset of growers (11%), orange production serves as their sole source of income. This insight suggests that the diverse activities on the visited farms go beyond subsistence (own consumption) and are integral to the family's commercial strategy. However, the production of oranges stands out as a cornerstone for the social reproduction of farming families.

Graph 1 - Representation of Orange in Family Income (Cooperative A)

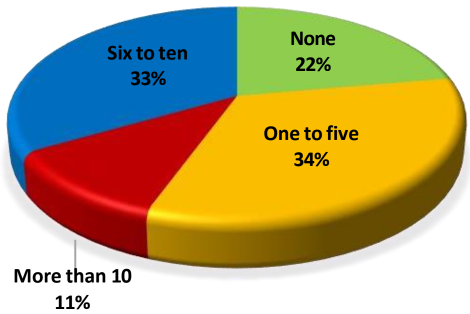


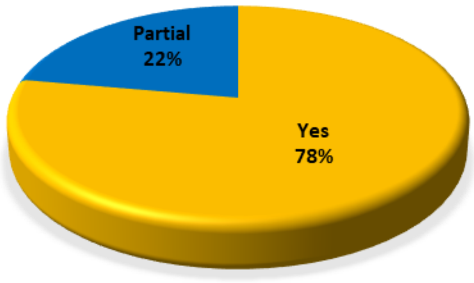
The following two graphs (2 and 3) illustrate the characteristics and extent of the farms included in this study. These metrics provide a snapshot of the family structure of producers and the employment of additional labor on the farms visited. A substantial majority of producers (67%) have moderately sized households engaged in orange production (ranging from 1 to 3 members), and a significant proportion of producers (78%) have enlisted at least one worker for agricultural activities.

Graph 2 - Number of family members in orange production (Cooperative A)

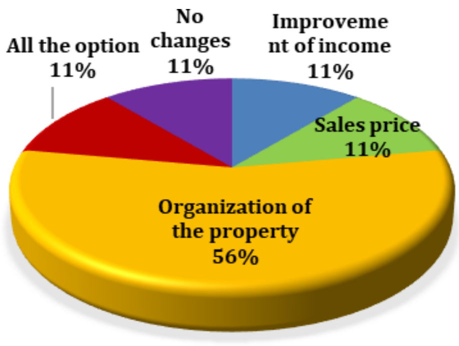


Graph 3 - Number of Employees Contracted for Orange Production (Cooperative A)





Graph 4 - Infrastructure (Cooperative A)



Graph 5 - Perception of changes after Fairtrade certification (Cooperative A)

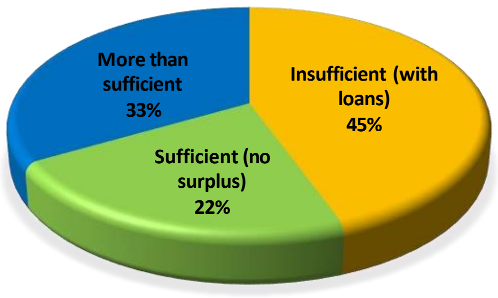
In Chart 4 above, it is evident that 78% of the properties have some level of infrastructure and resources for their operations, indicating high representativeness. A minority (22%) reports the need for improvements or the lack of certain equipment or structures. It is noteworthy that the considerable majority possesses all the infrastructure elements presented in the research, namely: machines, implements, shed, and supply tank.

Graph 5 illustrates the producers' perception of Fairtrade certification. The significant impact highlighted in the data is the "improvement of the organization of the property," with a high standard deviation of 18%, primarily due to the concentration of most responses in this category. Five producers (56%) mentioned this, indicating substantial representativeness. Fairtrade certification has had a notable impact on the organization of Cooperative A's producers' farms, leading to positive externalities related to efficient management, adoption of best agricultural and organizational practices, and a focus on the sustainability of agricultural operations.

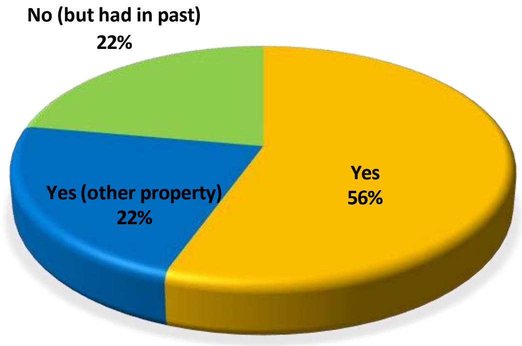
On the flip side, 11% of producers reported that "nothing has changed." This suggests that, for these specific producers, Fairtrade certification hasn't resulted in significant alterations in their operations or perceptions. It's conceivable that the pre-existing management and control measures required for certification didn't have the same impact for those who already had such measures in place to govern their farm processes.

Producer Characterization

Graph 6 - Perception of family income (Cooperative A)



Graph 7 - Access to rural credit (Cooperative A)



The perception of family income (Graph 6) unveils an intricate and diverse scenario. Considering the constraints of this data, we can deduce the following insights:

Most producers, constituting 45% of the sample, reported an insufficient financial situation, compelling them to seek loans. This suggests that despite the advantages of Fairtrade certification, some producers still grapple with significant financial challenges in their agricultural endeavors. It is assumed, therefore, that other factors are intertwined with the financial well-being of the producer. It is noteworthy that the standard deviation in this context is low (8.98%), indicating high consensus in the responses.

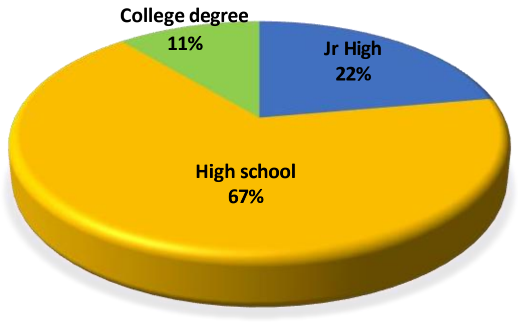
On the other hand, a significant minority of 22% of producers mentioned that their current income ensures a sufficient financial situation, but without surplus. These moderately representative numbers indicate that these producers can meet their basic financial needs but don't have a significant margin of resources available for investment or expansion.

A slightly higher quantity, 33% of producers, perceived that their financial situation is more than enough to maintain their standard of living. Therefore, the family income situation is at least sufficient for 55% of the producers, contrasting with another significant portion of respondents for whom income is still an obstacle due to its insufficiency in balancing finances.

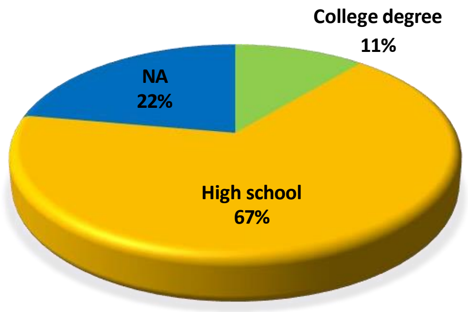
It's important to note that this analysis is based on a sample of nine family producers, and financial perceptions can be influenced by various factors, including property size, pre-existing debts, and the effectiveness of certification in each case.

Regarding the use of rural credit (Graph 7), most producers (56%) claim to have access, with a smaller portion having access to another property or having had access in the past.

Graph 8 - Producer's Schooling (Cooperative A)



Graph 9 - Schooling of the family member who works the most with the producer (Cooperative A)

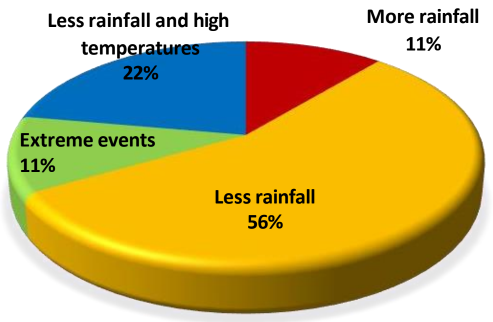


Graph 8 above highlights that a substantial portion of producers (67%) have completed high school education. Conversely, Graph 9 indicates that the education levels of family members working on the farm vary more widely than those of the producers themselves.

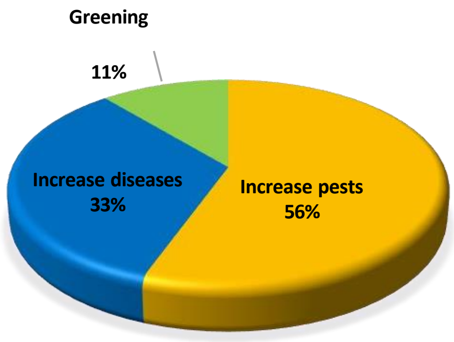
In the context of family production, these trends may suggest an enhancement in efficiency in farm operations, and, in a way, certification also contributes to this objective.

Perception of climate change

Graph 10 - Perception of climate change in recent years (Cooperative A)



Graph 11 - Changes in phytosanitary issues in recent years (Cooperative A)



Regarding climate change, almost a quarter of the producers shared the experience of "Less rainfall and high temperatures" (22% of the sample). Notably, 56% of farmers reported "Less rainfall," and just over a tenth of respondents (11%) stated the opposite: "More rainfall." The same amount pointed to the occurrence of "Extreme events" as part of their experience. Faced with these climate perception trends, it is possible to say that the resilience of the activity is key to cope with climate change scenarios.

In the case of data related to the perception of climate conditions, with a high standard deviation of 18.45%, it is associated with the high representativeness of the "Less rainfall" category with 56%. This agreement is particularly important, considering that agricultural activities are becoming more vulnerable to climate fluctuations, impacting agricultural productivity and farmers' income.

However, there is a positive sign that producers have a shared understanding of the challenges posed by climate change in agriculture and may be more inclined to adopt adaptation practices and strategies together. Cohesion in perceptions can also be beneficial for cooperation and collaboration among producers in finding solutions to address climate challenges in their agricultural activities.

Regarding phytosanitary issues, farmers face new challenges. A considerable portion of 56% pointed to the "Increase in pests," while 33% highlighted the "Increase in phytosanitary diseases." In this context, the presence of "Greening" was mentioned by only 11% of farmers.

The standard deviation regarding the perceptions of Cooperative A's producers about the effects of climate change on agriculture is approximately 18.37% (Moderate – High). This value reflects a small but considerable variability in respondents' opinions regarding these effects, as the values deviate from the average of the responses.

Table 17 - Strategies adopted to cope with climate change (Cooperative A)

Strategy	Number of producers	% of Producers
Increased spraying	1	11%
Application schedule	1	11%
Intention to irrigate	1	11%
Irrigation and increased spraying	1	11%
New plantings and intensification of treatments	1	11%
Water reserves	1	11%
Area systematization (Contour lines, water drainage, etc.)	1	11%
No changes.	2	22%

Table 17 above reveals that strategies to address climate change are highly individualized and adapted to the specific circumstances of each producer and farm. A strong hypothesis is that climatic and geographical conditions may vary considerably in different areas where the properties are located. What is effective on one farm may not be suitable on another due to differences in rainfall patterns, temperatures, altitude, among other local factors (microclimates that vary with different altitudes). Additionally, each farm may have specific needs in terms of water resources, soil, infrastructure, etc. Lastly, the availability of financial and technological resources varies, influencing the strategies adopted.

The standard deviation of the values above is very low (3.63%). This value suggests low variability in respondents' perceptions regarding these strategies, reinforcing the idea of a reasonable level of agreement among respondents regarding control actions. At the phenomenological level (consciousness and understanding), practices are highly cohesive and shared about the strategies to be adopted in the face of these challenges. This statement largely represents that producers have a similar view on the necessary actions to deal with climate change.

Thus, concerning the adaptation and mitigation measures necessary to face possible impacts of climate change on their agricultural practices at Cooperative A, there is high homogeneity in the implementation of strategies to confront climate challenges.

Cooperative B

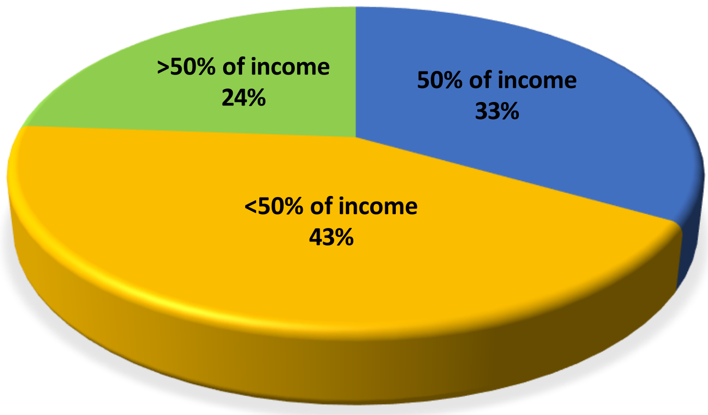
Farming Characterization

Table 18 - Other crops on the properties visited (Cooperative B)

Activities	Number of producers	% of Producers
Grains (soybeans, corn, etc.)	5	24%
Tobacco	4	19%
Only Orange	3	14%
Swine Farming and Dairy Livestock	2	10%
Pumpkin	1	5%
Beef Cattle Farming	1	5%
Dairy Livestock	1	5%
Tobacco and Grains	1	5%
Tobacco, Dairy Livestock, and Grains	1	5%
Grapes	1	5%
Others – Own Consumption	1	5%

The table 18 above presents interesting data from the sample of 21 farmers in this cooperative and is related to the high diversification of the production of the cooperatives visited in this study. The pursuit of income and financial security leads farmers to explore various sources of income, such as grain production, livestock farming, pig farming, and other crops. It also becomes a risk mitigation strategy, as different crops may respond differently to climate variations and market fluctuations.

Graph 12 - Representation of Oranges in Family Income (Cooperative B)

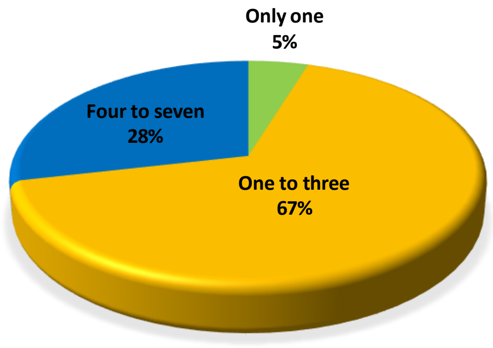


Graph 12 above illustrates the proportional impact of orange sales on the overall family income reported by Cooperative B producers. The data reveals that, for seven producers (33%), oranges constitute 50% of their family income, while for five producers (24%), this figure exceeds 50%. Therefore, a minimum of 57% of the visited producers primarily rely on orange production for their income (at least

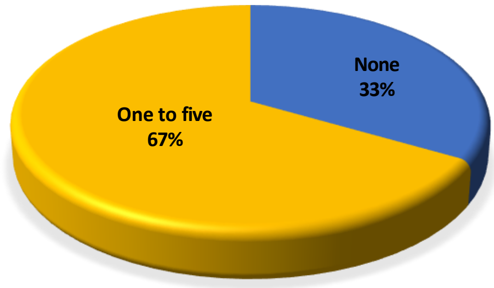
50% of their total income), while 43% indicate that orange income constitutes less than 50%, highlighting a noteworthy diversity in production.

The low standard deviation of 7.76% suggests minimal variation in responses regarding the contribution of oranges to family income. This indicates that the assigned percentages for each category (50% of income, <50% of income, >50% of income) deviate by approximately 7.76% from the mean.

Graph 13 - Number of family members in orange production (Cooperative B)



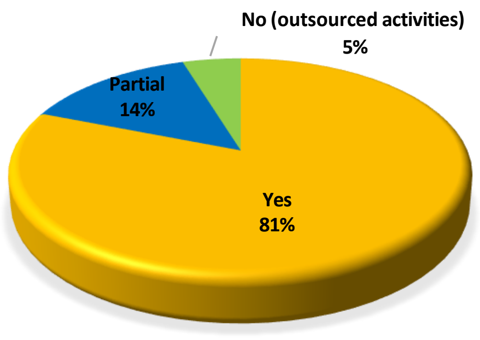
Graph 14 - Number of Employees Contracted for Orange Production (Cooperative B)



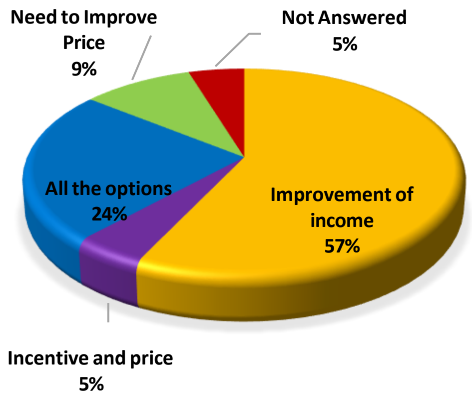
The analysis of graphs 13 and 14 indicates that a majority of producers have a limited number of family members engaged in orange production (67% of the interviewed families fall into this category). Regarding the employment of additional staff, a notable portion of the farmers surveyed (33%) does not hire any external labor, relying primarily on family members for agricultural tasks - a characteristic hallmark of family farming, where the family plays a central role in the production process.

However, it's noteworthy that a significant minority of 28% of growers report having families with four to seven members exclusively dedicated to oranges. This suggests a higher production capacity in terms of volume and area, making it feasible to involve all family members in the activity. The assumption here is that maintaining most family members engaged in citrus farming is viable due to the gains derived from it. Conversely, the alternative hypothesis posits that the impracticality of supporting more family members in the activity compels some members to seek additional income through various means, such as diversifying production on the farm, seeking wage employment, or providing services elsewhere.

Graph 15 - Infrastructure (Cooperative B)



Graph 16 - Perception of changes after Fairtrade certification (Cooperative B)



In terms of the strategies employed by producers to manage their agricultural activities with the existing infrastructure, the data indicates that most producers (81%) possess their own infrastructure to conduct agricultural operations. This suggests significant investment in resources and facilities, including buildings, equipment, implements, and other necessary structures for agricultural production.

A smaller segment of producers (14%) takes a more selective approach to acquiring fixed capital goods. The responses suggest two potential scenarios for this group, which may or may not be mutually exclusive: 1) they may have improvised infrastructure (such as workshops adapted for agrochemical and fuel storage) in certain aspects of their operations; 2) they may outsource certain operational activities, with harvesting being the primary example. This configuration may reflect a more adaptable management strategy, where producers aim to optimize their resources within the constraints they face. They utilize their own infrastructure where feasible and outsource in areas where they lack resources or expertise.

Lastly, a minority with minimal representation (5%) outsources all agricultural activities or leases their land, indicating complete dependence on third parties to carry out operations. This smaller number represents a niche trend, and only time will reveal if this process of leasing and outsourcing becomes more prominent. A comparable situation occurred in the sugarcane industry in São Paulo, particularly among small-scale sugarcane producers who witnessed the increasing oligopolization of sugarcane production by large, professionalized producers in a risky partnership with mills.

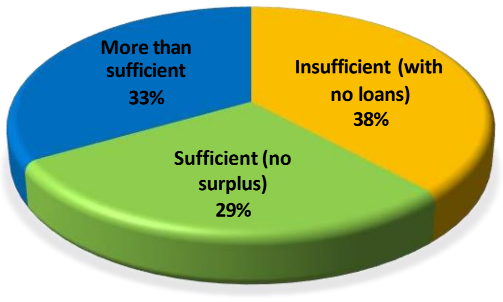
Examining these figures reveals another dimension related to the risks and the availability of credit for long-term investments. The absence of dedicated infrastructure cannot be solely attributed to a strategy chosen by small-scale producers to remain in the market. The lack of accessible credit at reasonable rates also hampers the ability to upgrade machinery and equipment, as well as make new investments.

Graph 16, on the other hand, emphasizes that a significant majority of producers (57%) perceive Fairtrade certification as having a positive impact on enhancing their incomes. In essence, the certification is fulfilling one of its primary objectives, which is to ensure a fair and stable price for producers, thereby contributing to the enhancement of families' quality of life.

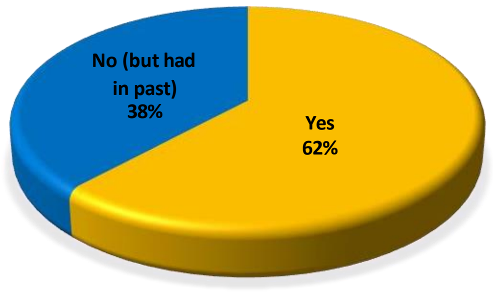
The standard deviation of 19.67% indicates substantial variability in responses regarding the impact of Fairtrade certification. This signifies that the percentages assigned to each category (Income Improvement, Incentive & Price, All Options, Need to Improve Price, Not Answered) exhibit significant variations from the average. The amplitude of this variation is approximately 19.67% (Moderate – High) in relation to the mean. The factor contributing to the higher standard deviation is the prevalence of the category "Income Improvement," which holds a substantial representation of 57%.

Producer Characterization

Graph 17 - Perception of family income (Cooperative B)



Graph 18 – Access to rural credit (Cooperative B)



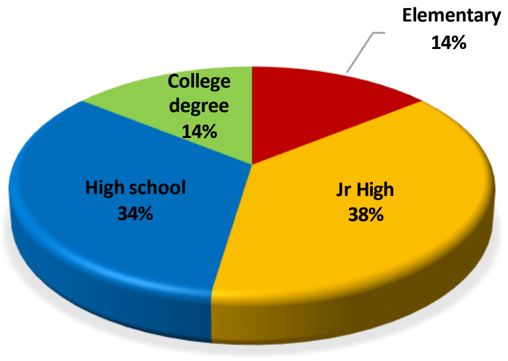
About two-thirds of the sampled Cooperative B producers perceive their family income as either "sufficient" (29%) or "more than sufficient" (33%) to sustain both production and family living standards. In the first scenario, expenses are covered, but no surplus income is generated. While there has been an improvement in their financial situation, accumulating surplus income remains a challenge. In the second scenario, producers not only cover their expenses but also have surplus income, indicating a high quality of life and favorable economic conditions for these families (Graph 17).

On the other hand, a significant portion of 38%, of producers still grapple with financial difficulties, as their income from agricultural activities is deemed insufficient to cover all family expenses without resorting to debt. Essentially, the income generated falls short of meeting the basic needs of their families.

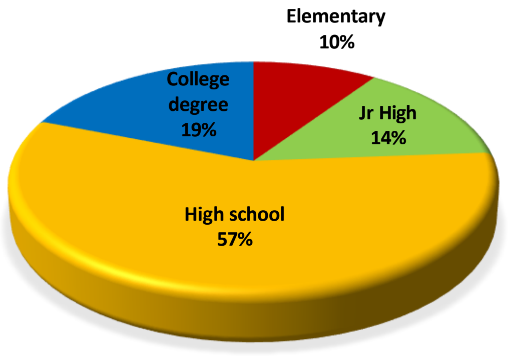
Considering the income perception of Cooperative B producers with a very low standard deviation of 3.68% and the "Insufficient (no debt)" category being the most influential, contributing 38% to the standard deviation, it is evident that the majority of Cooperative B producers believe their income is insufficient, even without incurring debts. This insight highlights heightened concern about the financial situation and the perception that current income fails to meet the financial needs of producers.

Graph 18 illustrates that most producers (62%) report securing bank credit to finance the harvest, signifying their ability to access financial resources through bank loans for expenses associated with the harvest. On the other hand, approximately 38% (just over a third) of producers mentioned that they do not currently have bank credit to support the ongoing harvest, although they have utilized it in the past. This indicates a variable dynamic regarding credit accessibility. It's possible that some producers have faced challenges or experienced changes in their financial circumstances, leading them to forego using bank credit in the current harvest, despite having utilized it before.

Graph 19 – Producer's Schooling (Cooperative B)



Graph 20 – Schooling of the family member who is most closely with the producer (Cooperative B)



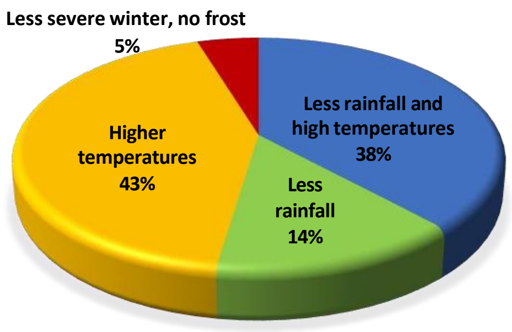
Graph 19 above indicates that over a third of the producers (34%) have completed at least high school, suggesting a more robust educational foundation. This characteristic, in principle, contributes to a more informed and effective participation in the cooperative's activities. A smaller yet significant portion of family members hold higher education degrees (14%).

This is noteworthy, as having members with higher education involved in the farm's activities undoubtedly enhances planning, decision-making, management, and innovation capacities.

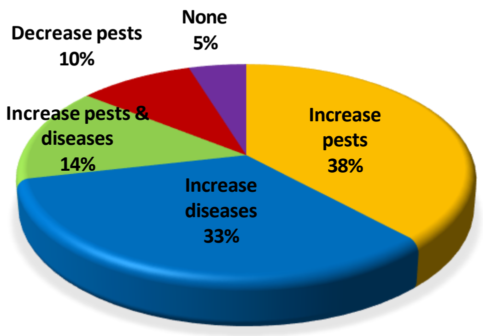
Although most of the members have a high educational level, it is important to note thar 14% have only elementary education and 38% have only junior high. In the case of a small portion of the interviewed families, it's possible to infer a generational shift behind these values. This is because, after 2006, elementary education (for children from 6 to 14 years old) became mandatory for all Brazilians, according to the LDB – Law of Guidelines and Bases of Education, of 2006. On the other hand, Graph 20 shows that most family members working with the producers have a high school education (57%), with a significantly higher presence of professionals with higher education (19%) who are more directly involved in the production of oranges.

Perception of climate change

Graph 21 – Perception of climate change in recent years (Cooperative B)



Graph 22 – Changes in phytosanitary issues in recent years (Cooperative B)



Graph 21 illustrates the degree of awareness among sampled producers about climate change and its potential consequences for agriculture. Concerns about water availability, higher temperatures, and changing seasons emerge as prominent themes. These concerns highlight the necessity of adopting climate change adaptation and mitigation strategies in agriculture, such as sustainable water management practices and the cultivation of varieties resistant to climate variations. A substantial portion of producers (38%) perceive that climate change is evident in the form of "less rainfall and higher temperatures," while a considerable percentage (43%) associates it solely with the increase in temperatures.

Regarding perceptions of climate change at Cooperative B in recent years, the standard deviation of 15.92% indicates a "moderate to high" variability in responses regarding the perception of climate change. Thus, the percentages assigned to each category ("Less rain and high temperature," "Less rainfall," "Higher temperatures," "Less severe winter, no frost") vary significantly from the average.

Concerning data related to the perception of climate change with a standard deviation of 15.92%, the factor contributing to the variability is the high representativeness of the categories "Less rain and high temperature" and "Higher temperatures," accounting for 81% of the responses. Finally, the presence of categories with very low representation, such as "Less severe winter, no frost" with 5%, adds to the variability due to the discrepancy between dominant and less represented categories.

Graph 22, on the other hand, presents figures that underscore diverse perceptions among producers regarding changes in phytosanitary issues affecting orange plantations on the farms visited by Cooperative B. The most common response among producers was reporting an increase in pests in the crops, prompting the need for additional control measures that can escalate production costs. Just over a third of producers (33%) also noted an increase in crop diseases, which can impact crop quality and productivity. A smaller group of producers observed an increase in both pests and diseases, intensifying the complexity of the phytosanitary challenges they face. These producers must address multiple issues in pest and disease management, necessitating the implementation of control and prevention strategies to address several challenges simultaneously.

Concerning data related to the increase in pests and/or diseases with a standard deviation of 13.06% (Moderate), the factor amplifying the standard deviation is the presence of the categories "Increase in Pests" and "Increase in Diseases" with significant representativeness.

The categories "Increase in Pests" at 38% and "Increase in Diseases" at 33% are the two most representative, collectively constituting most responses. This distribution indicates that the majority of participants selected these categories, thereby increasing variability in the responses. The most represented categories have more concentrated responses in relation to the mean, while the less represented categories exert minimal influence.

Furthermore, the presence of categories with very low representation, such as "None" at 5%, contributes to the overall variability, introducing a disparity between the dominant categories and the less represented ones.

Table 19 - Strategies adopted to cope with climate change (Cooperative B)

Strategy	Number of producers	% of Producers
Increase in spray applications	9	43%
Changes in chemical treatments	3	14%
Organic fertilization	1	5%
Green fertilization and organic management	1	5%
Organic management	1	5%
Tree planting and organic management	1	5%
No-till / minimum tillage	1	5%
Pruning of dry branches and fertilization for regrowth	1	5%
Land systematization (Contour lines, water drainage, etc.)	1	5%
No changes	2	10%

When addressing the primary strategy to combat climate change, the predominant approach among Cooperative B producers is an increase in spray applications (43%). This aligns with the hypothesis that a significant portion of growers respond to climate change by intensifying spraying to protect crops from pests and diseases influenced by unpredictable weather conditions. It's crucial to note that the rise in spraying alone doesn't directly correlate with increased greenhouse gas emissions. The latter depends on factors like fertilizer usage, organic waste management, and soil conservation practices, among others, which can either elevate or mitigate emissions in agriculture.

The standard deviation of 11.31% (Moderate) signifies a moderate variability in responses regarding climate change coping practices. This indicates that the percentages assigned to each category ("Organic fertilization," "Green manure and organic management," "Increase in spraying," "Organic management," "Changes in chemical treatments," "Tree planting and organic management," "No-till / minimum tillage," "Pruning of dry branches and fertilization for regrowth," "Systematization of areas," "No changes") exhibit fluctuations around the average, with an amplitude of approximately 11.31% concerning the mean.

This variability suggests that participants' responses aren't uniformly concentrated in a single category. While perceptions of climate change practices differ, there's still a degree of agreement. Therefore, responses are relatively dispersed in relation to the mean, showcasing diverse interpretations of the categories but maintaining a certain level of consistency in perceptions.

The percentage "Increase in sprays" commands a significantly larger portion of the responses, at 43%. Hence, the majority of participants favor this category, while the other categories hold much smaller representations (5% each). The pronounced representation of a specific category, such as

"Increased sprays," compared to the others, contributes to the heightened standard deviation. This concentration in responses amplifies variability relative to the less represented categories.

Cooperative C

Farming Characterization

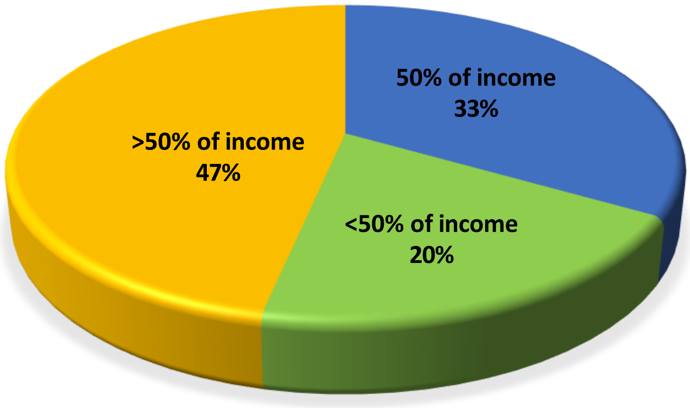
The information gathered from Cooperative C, involving a sample of 15 participants, highlights a diverse range of agricultural activities within the cooperative. The primary activity among producers is orange production, constituting 47% of the participants. This underscores the significant presence of orange cultivation within the cooperative, situated in the northern region of the State of São Paulo. Additionally, sugarcane emerges as the second most prevalent activity, with 13% of producers dedicated to it. Given São Paulo's concentration of the sugar and ethanol agroindustry, producers benefit from secure long-term contractual conditions for supplying sugarcane to processing units, offering advantages like soil preparation, health plans for small producers' families, and access to input cooperatives, among other benefits.

On a smaller scale, cooperative members engage in various additional productive activities, including beef cattle, lemons, cassava, rubber trees, coffee, fruit cultivation, soybeans, and sorghum. Peeled cassava, featured alongside oranges and lemons on the cooperative's website, undergoes processing in an agro-industry that prioritizes sanitary care. The facility includes a packaging and refrigeration unit equipped with a cold chamber, with the construction of this cold room being one of the cooperative's previous investments.

Table 20 - Other crops on the visited properties (Cooperative C)

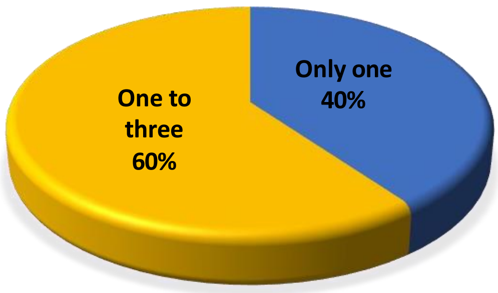
Activities	Number of producers	% of Producers
Only Orange	7	47%
Sugarcane	2	13%
Sugarcane and Beef Cattle Farming	1	7%
Lemon	1	7%
Cassava and Rubber Trees	1	7%
Coffee	1	7%
Fruit Cultivation	1	7%
Soybeans and Sorghum	1	7%

Graph 23 - Representation of Oranges in Family Income (Cooperative C)

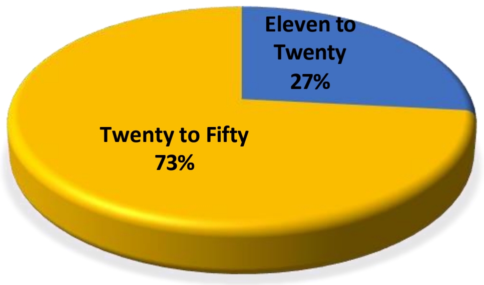


The data from Cooperative C reveals that 47% of its producers derive more than half of their income from orange production, while 33% indicate that oranges contribute to half of their income. This suggests that a significant portion, around 80%, relies on oranges for at least half of their earnings. Conversely, 20% of cooperative members report that oranges constitute less than half of their income, indicating diversification or other significant income sources, as shown in Table 17. The standard deviation for data related to the contribution of oranges to family income is 11.02% (moderate), with the ">50% of income" category, representing 47%, contributing significantly to the variability of responses. The presence of the "50% of income" category, though representative at 33%, adds to the variability due to the difference in representation compared to other categories.

Graph 24 - Number of family members in orange production (Cooperative C)



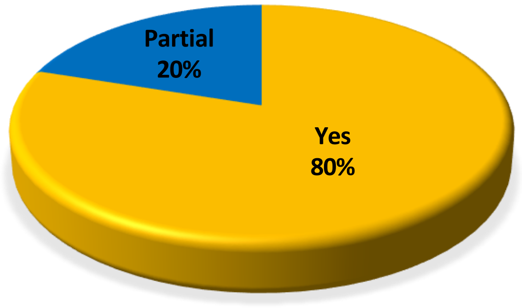
Graph 25 - Number of Employees Hired for Orange Production (Cooperative C)



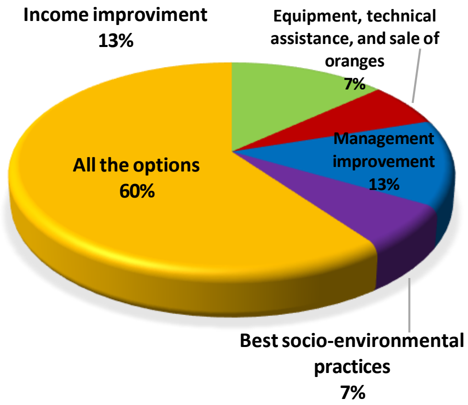
Cooperative C stands out among the cooperatives in this study with a significant number of hired workers for orange production, indicating a larger scale and a distinct risk profile. Nearly 75% of the producers hire 20 to 50 workers for orange harvesting during the harvest period, with an additional 27% hiring 11 to 20 workers for the same purpose (Graph 25). This reliance on hired labor emphasizes the substantial responsibilities and risks associated with a production system heavily dependent on subcontracting.

In contrast to cooperatives in the southern regions of the country (Paraná and Rio Grande do Sul), where owners themselves often handle harvesting or engage in reciprocal services, known as "mutirão," Cooperative C's approach involves significant outsourcing. This difference reflects variations in cultural capital and compensatory strategies to overcome limitations in task execution.

Graph 26 - Infrastructure (Cooperative C)



Graph 27 – Perception of changes after Fairtrade certification (Cooperative C)



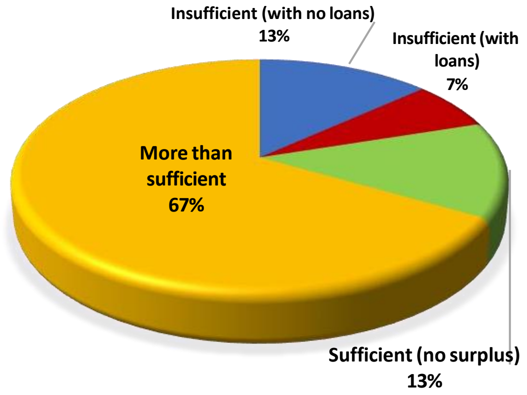
The data reveals that 80% of the visited farms have their own infrastructure for agricultural activities, indicating that most producers possess the necessary facilities and resources for independent operations, without relying on makeshift structures or outsourcing. In contrast, 20% of the cooperative's producers reported using improvised infrastructures and/or outsourcing some activities.

It's important to note that the data on Fairtrade certification reflects the subjective perception of the producers, requiring careful interpretation. With a standard deviation of 20.17% (High) in the perception of the impacts of Fairtrade certification, the factor elevating the standard deviation is the substantial representativeness of the "All options" category at 60%, highlighting a highly positive aspect of certifications.

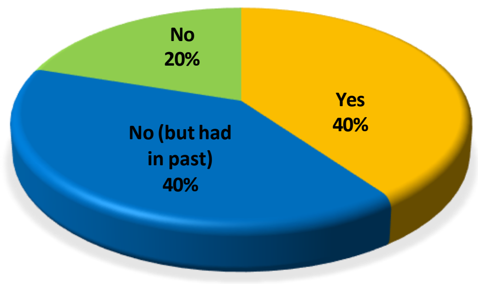
While the dominant category is "All options" with 60%, the presence of less represented categories such as "Income improvement" and "Management improvement" with 13% each, as well as "Equipment, technical assistance, and sale of oranges" and "Best socio-environmental practices" with 7% each, contributes to the variability. This variation stems from the divergence between the dominant and less represented categories.

Producer Characterization

Graph 28 – Perception of family income (Cooperative C)



Graph 29 – Access to rural credit (Cooperative C)

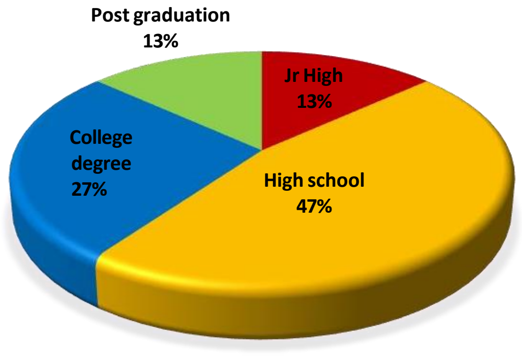


The graphs (28 and 29) are indirectly linked, reflecting farmers' perceptions of changes on their farms, whether in terms of increased income or access to credit. The farmers' view of the sufficiency or insufficiency of their family income may be tied to the changes implemented on their farms due to Fairtrade. Notably, the perception of certification results is significant, with a majority stating that farm income is sufficient, and within this group, a substantial percentage (67%) deems it more than enough. A hypothesis suggests that this improved income perception may be linked to the sustainable and ethical practices adopted as part of Fairtrade requirements. The standard deviation of 24.37% (High) supports this hypothesis, strongly influenced by the category "More than enough" at 67%.

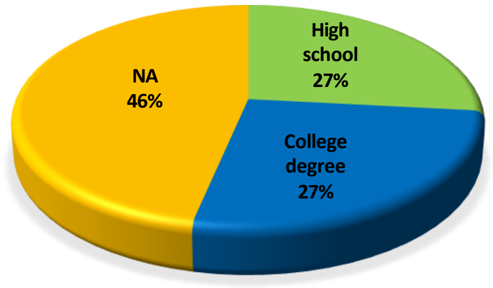
The category "More than enough" dominates responses, representing 67%. The presence of the categories "Insufficient (no debt)" and "Sufficient (no surplus)" with 13% each contributes to variability, highlighting a contrast between the dominant category and these less represented ones.

Another aspect involves the positive correlation between credit use and certification. The perception that income is "more than enough" might indicate the farmer's belief that Fairtrade-induced changes, coupled with access to credit, have positively impacted their economic well-being. Lack of credit access, on the other hand, may contribute to the perception of insufficient income.

Graph 30 – Producer's Schooling (Cooperative C)



Graph 31 – Schooling of the family member who is closest to the producer (Cooperative C)

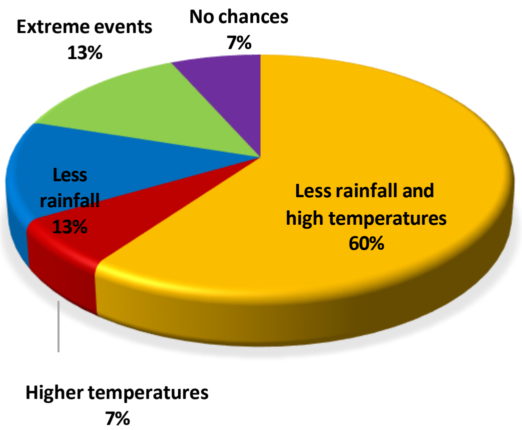


The analysis of Cooperative C's producers' education reveals a notable proportion with higher education (27%) and post-graduation (at least 40%, implying higher education). This signifies a substantial intellectual capital that reinforces the positive perception of certification. The successful implementation of sustainable practices, coupled with adherence to Fairtrade requirements, is complemented by the academic knowledge acquired in agricultural management, sustainable practices, and sustainability.

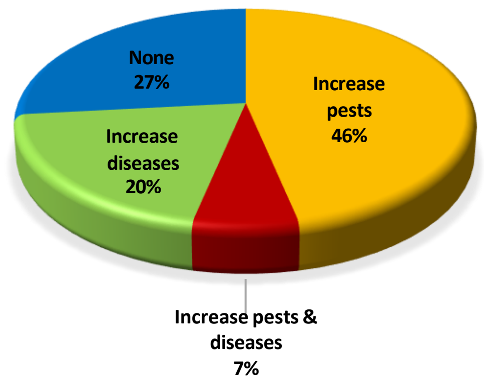
Formal higher education enhances adaptability, preparing individuals to embrace new approaches and innovations. The value of education in agricultural activities extends beyond intellectual capital, encompassing access to financial and technical resources for sustainable practices (economic capital). Moreover, it deepens understanding of the implications of actions, particularly in terms of environmental sustainability and social responsibility, highlighting the role of education in shaping holistic agricultural practices.

Perception of climate change

Graph 32 – Perception of climate change in recent years (Cooperative C)



Graph 33 – Changes in phytosanitary issues in recent years (Cooperative C)



Concerning climate change, a notable portion of growers (60%) observed a pattern of "less rain and high temperature," signaling potential water stress that could impact orange production. Additionally, 13% of producers noted "more extreme events," reflecting concerns about unpredictable weather events like storms and severe droughts, which could cause substantial damage to crops and lead to significant losses.

Regarding climate perception data, the standard deviation of 20.17% (High) is primarily influenced by the high representation of the category "Less rain and high temperature" with 60%. While this category dominates responses, the presence of other categories, including "Less rainfall" (13%), "More extreme events" (13%), "Higher temperatures" (7%), and "No changes" (7%), contributes to variability, showcasing disparities among different perceptions.

In terms of phytosanitary issues, the challenge of increased pests is significant (47%), potentially resulting in production losses and necessitating additional control measures. The rise in diseases (20%) also poses risks to fruit quality. On a positive note, 27% of producers reported "no" change in phytosanitary issues, suggesting effective control measures on some farms.

The standard deviation of 14.46% (Moderate) is primarily influenced by the category "Increase in Pests" with 47%. Secondary influences include the presence of categories like "None" (27%), "Increase in Diseases" (20%), and "Increase in Pests and Diseases" (7%), contributing to variability due to differences in dominant and less represented categories.

Table 21 - Strategies adopted to cope with climate change (Cooperative C)

Strategy	Number of producers	% of Producers
Increase in spraying	4	27%
Replanting oranges with rootstocks resistant to drought and diseases	2	13%
Weekly insecticide application	1	7%
Installation of irrigation	1	7%
Installation of irrigation + Nutritional management	1	7%
Crop rotation	1	7%
Planning to implement irrigation	1	7%
Tree planting	1	7%
Weekly spraying + Irrigation	1	7%
Reduction of herbicides / tractor operations	1	7%
No changes	1	7%

The Cooperative C producers' perception of resilience and adaptation, with a very low to low standard deviation of 5.85%, highlights the category "Increase in spraying" as the most influential. This affirms that most producers see the necessity of heightened spraying as a strategy for resilience and adaptation to climate challenges.

The category "Orange replanting with drought and disease-resistant rootstock" also holds significance, contributing 13% to the standard deviation. This implies that a substantial portion of producers views changing rootstocks as a crucial strategy in addressing climate challenges.

While other categories like "Weekly insecticide application" and "Irrigation installation" play a role, their contribution is smaller, each accounting for 7%. These strategies are considered relevant but do not dominate as much as increased spraying and replanting with resistant rootstocks.

Overall, these strategies reflect a high level of awareness among producers regarding the impacts of climate change, and they are actively adopting diverse measures to ensure the sustainability and productivity of orange plantations in response to these challenges.

Cooperative D

Farming Characterization

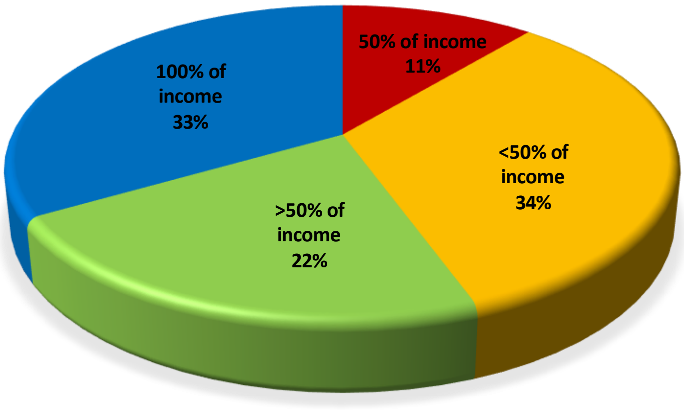
Table 22 - Other crops on the properties visited (Cooperative D)

Activities	Number of producers	% of Producers
Only Orange	4	44%
Orange and intercropping in renewals	1	11%
Cassava, rubber, and mahogany	1	11%
Beef cattle farming	1	11%
Beef cattle farming and leasing for sugarcane	1	11%
Dairy and beef cattle farming	1	11%

Apart from cultivating oranges, Cooperative D members are involved in a diverse array of agricultural activities, encompassing crops like sugarcane, cassava, and rubber trees, as well as dairy and beef cattle. Despite this variety, a noteworthy portion of producers (44%) exclusively focuses on orange cultivation. This characteristic is emblematic of family farming, serving as a vital income source for producers and contributing significantly to community food security by providing sustenance for both the producers' families and the local community.

The prevalence of orange cultivation is intricately linked to the necessary specialization of the cooperative. This specialization involves the development and enhancement of expertise in specific markets, encompassing concealed institutional processes such as technical assistance, rural extensionism, certifications facilitating access to more lucrative markets, effective marketing and export strategies, and the implementation of advanced storage technologies and transport logistics.

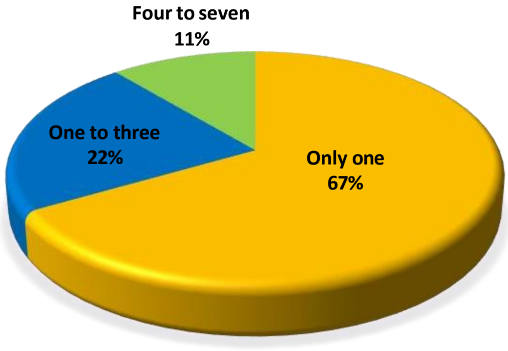
Graph 34 - Representation of Oranges in Family Income (Cooperative D)



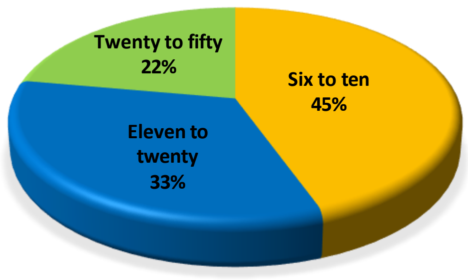
The data on the household income of Cooperative D producers underscores the substantial role of oranges in their income sources. Approximately 55% of producers state that over half of their household income is derived from orange production (22% + 33%), closely aligning with the proportion of oranges in the overall food produced on the visited farms. This emphasizes oranges as the primary income source for a significant portion of family farmers associated with the cooperative. Notably, 11% mention that oranges precisely constitute 50% of their household income, further emphasizing the significance of this crop in their livelihoods. Conversely, 34% indicate that oranges contribute less than half of their household income, suggesting that other food items produced might yield more income than orange production.

The low standard deviation of 9.12% indicates a minimal variability in responses regarding the contribution of oranges to family income. In other words, there is a consistent agreement among producers regarding the proportion of income derived from oranges in their households.

Graph 35 - Number of family members in orange production (Cooperative D)



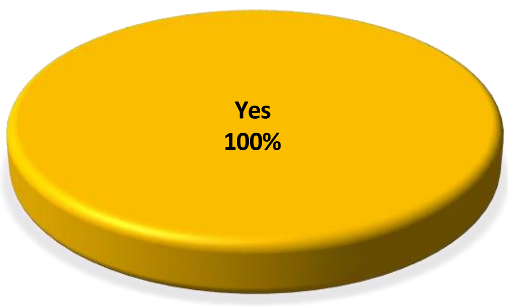
Graph 36 - Number of Employees Contracted for Orange Production (Cooperative D)



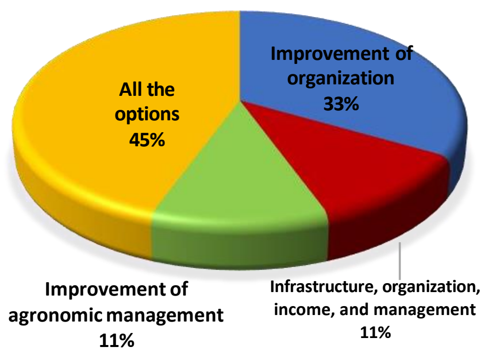
On family farms, irrespective of their size, active involvement of family members in agricultural activities is a common practice. This stems from the reliance of households on agricultural production for income and sustenance, and engaging multiple family members is a practical way to meet the demands of farming. Utilizing the social capital network is not exclusive to small farms; it is observed across various types of family farms where family collaboration plays a pivotal role in the operation and success of agricultural endeavors. At Cooperative D, most families (67%) have only one person dedicated to orange production, representing the most significant category. Additionally, 22% of households involve one to three people in orange production.

The hiring of temporary workers, with the majority of sampled producers (45%) hiring between six and ten workers during the harvest period, indicates the seasonality of the labor force in citriculture. The need for a substantial workforce during the harvest is common due to the high demand during this period. Relying on temporary labor is a prevalent practice in citriculture, allowing for efficient completion of the harvest in less time and at a lower cost.

Graph 37 - Infrastructure (Cooperative D)



Graph 38 - Perception of changes after Fairtrade certification (Cooperative D)

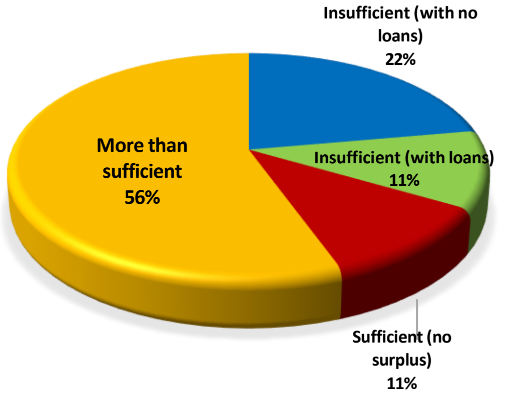


The fact that 100% of the producers have their own structures for orange production underscores the robust infrastructure of Cooperative D's farms. This reflects significant investments and resources directed towards enhancing production and meeting certification requirements, undoubtedly linked to the certification process. Having their own infrastructure provides producers with greater logistical and administrative control over operations, ensuring product quality.

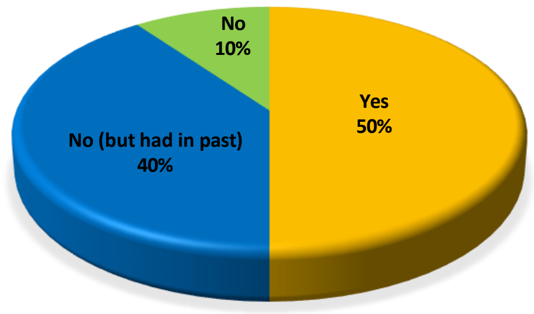
The standard deviation of the perception regarding the impact of certification on the economic life of Cooperative D producers is approximately 14.28% (moderate). The "All Options" category, representing 45%, is the most prominent and encompasses the majority of responses. This indicates that most participants selected this category, contributing to variability in responses, as the most represented category has more concentrated responses relative to the mean, while the less represented categories have limited influence. The presence of categories like "Improvement of organization" (33%), "Infrastructure, organization, income, and management" (11%), and "Improvement of agronomic management" (11%), although less dominant, contributes to variability by introducing diversity in responses. The overall response is highly positive, suggesting that all factors resulting from certification have positively impacted their lives, including improved income, acquisition of equipment, technical assistance, sale of oranges, enhanced management, and better socio-environmental practices.

Producer Characterization

Graph 39 - Perception of family income (Cooperative D)



Graph 40 - Access to rural credit (Cooperative D)



The statement that a significant majority (56%) of farmers consider their household income to be "more than sufficient" suggests that most of them are financially comfortable and do not face significant financial difficulties. However, as noted, it is important to acknowledge that there is still a noticeable portion that considers their income to be insufficient, whether with or without debt.

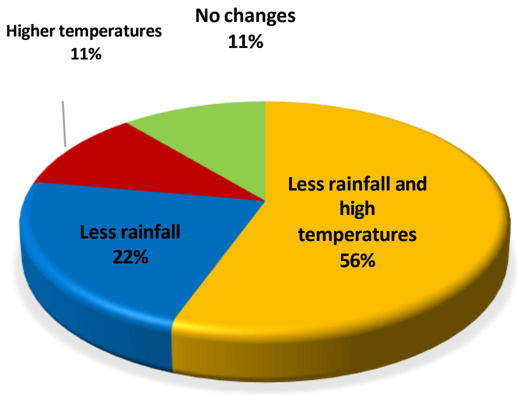
The standard deviation of 18.45% (classified as "High") indicates a high variability in income data, reflecting the fragmented presence of less representative categories such as "Insufficient (no debt)" with 22%, "Insufficient (resorting to loans)" with 11%, and "Sufficient (no surplus)" with 11%. This discrepancy between the dominant category, "More than enough," and these underrepresented categories contributes to the overall variability.

The assertion that income is "more than sufficient" implies that, from the producers' perspective, they have disposable income that meets their financial needs well, providing a level of financial comfort.

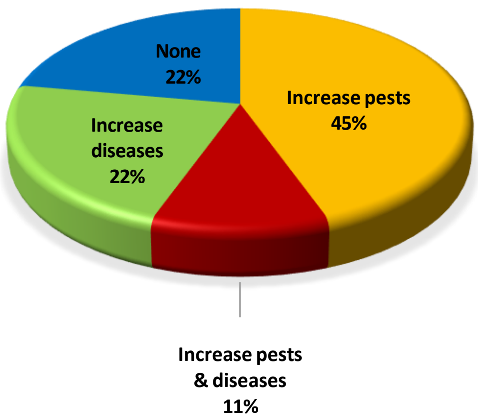
However, examining the less representative categories is crucial to understanding the financial conditions of those who consider their income insufficient, whether due to debt or lack of financial surpluses.

Half of the producers are currently using or have already used bank credit to finance their crops, indicating a relatively common practice among family farmers (Graph 40). The fact that 50% answered "Yes" and 40% answered "No (but has already had it)" suggests that a significant number of farmers resort to credit at some point in their activity. Only 10% of producers have never used bank credit to finance their crops, possibly indicating a preference for alternative financing methods or reliance on their own resources or local partnerships.

Perception of climate change



Graph 41 - Perception of climate change in recent years (Cooperative D)



Graph 42 - Changes in phytosanitary issues in recent years (Cooperative D)

In general, producers share a common perception of climate change (Graph 41). In the case of data related to the perception of climate change with a standard deviation of 18.45% (High), the dominant factor contributing to variability is the high representativeness of the category "Less rain and high temperature" with 56%. The presence of the categories "Less rainfall" with 22%, "Higher temperatures" with 11%, and "No changes" with 11%, although less representative, also contribute to the variability, highlighting divergent opinions among producers. The prevailing perception among producers is that climate change is associated with "Less rain and high temperature". However, the high variability in the data suggests that there are still differing opinions, possibly influenced by local factors, individual experiences, or varied interpretations of climate change.

Regarding the perception of phytosanitary aspects (Graph 42), in the case of data related to the incidence of pests and diseases, the standard deviation of 11.98% (Moderate) is influenced by the high representativeness of the category "Increase in Pests" with 44%. The presence of the categories "Increase in Diseases" with 22%, "Increase in Pests and Diseases" with 11%, and "None" with 22%, although relatively representative, also contribute to the variability. In summary, the common perception among producers is that there has been an "Increase in Pests," indicating a shared concern. This convergence may suggest that climate change plays a significant role in the rise of pests. This insight can be valuable for Cooperative D in implementing measures to address this challenge effectively.

Table 23 - Strategies adopted to cope with climate change (Cooperative D)

Strategy	Number of producers	% of Producers
Spraying Schedule	3	33%
Irrigation	2	22%
Orchard Nutrition	1	11%
Increased Spraying	1	11%
Equipment Improvement	1	11%
No Changes	1	11%

Looking at the table above, the factor that most contributes to the low variability is the high representativeness of the "Spraying time" category with 33%. This indicates that most growers are focused on adapting spraying practices in relation to climate change, specifically adjusting spraying schedules. Although the standard deviation is low, it suggests that, in general, producers are more aligned on the adaptation strategy. The resilience of orchards is mainly related to optimizing the timing of spraying, which can be an effective approach to deal with the challenges posed by climate change. This indicator further demonstrates that producers are aware of the challenges of climate change and are taking steps to adapt to these changes. These strategies can include actions such as irrigation, pest and disease management, climate-resilient crops, and other agricultural practices that aim to mitigate the impacts of climate change on their orchards.

Pictures

During the field visits, photos were taken to demonstrate the orchards and the structures of the producers. Below are some images, a compilation of the photos can be seen in Appendix 5.

Orchard (Cooperative A)

Agrochemicals Storage (Cooperative C)

Machines (Cooperative C)

Machines (XX))

Agrochemicals prepare area (Cooperative D)

Producer (Cooperative B)

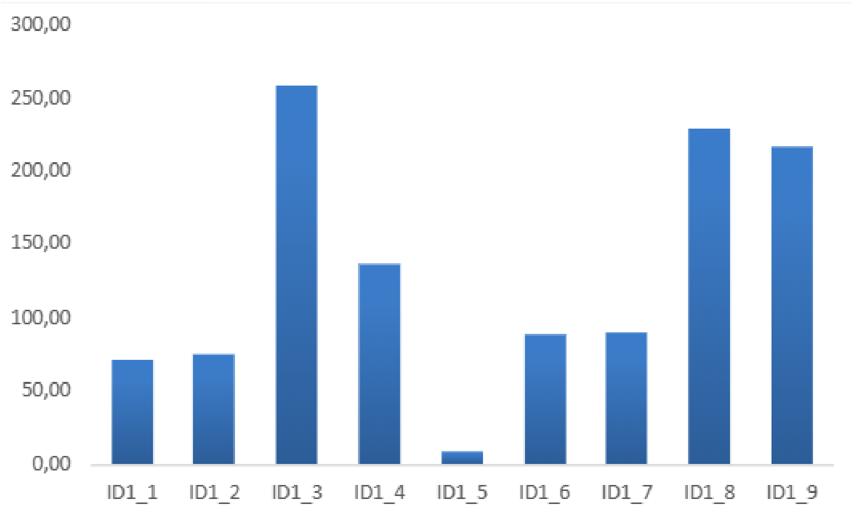
6. Analysis

COOL FARM TOOL

Once the field research had started, all collected date was processed and arranged in order to put it in the Cool Farm Tool. After this stage, the outputs were generated, and the results obtained are presented below.

Cooperative A

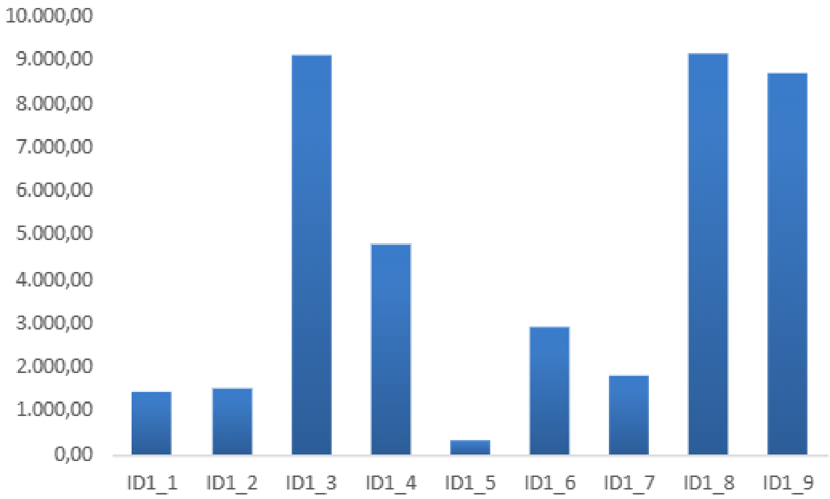
Graph 43 - Kg CO_{2eq} emissions per ton of produced orange (Cooperative A)



Most of the emission values in Kg of CO_{2eq}/ton are concentrated in lower values, without the presence of outliers. Most values are grouped at lower levels relative to the median, which is 90,98 $KgCO_{2eq}$ per ton of oranges produced on farms. The lower limit, represented by producer ID1_5, is 8.81 $kgCO_{2eq}$ per ton, this producer didn´t use any mineral nitrogen fertilizers, only organic sources and changed the use of land from annual crop to perennial in 2009 This quite good index shows how that type of inputs affects positively the estimative of carbon emissions. On the other hand, indicating the higher emissions are ID1_3 (260.58 $KgCO_{2eq}$ per ton), ID1_8 (229.84 $KgCO_{2eq}$ per ton) and ID1_9 (218.41 $KgCO_{2eq}$ per ton). ID1_3 has a part of his orchard in formation, meaning that the farmer is using fertilizer and diesel but harvesting less oranges. For ID1_8 and ID1_9 the highest contribution came from the residues management (referred to the crop residues left in the orchard after pruning and harvest) and use of nitrogen fertilizers.

For both producers, the "crop residue management" was estimated in 20% (as suggested by Cool Farm Tool) and considered “distributed on field”. This input contributes to the overall increase in emissions. A way to improve this value is remove this residue of the field or carry out a composting process throughout the farm.

Graph 44 - Kg CO_{2eq} emissions per ha of orange (Cooperative A)

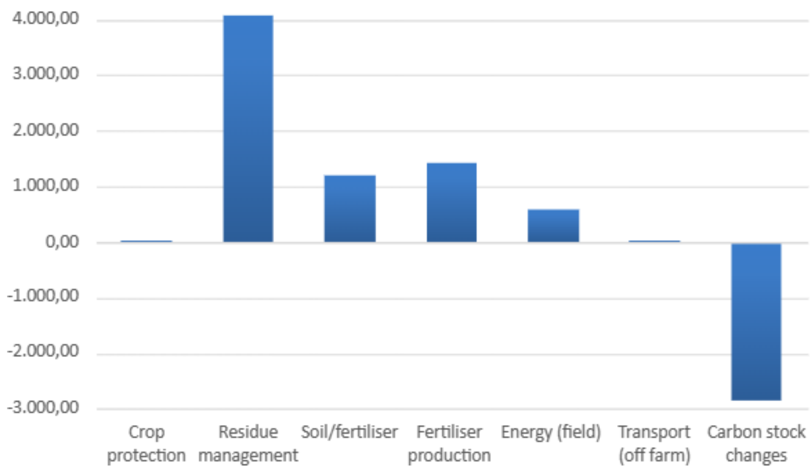


The producers exhibit emissions within a moderate range, typical for Cooperative A's producers. The lowest and the highest emissions follows the same shape as above (estimate per tonne), thus the former analysis above described applies to this latter one too. .

Table 24 - Contributions to emissions (Cooperative A)

Source	Kg de CO_{2eq}/ha
Crop protection	11.04
Residue management	4,060.70
Soil/fertilizer	1,184.88
Fertilizer production	1,420.71
Energy (field)	592.21
Transport (off farm)	22.95
Carbon stock changes	-2,847.96

Graph 45 - Detailed emissions - Kg CO_{2eq} per hectare (Cooperative A)

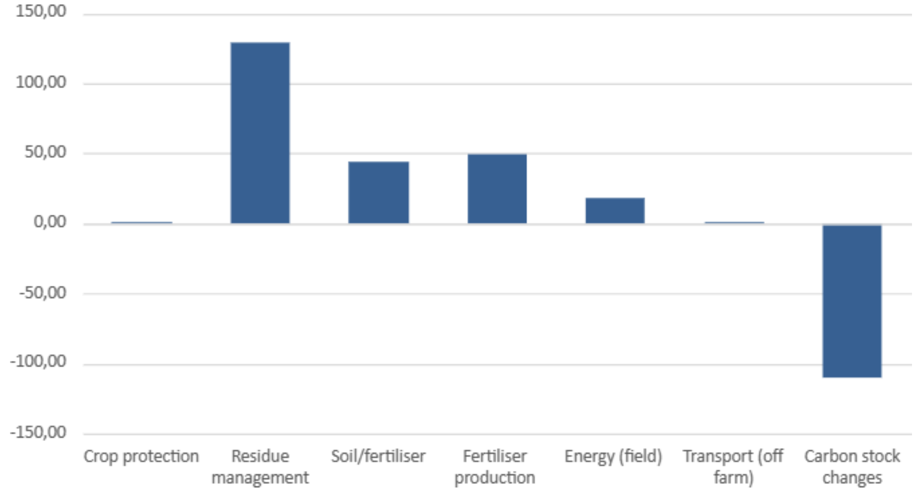


At Cooperative A, the primary emission factor among those listed is "Residue Management," generating emissions of 4,060.70 Kg of CO_{2eq} per hectare. This value was estimated in 20% of the yield and considered as distributed on field, as producers do not manage the residues from pruning and/or harvesting, composting it for example. The second-highest emitting factor per hectare is "Fertilizer Production," with average emissions of 1,420.71 Kg of CO_{2eq}. This factor, also auto generated in the Cool Farm Tool, accounts for indirect emissions (Scope 3).

The "Carbon Stock Changes" factor, representing the carbon stock, indicates average emissions of -2,847.96 Kg of CO_{2eq} per hectare. This factor is primarily associated with changes in land use, transitioning from a crop with lower carbon content to one with higher carbon input into the soil.

The Cool Farm Tool permits only one change of land use or changes in the same area. Growers often incrementally develop their orchards over time through partial changes in land use. So, it can be a bias in this study.

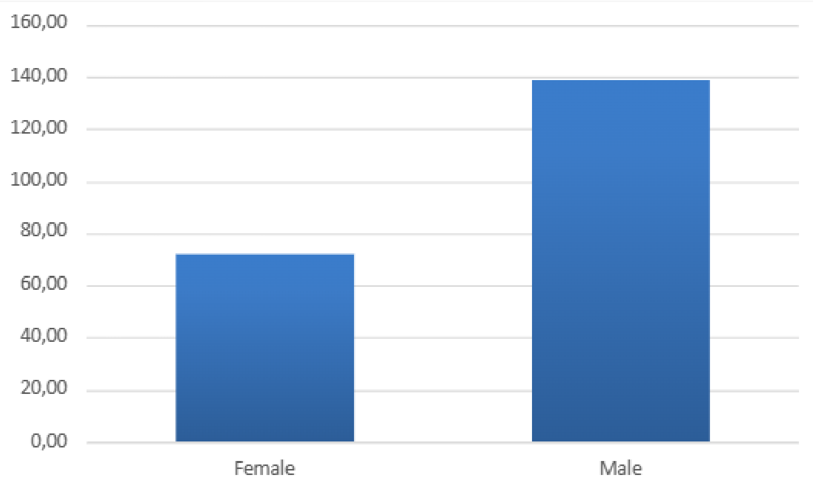
Graph 46 - Detailed emissions - KgCO_{2eq} per ton of orange (Cooperative A)



According to the graph above, the highest emitter of CO_{2eq} per ton of oranges produced was "Residue Management," contributing 128.99 Kg of CO_{2eq} per ton. The second-largest emitter was "Fertilizer Production," accounting for 49.58 Kg of CO_{2eq} per ton.

On the other hand, the "Carbon Stock Changes" factor reflects a carbon stock with negative emissions, indicating a net carbon sequestration of -109.82 Kg of CO_{2eq} per ton of oranges produced in the sampled volume of 9 producers. This suggests that the change in land use, transitioning from one crop to another with higher carbon input into the soil, resulted in a net removal of carbon dioxide from the atmosphere per ton of oranges produced.

Graph 47 - Kg CO_{2eq} per ton (Gender - Cooperative A)

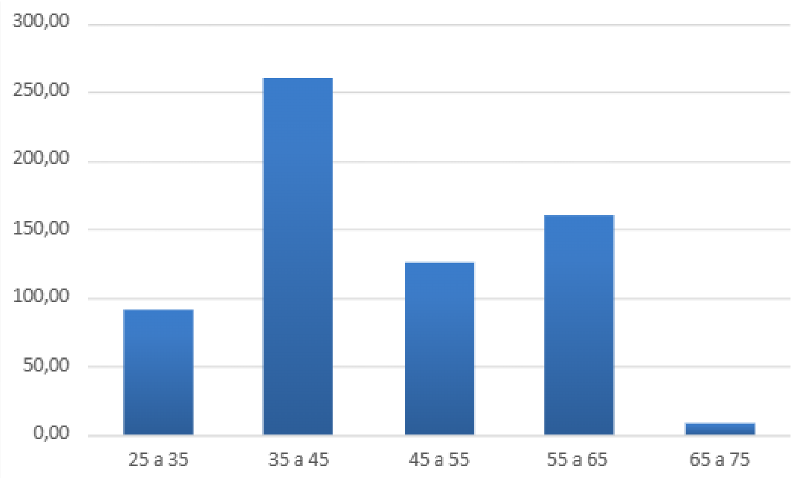


The analysis reveals that the average emissions for women at Cooperative A are approximately 0.519 times that of men. This implies that women emit about 48.10% less CO_{2eq} compared to men when evaluating emissions per ton of output.

Furthermore, the emissions associated with the female gender are within the group of the 25% lowest emissions at Cooperative A, with an average emission of 131.41 Kg CO_{2eq} per ton. This indicates that, on average, women contribute to the lower end of the emissions spectrum within the cooperative.

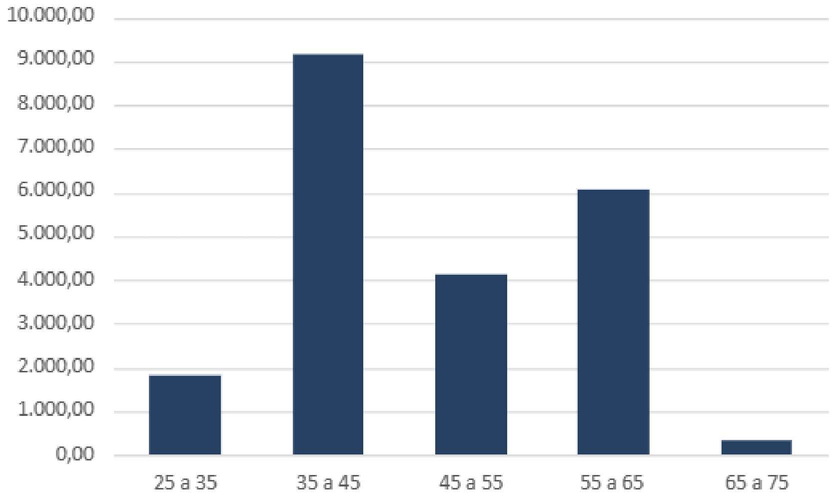
In Cooperative A only one woman participated in the sample, this property has a land use change from pasture to perennial in 2020, which reflect in a great stock of carbon when the data is analyzed by Cool Farm Tool.

Graph 48 - Kg CO_{2eq} per tonne (Age – Cooperative A)



In the estimation for the year 2022, the age group between 35 and 45 years old emitted the most greenhouse gases per ton of product and per production area (hectares).

Graph 49 - Kg CO_{2eq} per ha (Age – Cooperative A)

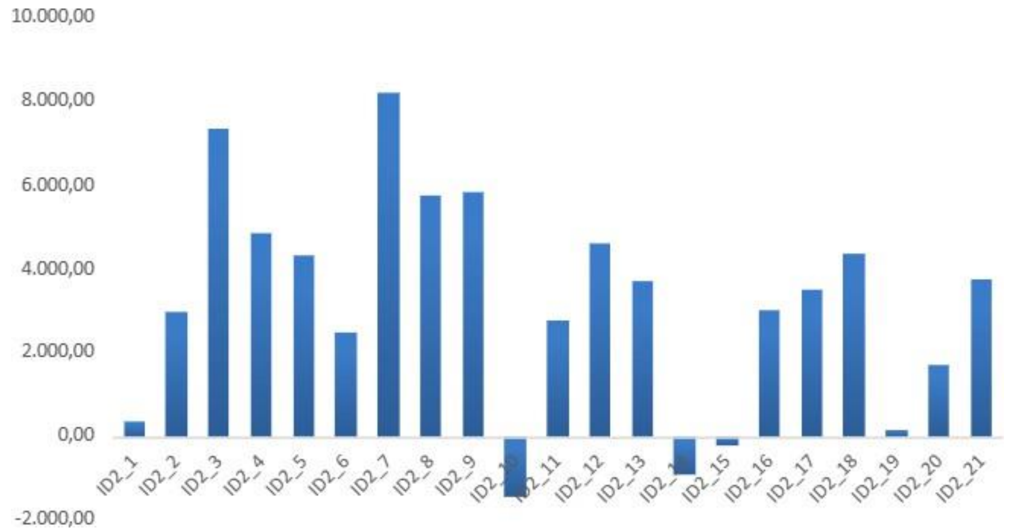


The analysis indicates a downward trend in CO_{2eq} emissions per ton of oranges produced as the age of the producer increases. This suggests that, on average, older producers within the cooperative tend to have lower greenhouse gas emissions per unit of product compared to their younger counterparts (the age group 35-45).

A hypothesis could be formulated based on different economic behaviors at different ages, suggesting that more experienced and older producers may adopt more sustainable and efficient agricultural practices, resulting in lower greenhouse gas emissions per ton of oranges produced. Additionally, it is possible that younger producers may be more inclined to adopt more emission-intensive practices, such as the use of non-optimized agricultural inputs, contributing to higher emissions per unit of production. However, further in-depth analysis and additional data are required to validate or refute this hypothesis.

Cooperative B

Graph 50 - Kg CO_{2eq} per hectare (Cooperative B)



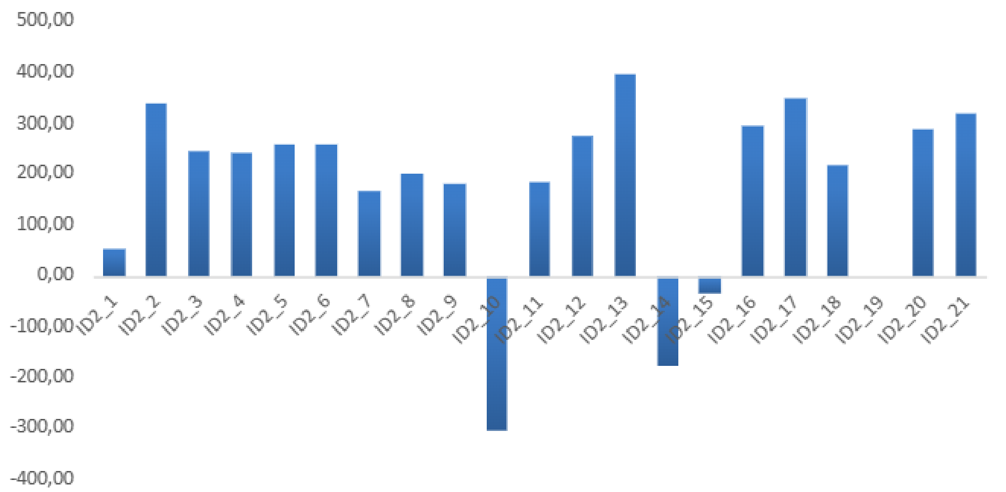
The average emissions in this sample are 3,199,67 Kg of CO_{2eq} per hectare. It's important to note that producer ID2_7 stands out as the higher emitter, recording 8,218.27 Kg of CO_{2eq} per hectare. This notable difference is partly due to the area harvested by this producer, covering 1.5 hectares, with a productivity of 72.89 tons of oranges.

It's relevant to mention that producer ID2_7 follows a conventional, non-organic production method. Additionally, there was a land-use change in their area in 2016, incorporating carbon due to the transition from conventional annual cultivation to orange cultivation with reduced cultivation.

Agricultural residue management factor is the main responsible for it’s increasing in emissions per hectare, contributing to 76% of the total emissions. Except for this one (ID2_7), the other producers (almost 100% of the sample) have emissions within the range varying between -906.56 Kg of CO_{2e} per hectare (ID2_14) and 5,864.58 Kg of CO_{2eq} per hectare (ID2_9).

It's interesting to note that both producer ID2_14 and producer ID2_10 (with –1,461.34Kg of CO_{2eq} per hectare) had negative emissions, indicating that the carbon stock in their soils is greater than the emissions. The grower ID2_10 is an organic producer and implemented a partial land-use change in 2018, storing more carbon in the soil by transitioning from annual crops to perennials. On the other hand, producer ID2_14 underwent a significant change in land use in 2007, transitioning from annual crops to perennial crops with the addition of manure, despite following a conventional production method.

Graph 51 - Kg $CO_{2e}q$ per ton (Cooperative B)



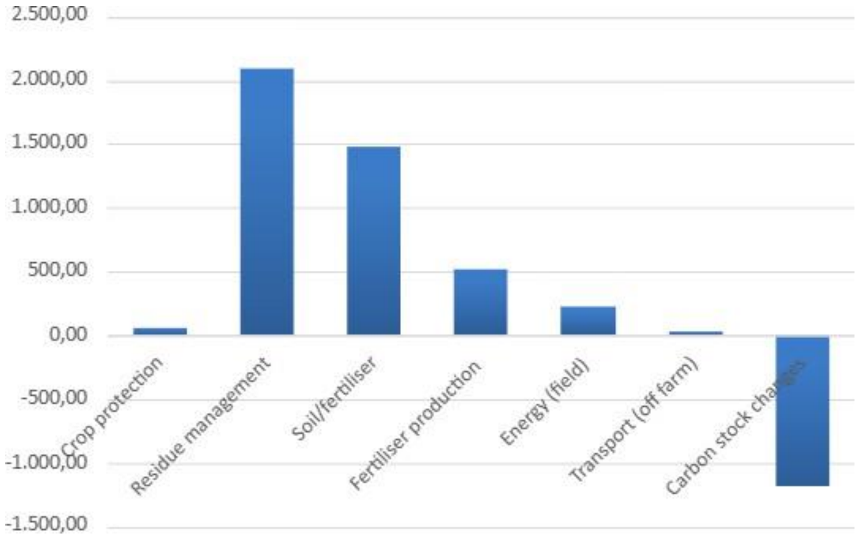
Note: The ID2_19 has not yet been collected, so the data referring to emissions per ton was disregarded.

In the above distribution, there are three outliers (ID2_10, ID2_14 and ID2_15), all of them showing negative emissions (therefore, carbon sequestration) and increasing in carbon stock after land use changes – from annual to perennial crop between 2007 and 2018. The ID2_13 stands out as the higher emitter (396.89 Kg CO_{2eq} per ton) due to its large use of fertilizers (326 Kg CO_{2eq} per ton). It is flowed by the ID2_2 producer, which had a recent land use change in 2019 (25% of his 4-hectare area). Additionally, it is worth noting that the management of agricultural residues (129 Kg of CO_{2eq} per ton) of this producer is the factor that shot up its emissions.

Table 25 - Contributions to emissions (Cooperative B)

Source	Kg de CO_{2eq}/ha
Crop protection	60,38
Residue management	2,085.82
Soil/fertilizer	1.474,06
Fertilizer production	516,13
Energy (field)	219,52
Transport (off farm)	23,67
Carbon stock changes	-1.178,92

Graph 52 - Detailed emissions (Kg CO2 per hectare - Cooperative B)



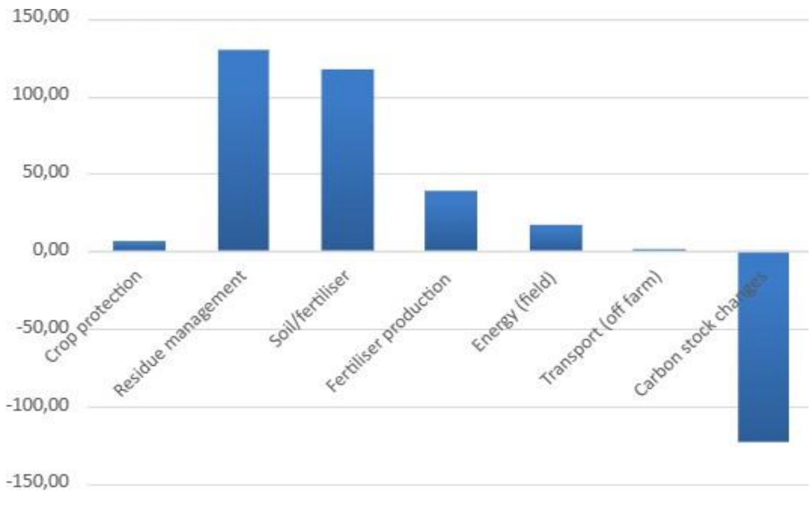
The most significant contributor to emissions on Cooperative B's sampled farms is residue management, accounting for a substantial portion of emissions, totaling 2,085.82 kg of CO_{2eq} per hectare.

In second place, the category related to the use of fertilizers (Soil/fertilizer) contributes, on average, with 1,474.06 Kg of CO_{2eq} per hectare. Soil management practices and fertilizer use play a significant role in emissions, making them crucial focal points for emissions reduction efforts.

Notably, the category of changes in carbon stock has negative emissions of -1,178.92 Kg of CO_{2eq} per hectare. These figures indicate that, on average, the carbon stock in the soil is increasing over time, a desirable situation where the soil absorbs more carbon than it emits. This reflects sustainable soil management practices crucial for mitigating CO_{2eq} emissions.

Taken together, the categories of crop protection, off-farm transportation, and field energy use contribute relatively low emissions, accounting for a small share of the total emissions at 303.57 Kg of CO_{2eq} per hectare.

Graph 53 - Detailed emissions (Kg CO_{2eq} per ton - Cooperative B)



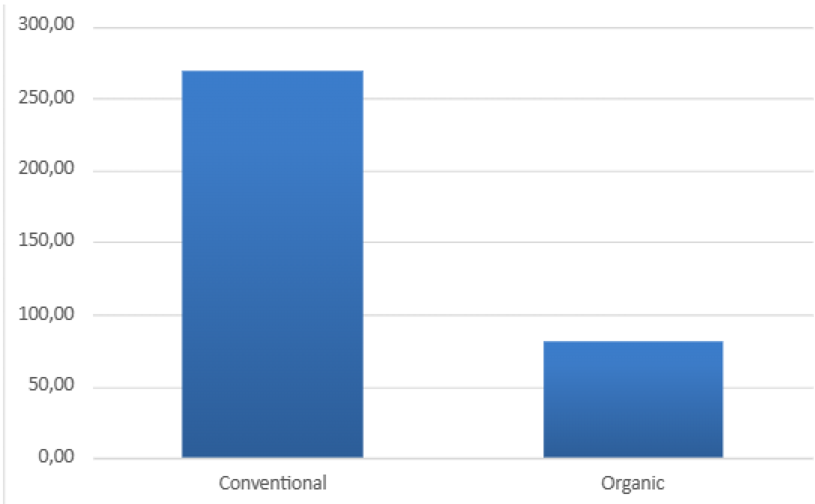
The largest contribution to emissions is also in residue management, representing a significant portion of 129.94 Kg of CO_{2eq} per ton. In second place, emissions related to soil and fertilizers contribute 126.56 Kg of CO_{2eq} per ton. Fertilizer production, in turn, contributes 38.46 Kg of CO_{2eq} per ton, ranking third in terms of emissions per ton.

The energy category in the field represents 16.68 Kg of CO_{2eq} per ton. This indicator is related to the use of energy for agricultural operations, such as the use of diesel and energy used in irrigation (non-existent in Cooperative B). Emissions related to crop protection contribute 6.47 kg of CO_{2eq} per ton produced, and finally, emissions related to off-farm transport are relatively low, totaling 1.26 kg of CO_{2eq} per ton.

In particular, the category of changes in carbon stock presents negative emissions of -133.22 Kg of CO_{2eq} per ton produced at Cooperative B. The increase in soil carbon stock reflects sustainable soil management practices that contribute to the mitigation of emissions per ton of oranges produced.
Evidently, the organic production system has a lesser impact, and the obtained data support this conclusion. The emission estimates for the 21 producers in the sample reveal that 16 producers with a conventional system emit, on average, 7,534.70 Kg CO_{2eq} per hectare. In contrast, 5 producers with an organic system emit, on average, 2,046.25 Kg CO_{2eq} per hectare.

Therefore, conventional producers emit approximately 3.7 times more carbon in this cooperative compared to organic producers.

Graph 54 - Kg CO_{2eq} per ton – Production System (Cooperative B)



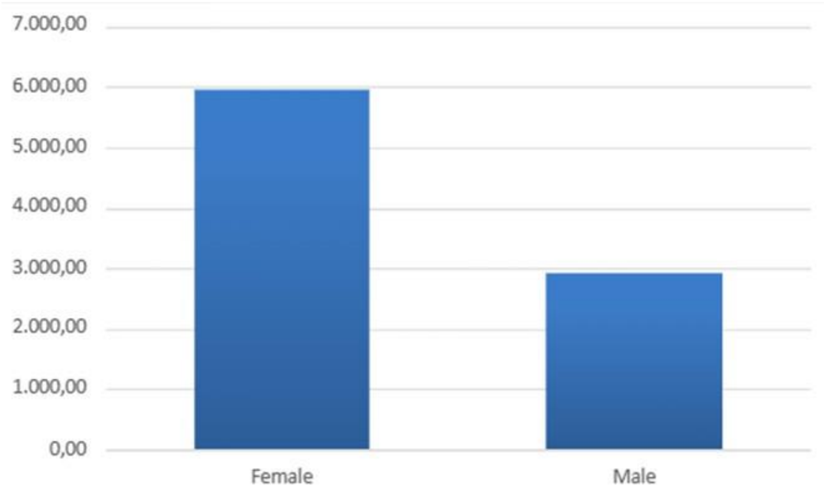
If we examine it from the perspective of $KgCO_{2eq}$ emissions per ton of orange production, the difference between the two production systems diminishes, as the yields of organic producers were lower in this study:

- Conventional (Average) = 18,867.69 tons/ha;
- Organic (Average) = 6,472.38 tons/ha.

Thus, conventional production emits about 1.61 times more carbon per ton of oranges produced compared to organic production (considering the same number of producers in the Cooperative B sample).

- Average Emissions per Ton for Conventional Production: 436.70 $KgCO_{2eq}$ per ton of orange;
- Average Emissions per Ton for Organic Production: 270.80 $KgCO_{2eq}$ per ton of oranges.

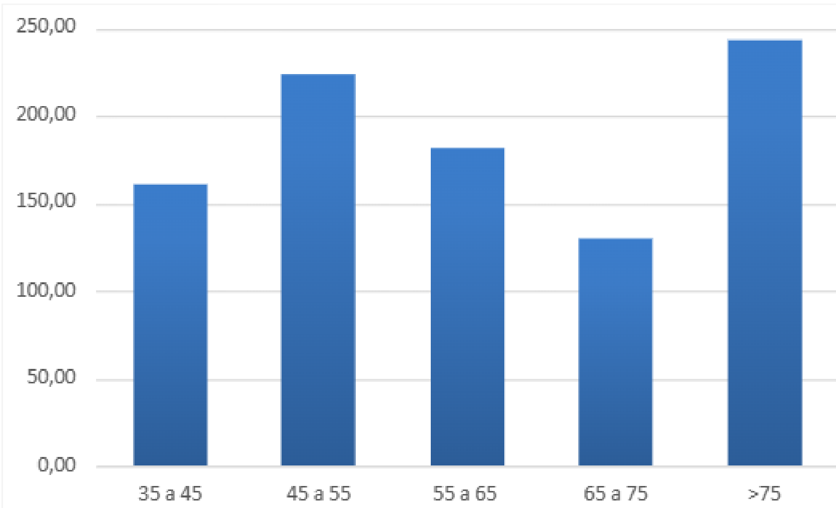
Graph 55 - *Kg CO_{2eq} per ha - Gender (Cooperative B)*



The graph above indicates that there is approximately .292.05 times higher CO_{2eq} emissions per ton of product produced by the average of women compared to the average of male producers, representing an amount of 105.5%between both. This suggests potential differences in production practices or other variables between genders that impact CO_{2eq} emissions. The other variables include orchard in formation for instance.

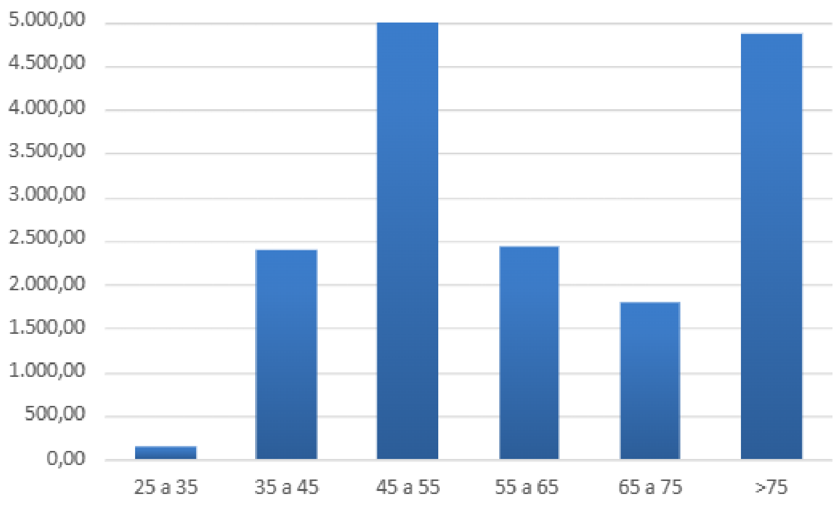
Among the 21 members of the Cooperative B sample (excluding one producer who hasn't harvested the first crop yet), the women (depicted in red) show varying emissions. One producer ranks among the top 25% emitters in the cooperative, with 396.89 kg CO_{2eq} per ton. Surprisingly this group revels three negative outliers, that is those who present already carbon sequestration throughout their practices: 10, 14 and 15. -. The red line illustrates the cooperative's upward trend in emissions, indicating that factors contributing to emissions are experiencing increased use (in the case of inputs) or changing practices (in the case of land-use change and residues management).

Graph 56 - Kg CO_{2eq} per ton (Age - Cooperative B)



The graph above illustrates that older producers emit more per ton of product. This observation suggests that older producers might be employing less efficient production methods in terms of greenhouse gas emissions per unit of product. This could involve the adoption of more traditional or less sustainable agricultural practices.

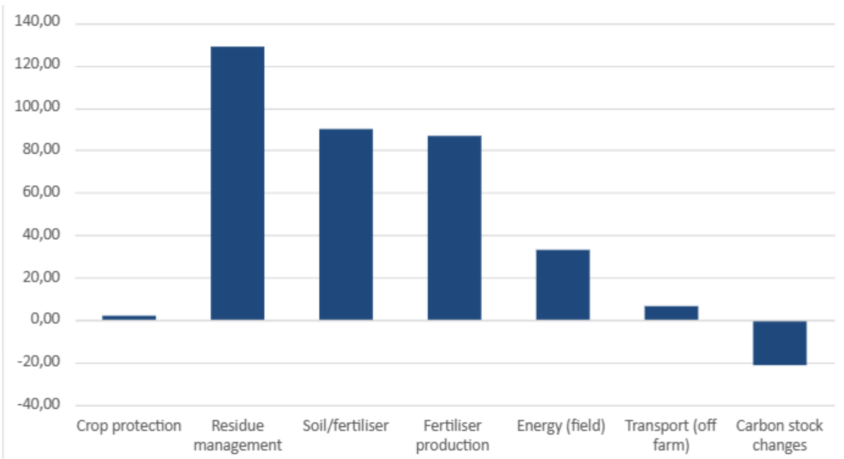
Graph 57 - Kg CO2e per ha (Age - Cooperative B)



On the other hand, the graph above indicates that younger producers emit more per hectare. This could imply that younger producers are adopting land-intensive agricultural practices, potentially leading to higher emissions per cultivated area. Such practices may involve the utilization of modern technologies that enhance productivity but could also contribute to increased emissions per hectare.

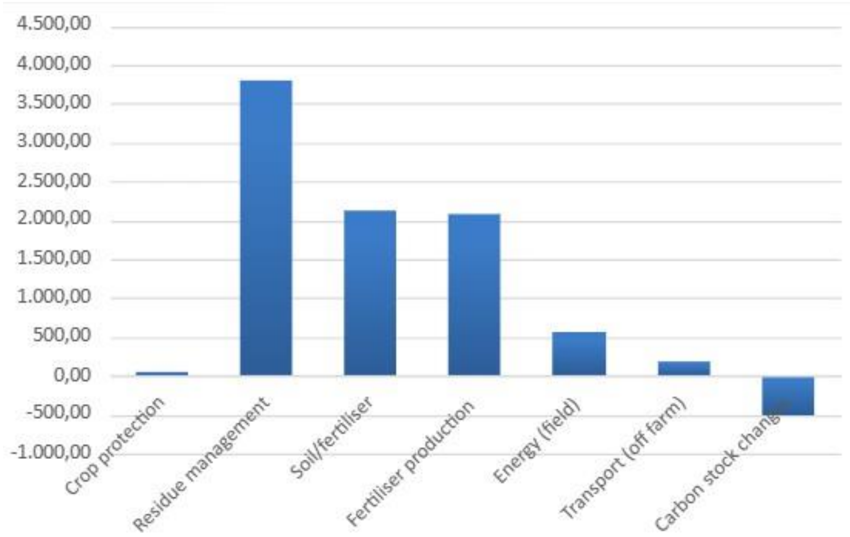
Cooperative C

Graph 58 - Detailed emissions (Kg CO2 per ton - Cooperative C)



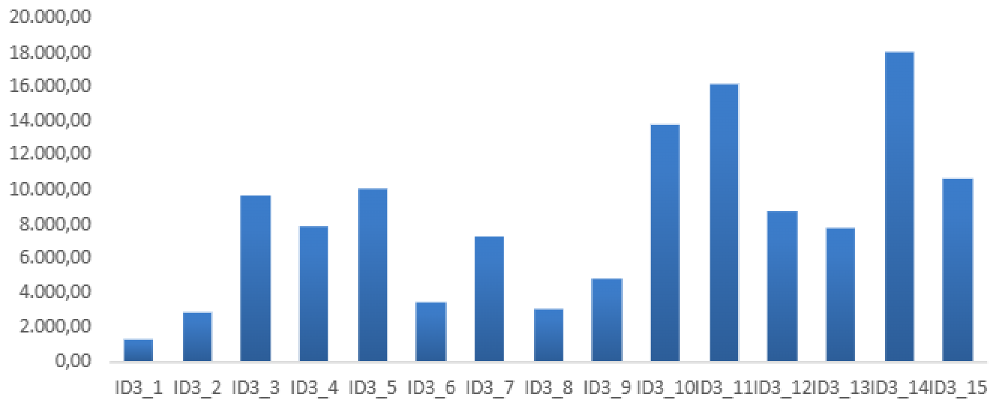
The "residue management" factor emits approximately 1.4 times more than the second factor, which is fertilizer use, based on the sampled values of emissions per ton of product. On the contrary, land-use change contributes to a carbon stock in the soil in an amount of 21.29 $KgCO_{2eq}$ per ton of orange harvested.

Graph 59 - Detailed emissions (Kg CO_{2eq} per hectare - Cooperative C)



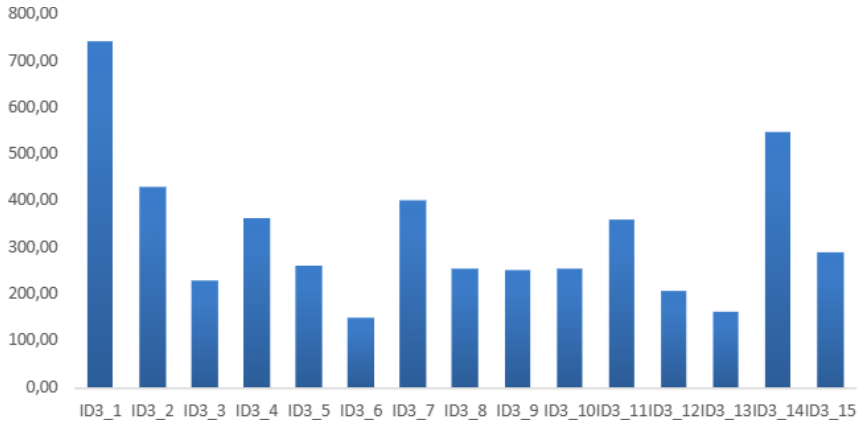
Emissions per hectare remain constant. An important detail is the negligible number of emissions in proportion to the use of pesticides. Family farming often exhibits this characteristic, and certification processes encourage producers to adopt alternative methods, minimizing the impact of chemical pesticides on ecosystem services.

Graph 60 - Kg CO_{2eq} per hectare (Cooperative C)



In this distribution of 15 producers, there are not outliers and the distribution tend to be more symmetric (the median and average are coincident). The upper value is placed by the ID3_14, and due lower by the ID3_1. The former has 71% (out of 18,116 $KgCO_{2eq}$ per hectare) of his emission from soil fertilizer; and the latter has 56% of his emission originated from the same source. The point which explains the contrast between values is related to crop yield: the latter got less than 2 tones by hectare that is likely linked to its orchard in formation.

Graph 61 - Kg CO_{2eq} per ton (Cooperative C)



In terms of Kg CO_{2eq} emissions per production ton , there is a slight variation in the scenario, with only ID3_1 being an outlier. The prominence that producers ID3_1 and ID3_14 have is striking.

ID3_1:

- Total emission: 745 kg CO_{2eq}/ton of oranges produced in 2022.
- Agricultural residue management: 17% of total emissions.
- Fertilizer use: 56% (includes Scope 3 – fertilizer production).
- Energy use: 25%.

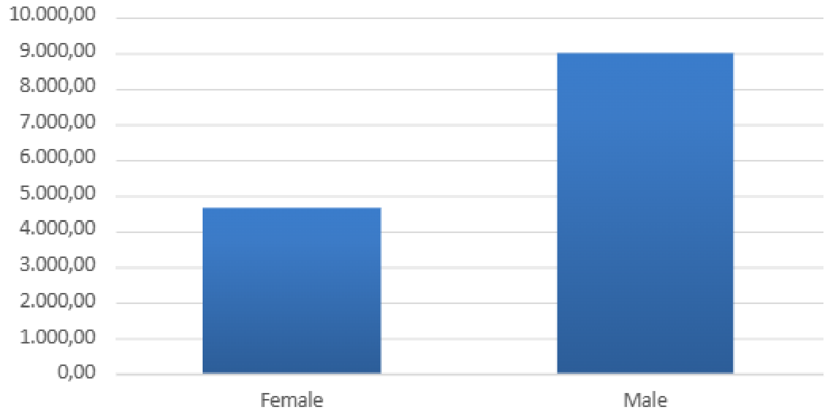
Conventional producer with very low productivity (1.77 tons/ha against an average of 36 tons/ha in the state of São Paulo). This may be reflective of orchard renovation in 2022, not yet reaching its productive potential.

ID3_14:

- Total emission: 549 kg CO_{2eq} /ton of oranges produced in 2022.
- Agricultural residue management: 23% of total emissions.
- Fertilizer use: 71% (includes scope 3 – fertilizer production).
- Energy use: 5%.

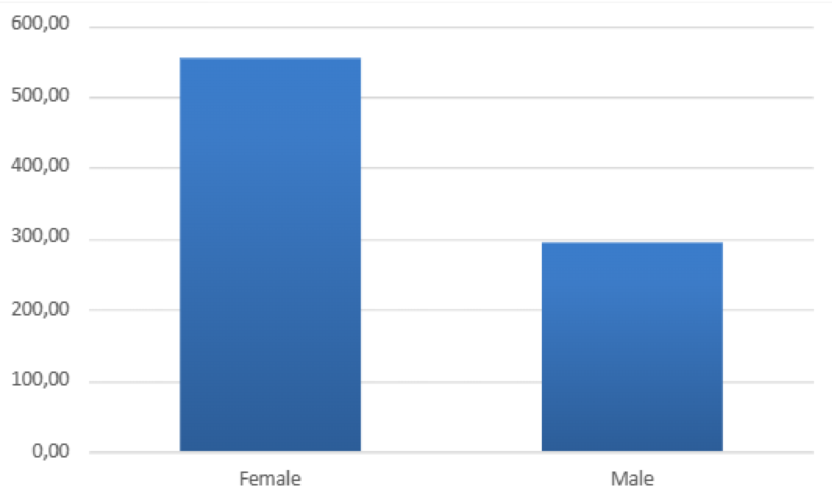
Conventional producer with considerable yield (32,99 tons/ha against an average of 36 tons/ha in the state of São Paulo).

Graph 62 - Kg CO_{2eq} per ha (Gender - Cooperative C)

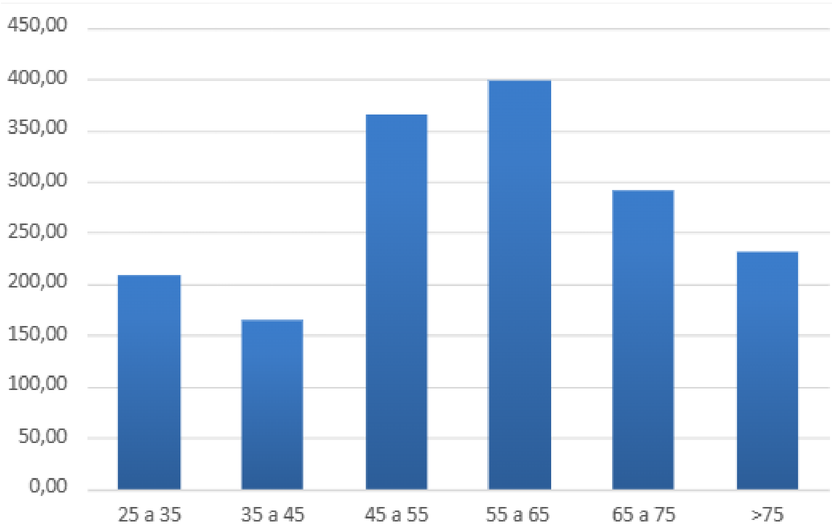


The farms ran by men at Cooperative C has been emitting on average likely 2 times more CO_{2eq} than farms ran by women, constituting about 92.64% of the cooperative's total emissions, based on the sample of 15 producers. However, the analysis of the average emissions per ton for each gender group reveals a different scenario, as depicted in the graph below. This outcome is primarily attributed to the low productivity of the orchards, leading to increased emissions per ton produced.

Graph 63 - Kg CO2eq per ton (Gender - Cooperative C)

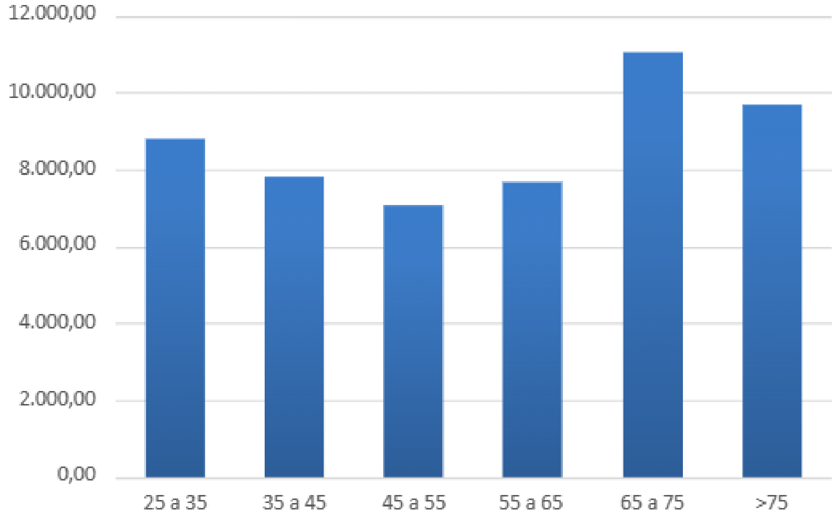


Graph 64 - Kg CO2e per ton (Age - Cooperative C)



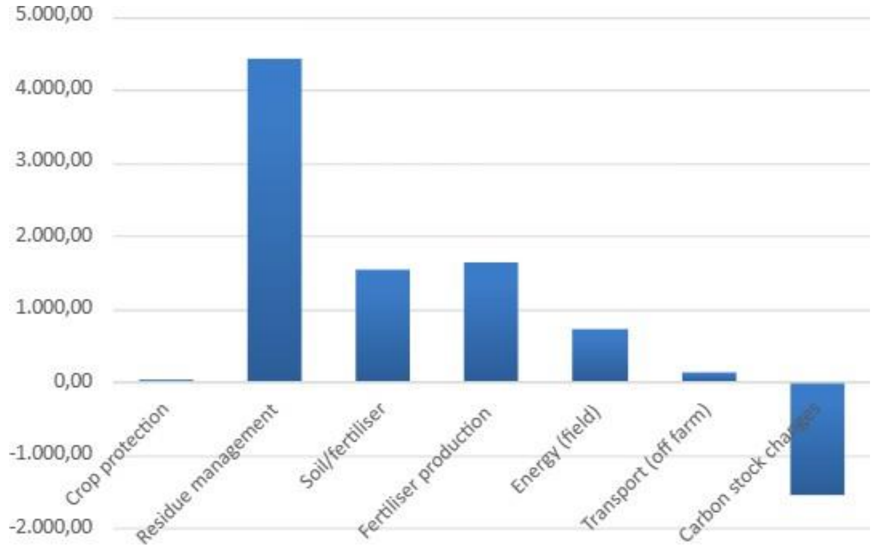
The age group that contributes the most to greenhouse gas emissions (per ton of product) within this cooperative fall between 55 and 65 years old. The subsequent chart presents emissions relative to the production area (hectares) with the age group. In this scenario, the next age group is the most emissor (65-75 yo) Followed by the second age group, notably represented by those farmers beyond the 75 years old. That suggests the newer generation (55-65) has higher yield and less cropland.

Graph 65 - Kg CO_{2eq} per ha (Age - Cooperative C)



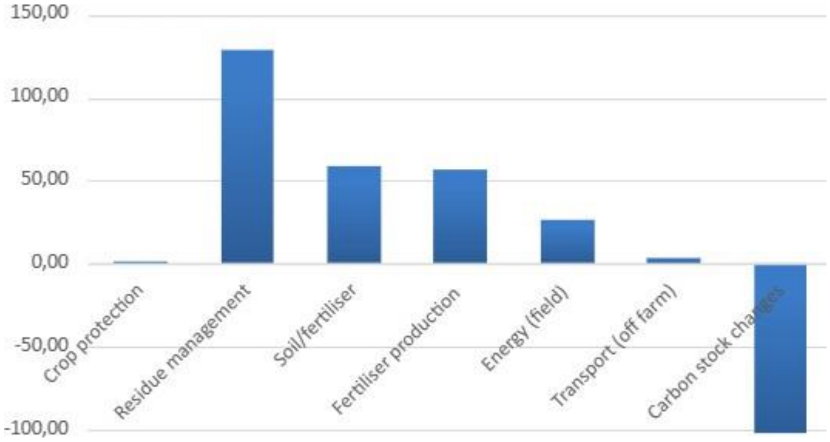
Cooperative D

Graph 66 - Detailed emissions (kg CO_{2eq} per hectare) - Cooperative D



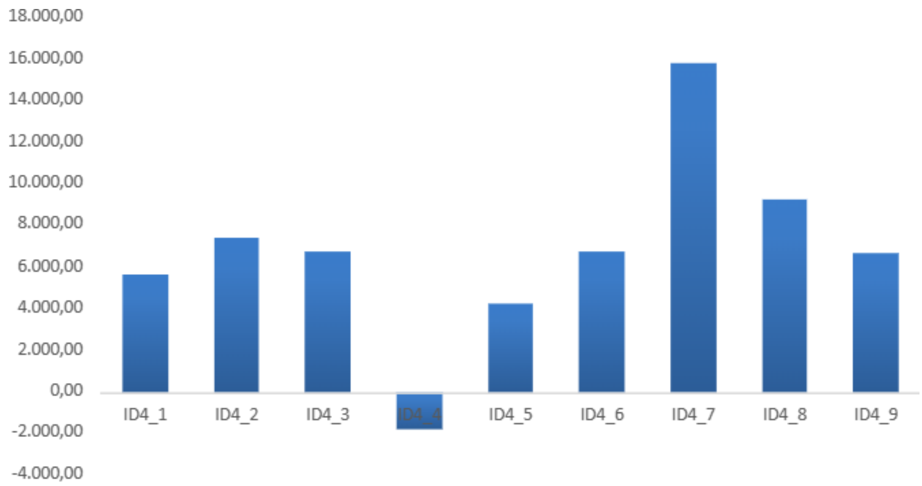
The analyses present that emissions from production residue management are approximately 10.63 times higher than the average of emissions from the other categories. The negative emissions of -1,558.30 kg of CO_{2eq} per hectare indicate carbon sequestration, which, within the context of the 9 sampled producers from Cooperative D, is directly correlated with the change in land use that allowed for greater carbon retention from a crop that retains less carbon (pasture, annual crop, etc.) to perennial crops. The same proportion is repeated in the analysis of emissions per ton of oranges produced.

Graph 67 - Detailed emissions (Kg CO_{2eq} per ton) - Cooperative D



The same proportion is repeated in the analysis of emissions per ton of oranges produced.

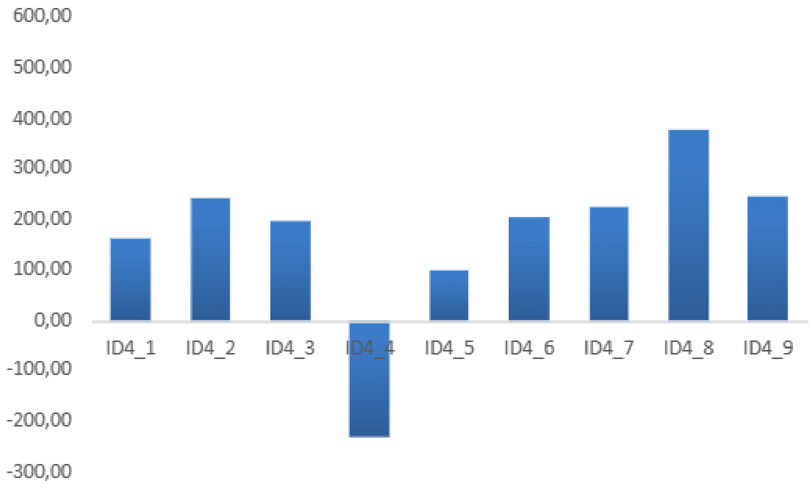
Graph 68 - Kg CO_{2eq} per hectare (Cooperative D)



The producers ID4_4 and ID4_7 stand out as outliers, deviating significantly from the rest of the sample. The emissions of the ID4_7 producer are approximately 2.81 times higher than the average of the other producers (5604.2 kg CO_{2eq} per hectare). This producer has a yield well above the state average in Paraná, with 69 tons per hectare in 2022 compared to the regional average of 32 tons per hectare. The high yield automatically leads to increased residue generated from production, as calculated by the Cool Farm Tool, contributing to higher emissions. Residue management is the primary driver of emissions for both this producer and the cooperative.

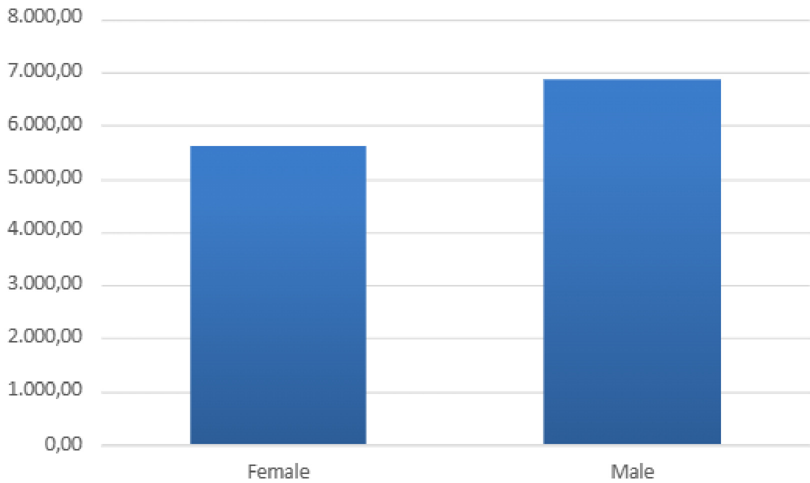
For the ID4_4 producer, two factors converged, resulting in nearly neutralized emissions. Firstly, the farm's low productivity, with a yield of 7.81 tons per hectare harvested from the 32-hectare farm planted with orange trees in 2019. Secondly, there was a change in land use from annual agriculture (cassava) to perennial (no-till) with significant carbon input through manure in 2019. In 2023, this producer started irrigation, which may potentially lead to an increase in emissions.

Graph 69 - Kg CO_{2eq} per ton (Cooperative D)



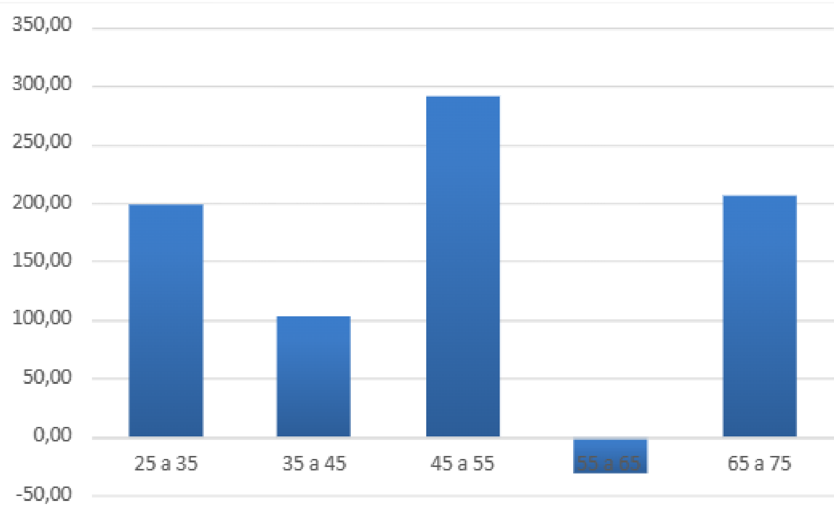
In the context of emissions per ton of product, the producer ID4_8 emerges as the largest emitter, with 379.31 Kg CO_{2eq} per ton produced. This is nearly 610 times higher than the producer with the lowest emissions, ID4_4. However, if we exclude the ID4_4 producer, who is not yet in the production phase (outlier – orchard in formation), the average emissions are not significantly distant from those of the producer ID4_8, standing at 221.35 Kg of CO_{2eq} per ton of oranges produced.

Graph 70 - Kg CO_{2eq} per tonne (Gender - Cooperative D)



The ratio between the average emissions of men and women at Cooperative D is approximately 1.04, indicating that women emit about 4.07% less CO_{2eq} per ton of product produced compared to men. Additionally, the analysis reveals that emissions associated with the female gender fall within the group of the 25% lowest emissions at Cooperative D, placing them in the first quartile of values.

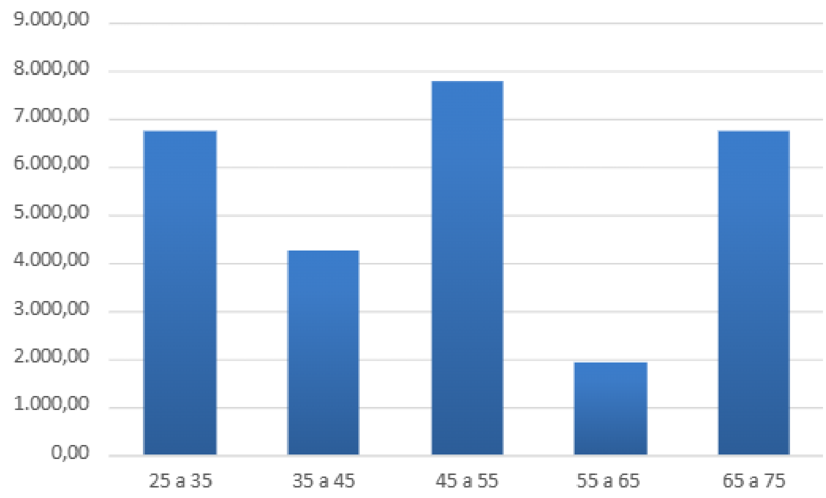
Graph 71 - Kg CO_{2eq} per ton (Age - Cooperative D)



The age group that emits the most GHGs (per ton of product) is between 45 and 55 years old in this cooperative.

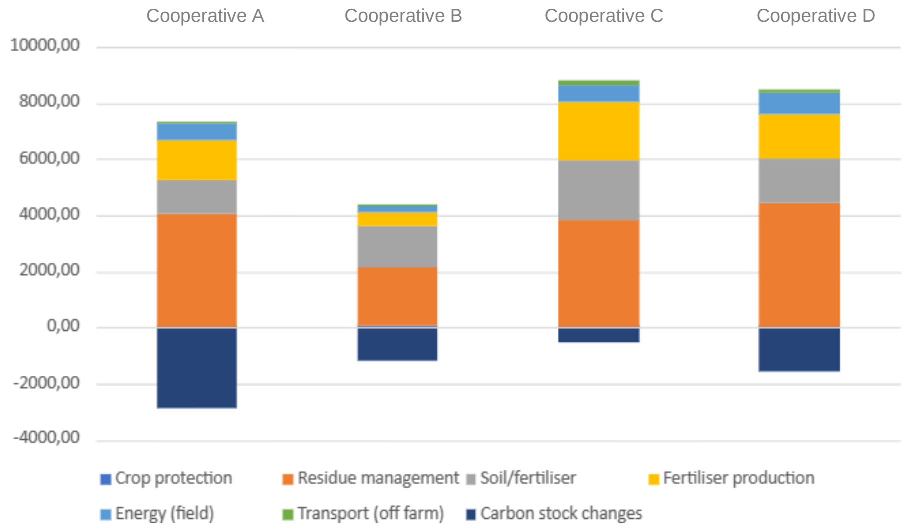
The same trend in emissions is observed in the following graph, which examines emissions in relation to the production area (hectares). In this case, younger age groups show a significant increase in emissions.

Graph 72 - Kg CO_{2eq} per ha (Age - Cooperative D)



Cooperative comparisons

Graph 73 - Kg CO_{2eq} per hectare (average)



The overall data indicates that, on average, emissions for the entire sample amount to 5,714.82 Kg of CO_{2eq} per hectare. However, a notable exception is Cooperative C, where emissions are significantly higher, reaching 8,305.41 Kg of CO_{2eq} per hectare. This difference suggests that Cooperative C may employ more intensive agricultural practices, involving increased fertilizer application and, consequently, higher diesel usage. Trends such as orchard eradication for leasing purposes and replanting with potentially more resilient varieties may also contribute to elevated emissions. Notably, changes in land use do not seem to be a major factor, given that most orchards have been established for at least two decades.

Conversely, Cooperative B exhibits the lowest estimated emissions among the cooperatives, averaging 3,200.66 Kg of CO_{2eq} per hectare. This likely indicates a focus on organic management practices by producers, emphasizing sustainability and reduced environmental impact.

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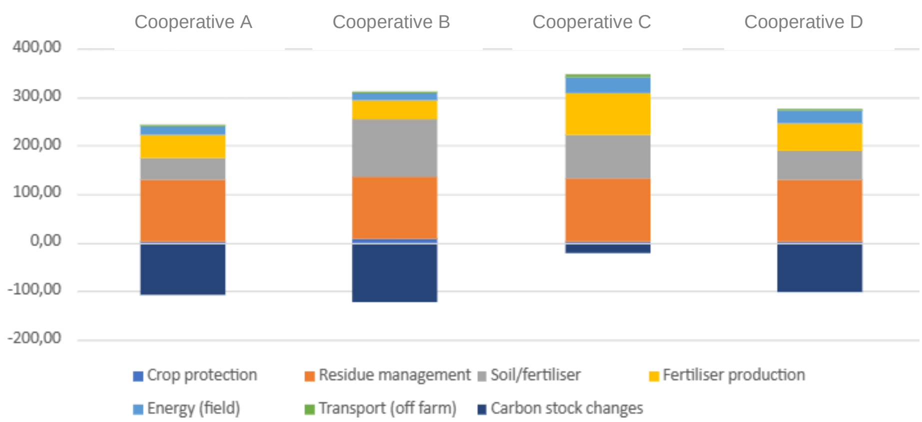
Graph 74 - Kg CO_{2eq} per tonne (average)



When considering emissions per ton of oranges produced, Cooperative C consistently maintains higher emissions, approximately 2.8 times in relation to the average emission of all four (116.68 $KgCO_{2e}$ per ton). This can be attributed to factors such as higher input usage (fertilizers and pesticides). However, the average productivity, at 29.39 tons per hectare, is comparable to the average of other cooperatives, standing at 26.84 tons per hectare. Additionally, Cooperative C's producers transport oranges over longer distances, contributing to emissions related to transportation outside the properties.

Regarding carbon storage, looking at both graphs (73 and 74) something interesting occurs. The Cooperative A has the higher storage per hectare (2847,96 KgCO2e per ha), while Cooperative B presents the higher storage per ton (123,27 KgCO2e per ton). The storage of carbon is totally related to the Land Use Change, that is, when the lands underwent changes and whether this change(s) had contributed to store more or less carbon in the soil. So, the main hypothesis here is related to that possible change, from a culture annual to another perennial, for instance. Secondly, the producer profile also contributes to define this index. The more sustainable the farming practices are, the more carbon will be stored.

7. Discussions

Limitations

During any research, limitations can emerge from design constraints, methodological choices, available materials, or even the inherent constraints of the researchers themselves. These factors can impact the interpretation of results and their implications. In this study, we conducted a comprehensive exploration of potential limitations, identifying gaps to achieve a thorough understanding of the study's boundaries, outcomes, and conclusions.

Recognizing the limitations outlined below provides an opportunity to propose ideas for future complementary research.

Methodological limitations

Sample size

The sample employed in this study operates with a 90% confidence margin. While statistically robust, it is essential to acknowledge the potential for deviations during data collection. Opting for a higher confidence margin, such as 95%, would enhance statistical reliability but comes with trade-offs. This adjustment would necessitate a larger sample size, leading to increased costs and a greater demand for the participation of producers and cooperatives. Managing these challenges poses additional considerations for the study.

Lack of available or reliable data

The absence or incompleteness of data, as well as the presence of less reliable data, should be considered as limitations in this research, potentially hindering the identification of patterns and meaningful connections. To mitigate this limitation, a decision matrix was employed, as detailed in the "Data Processing and Tabulation" chapter. This strategic approach was adopted to enhance the quality and reliability of the available data.

The methodology used for engagement and data collection

The time allocated for the research was relatively brief, while the issue of engagement proved to be a prolonged challenge, marked by average to poor adherence. Cooperatives and producers are actively involved in various commitments and the ongoing harvest, rendering them less available for an in-depth study within an extended timeframe.

Questions Related to Research and Sample Selection

In this study, the adoption of a sample stratification methodology significantly mitigated potential limitations.

Biases

A noteworthy bias encountered in this study pertains to the settings of the "Cool Farm Tool."

Firstly, it is essential to highlight that the tool lacks a specific programming option for citrus or orange cultivation. Consequently, the decision was made to utilize "Tree Crops" in the Cool Farm Tool. However, this setting automatically generates a quantity of crop residues that may not accurately reflect orange tree management, resulting in the highest estimated emissions in this study. To reduce this discrepancy, the residues was estimated in 20% (as suggested by Cool Farm Tool) and considered "distributed on field". This residue refers to pruning and harvest residues and does not receive any management.

This input contributes to the overall increase in emissions. A way to improve this value is remove this residue of the field or carry out a composting process in the farms.

Additionally, the tool's scope limitation is noteworthy, as it solely employs data related to the orange production area, preventing the evaluation of other property areas that could influence emission estimates, such as reforestation areas.

Lastly, regarding carbon stock emission estimates, the Cool Farm Tool permits only one change of land use or changes in the same area. In reality, growers often incrementally develop their orchards over time through partial changes in land use. To address this bias, the study adopted the worst-case scenario of emissions related to land use changes observed on the visited properties.

Despite these identified limitations, the analysis revealed evidence and trends that allow the identification of potential actions.

Possibilities for Carbon Emission Reductions

As observed throughout this study's analysis, the predominant emissions result from "residue management, based on the yield and type of management. If we disregard this input, the highest estimated emissions for the properties are associated with fertilizer use and energy consumption, primarily diesel. Therefore, the most promising opportunities for reduction lie in these categories. Considering the cooperative and producer profiles presented, a range of possibilities aimed at reducing carbon emissions has been outlined. It's worth noting that some of these options, in addition to carbon reduction, also contribute to lowering nitrous oxide emissions, further impacting the overall reduction of greenhouse gases.

The concept of agroecosystems encompasses various cultural perspectives, reflecting contemporary values associated with the material, immaterial, and regulatory benefits of these systems. Importantly, these values are not static but adaptable to future needs. Agroecosystems represent socio-ecological systems that acknowledge the intricate interplay between nature and society, aiming to comprehend the complexities, emergent properties, and spatio-temporal dynamics inherent in these systems.

In essence, agroecosystems are ecosystems—whether natural or modified by human intervention—crafted for the cultivation of agricultural farming systems. These systems commence with the introduction of inputs such as fertilizers and the implementation of controls for water supply, pest management, and disease prevention, all directed towards optimizing harvesting and marketing processes. An agroecosystem, distinguished by the presence of at least one agricultural population, can be perceived as a cohesive unit of work within agricultural systems. This differentiation from natural ecosystems lies in the essential regulation by human intervention, driven by specific objectives.

Agroecosystems embody five key properties—productivity, stability, sustainability, equity, and autonomy—that serve as benchmarks for evaluating whether the system effectively achieves its goals, namely enhancing the economic well-being and social values of producers.

Properties of Agroecosystems:

Productivity: Productivity refers to the yield of a specific product per unit of resources introduced into an area.

Stability: Stability involves the preservation of productivity, acknowledging the potential occurrence of unforeseen and uncontrollable events.

Sustainability: Sustainability represents the capacity of an agroecosystem to uphold its productivity when subjected to significant disturbances.

Equity: Equity pertains to the distribution of productivity within the agroecosystem, emphasizing fairness and balance.

Autonomy: Autonomy is defined as the agroecosystem's ability to sustain itself over time, irrespective of external fluctuations.

Considering this perspective, the potential for enhancements, encompassing opportunities to reduce greenhouse gas (GHG) emissions and promote carbon sequestration, extends beyond environmental benefits to influence the local culture. In this context, cultural values play a pivotal role in decision-making, merging traditional wisdom with scientific and technological innovations. It becomes imperative to ensure that accurate and valuable information reaches producers. Moreover, the successful adoption of these changes requires supportive public or private incentives, facilitating comprehension, acceptance, and practical implementation of the transformation process.

Hence, the decision-making processes of communities and individuals are significantly shaped by socioeconomic and cultural factors. It is crucial to prioritize these influences in the structural decision-making of productive sectors. This perspective allows for a more nuanced discussion on the genuine opportunities for reducing greenhouse gas (GHG) emissions and enhancing carbon sequestration among the producers and cooperatives participating in this study.

Citriculture and its Agro-industrial Complex possess significant potential for carbon emissions reduction, making them an integral component of global climate change mitigation endeavors. As an illustrative example, a study conducted by DeltaCO2 in 2013 extensively analyzed greenhouse gas (GHG) emissions linked to the production and export of orange juice by companies affiliated with CitrusBR from 2009 to 2012.

This study, employing established methodologies, evaluated emissions across all stages of the production chain, from primary material sourcing to manufacturing processes and logistical transportation, providing a comprehensive insight into the carbon footprints associated with this industry. Despite more than a decade passing since the mentioned research, its findings remain pertinent and lend support to the present study, emphasizing key aspects to consider when estimating emissions during the "agricultural phase".

Strategies for Carbon Emission Reduction in Citriculture

- Preventive Maintenance and Adjustment of Machinery:
    1. Impact on Diesel Use Reduction
- Equipment Replacement:
    1. Enhanced Machinery Efficiency for Lower Diesel Consumption
- Implementation of IPM (Integrated Pest Management):
  Potential Reduction in Pesticide Use and Quantity
  Facilitation of Transition to Biological Pesticides with Reduced Environmental Impact
- Optimization of Agronomic Practices Management:
  Continuous Training in Modern Techniques for Enhanced Operational Efficiency (Reduced Diesel Consumption).
  Reduced Input Usage or Deployment of More Efficient Inputs
  Increased Productivity
- Substitution of Traditional Nitrogen Fertilizers with Slow-Release Encapsulated Alternatives:
  Resulting in Lower Carbon Emissions
- Biological Nitrogen Fixation:
  Contributing to Lower Carbon Emissions
- Utilization of appropriate type and quantity of Limestone:
  Resulting in Lower Carbon Emissions
  Improving Production Outcomes
- Use of renewable energy sources, improving efficiency in the "energy" factor in greenhouse gas emissions estimates.

All these aspects are representative, but they must be taken into account – for their real application, the cultural and educational level, the level of income, the number of workers and family members involved in production activities, the existing infrastructure, access to credit and technical assistance.

When we look at the emissions resulting from the "agricultural phase", the options for reduction are as follows.

Table 26 - Key GHG Sources Identified in Orange Juice Carbon Footprint and Potential Mitigation Actions.

GHG Sources	Mitigation Strategies
Synthetic Fertilizers	• Use agricultural inputs efficiently, adjusting the doses, season, type of input and form of application to obtain the maximum benefit, avoiding waste; • Reduce the use of synthetic inputs (which cause high GHG emissions in their production and transportation), prioritizing organic sources.
Nitrification and urease inhibitors	• Use of fertilizers with urease inhibitors.
Biological fixation	• Use of microorganisms that promote nitrogen nutrition in plants.
Organic inputs	• Promote the composting of residues within the properties, taking advantage of the organic matter and nutrients available, or its purchase in the region of the property, thus avoiding and reducing GHG emissions in its production and transportation.
Energy	• Use of renewable energy sources.
Fuels	• Replace fossil fuels with biofuels such as biodiesel, ethanol and biomass.
Pesticides	• Rational use of agrochemicals, based on IPM.
Crop residue management	• Residue from agricultural production, especially pruned branches and trunks, as well as fallen and discarded fruits, can be composted, which generates lower emissions

Source: Adapted from the table presented by the cited study (DELTACO2, 2013)

Below, we will discuss some details regarding each reduction possibility.

Use of Fertilizers

The use of fertilizers plays an important role in greenhouse gas emissions, especially when it comes to nitrogen fertilizers, which are essential for increasing crop productivity. Nitrogen fertilizers contribute to large emissions of nitrous oxide (N_2O), a gas with a global warming potential about 300 times greater than carbon dioxide (CO_2). The impact is so significant that when we evaluate the Annual Estimates of Greenhouse Gas Emissions in Brazil, published by the Ministry of Science, Technology and Innovation (Brazil, 2022), we find a contribution of more than 22% of all N_2O emissions classified as "Managed Soils," which refer to agricultural cultivation, in this report. These contributions come in two forms:

- Direct emissions – Approximately 17% of N_2O emissions, primarily associated with urea volatilization.
- Indirect emissions – About 5.6% of N_2O emissions, linked to leaching.

Direct emissions are largely influenced by the type of fertilizer and its application method. The application of urea tends to result in higher N_2O emissions due to its elevated nitrogen concentration compared to other nitrogen sources like ammonium nitrate and ammonium sulfate. Additionally, urea contains carbon in its composition, released as CO_2 after reacting in the soil. Therefore, replacing urea with alternative nitrogen sources can contribute to reducing GHG emissions. The implementation method also plays a crucial role in managing these emissions. Transitioning from surface distribution to application in furrows or small holes within the canopy projection area, whether injected or dripped, can significantly decrease N_2O emissions.

Indirect emissions, on the other hand, are strongly linked to dosage; it is estimated that 60% of the nitrogen applied to crops is lost through leaching because this nutrient is highly mobile in the soil. Thus, applying fertilizers in the amount necessary to meet the nutritional needs of the orchard can result in lower N2O emissions, in addition to contributing to lower expenses and better productivity performance, avoiding nutritional imbalances.

An additional alternative is to split the use of nitrogen fertilizers into several applications throughout the year, increasing the utilization of this element by plants. However, this operation must be carefully evaluated, as it requires a greater number of agricultural operations and fuel use.

Use of nitrification and urease inhibitors

These compounds act by inhibiting the nitrification or hydrolysis stage of urea, thereby reducing losses due to leaching or volatilization. This could be a promising practice for reducing GHG emissions. In the Delta CO2 study (2013), a potential reduction of 18% or 22% in emissions was presented when a 2.5% or 5% inhibitor was used, respectively.

Biological fixation:

- Biological nitrogen fixation (BNF) is a process carried out by certain microorganisms that promote nitrogen nutrition in plants. This process can directly contribute to the reduction of atmospheric nitrous oxide emissions. BNF is a natural biochemical process performed by bacteria capable of extracting nitrogen from the air and supplying it directly to the roots of plants, fertilizing the system. It is the primary route for incorporating nitrogen into the biosphere and, after photosynthesis, is the most important biological process for plants.;
- BNF allows for the application of less nitrogen fertilizer to crops without compromising production. The use of green manure, such as jack beans, pigeon peas, and sun hemp, in orchards provides BNF, adding nitrogen to agricultural production without the associated burden of N2O emissions.

Organic inputs

Replacing a portion of synthetic fertilizers with organic fertilizers produced locally near the orchards can be a viable strategy to reduce GHG emissions. Organic and organo mineral sources generally exhibit lower upstream emissions (during production) than synthetic fertilizers, as the latter are known to be energy-intensive, resulting in high emissions per unit of product.

Furthermore, the proximity to nutrient sources, as observed in composting, reduces emissions associated with the transportation of these materials, contributing to a lower carbon footprint in the agroecosystem. Studies indicate that the use of organic fertilizers in citrus orchards not only reduces GHG emissions but also promotes carbon sequestration in the soil:

> "In a study conducted on the production and utilization of organic fertilizers in Egyptian citrus orchards, Luske (2010) discovered that when the crop is fertilized with organic compost, it carries a carbon footprint of 162 kg CO2/ton. In contrast, when nitrogen fertilization is done using ammonium nitrate, the carbon footprint increases approximately thirtyfold, reaching a value of 1,813 kg CO2e/ton. Additional research has indicated that N2O emissions are also reduced when organic compost is applied, concurrently fostering carbon sequestration in the soil" (DELTACO2, 2013).

Diesel

The citrus sector, much like any other agricultural activity, heavily relies on diesel-powered machinery for various operations throughout the production cycle. However, being a fossil fuel, diesel is linked to a range of greenhouse gas (GHG) emissions, including carbon dioxide (CO_2) and nitrous oxide (N_2O), significantly contributing to the environmental impact of citrus farming.

In this context, the importance of rationalizing agricultural activities is underscored – making operations more efficient with a reduction in fuel consumption. This includes the training of tractor and implement operators to improve gear shifting, engine torque, among other factors, which can lead to reduced fuel consumption. Additionally, the replacement of fossil fuels with more sustainable alternatives, such as biodiesel or other renewable energy sources, is integral to GHG emission mitigation strategies in citriculture.

The transition from fossil fuels not only reduces direct CO_2 emissions associated with burning diesel but also decreases indirect emissions from the removal, transportation, and processing of this fuel. The significance of conservation management in citrus orchards as a strategy to reduce diesel consumption should also be emphasized. Implementing farming practices that minimize orchard operations not only saves fuel but also contributes to soil health and reduces GHG emissions associated with growing operations.

Limestone

The application of lime in arable areas plays a crucial role in controlling soil acidity, enhancing the availability of vital nutrients like calcium and magnesium, and fostering microbial activity. However, it's essential to acknowledge that improper use of limestone can contribute to greenhouse gas emissions, specifically carbon dioxide.

Therefore, a thorough soil analysis before applying limestone is imperative to determine the appropriate quantity needed. The choice of limestone type is another crucial factor: opting for more reactive limestones, which neutralize acidity more rapidly, allows for the application of smaller quantities, thereby reducing CO_2 emissions.

Additionally, attention to factors such as uniformity in application, incorporation methods, timing, climate, and location of limestone application is crucial. This ensures a reduction in waste and maximizes the positive effects of the product on the soil.

Pesticides

The use of pesticides, encompassing insecticides and herbicides, is a widespread practice in agriculture, particularly in citrus farming, to manage pests and diseases and ensure high-quality orange production. However, it is crucial to recognize that the improper application of these products can significantly contribute to greenhouse gas (GHG) emissions, posing risks to both human health and the environment.

Integrated Pest Management (IPM) emerges as a solution by focusing on monitoring agroecosystem conditions and employing targeted and controlled pesticide use only when strictly necessary. This approach serves as an alternative to prevent the inappropriate use of these products. When pesticides are misapplied, exceed recommended amounts, or are used unnecessarily, they can result in avoidable GHG emissions and contribute to soil and water contamination, causing adverse environmental impacts.

An alternative approach is to substitute conventional pesticides with alternative options like *Bordeaux Mixture*[8] and sulfocalcium syrup. Correct application of these alternatives can lead to a reduction in greenhouse gas (GHG) emissions. Additionally, emphasizing biological pest control serves as another viable option, not only minimizing pesticide usage but also aiding in the reduction of emissions associated with these inputs.

Crop residue management

Agriculture can contribute significantly to carbon emissions, mainly through inefficient crop residues management practices. This is a point that requires attention and includes: pruned branches and trunk or eradicated orange trees, post-harvest losses and other by-products. Implementing innovative crop residues management strategies not only mitigates environmental impact, but also increases the overall sustainability of agricultural practices.

<u>Adopting Circular Economy Principles</u>:
The transition to a circular economy in agriculture involves minimizing crop residues and maximizing the utility of resources. By adopting practices such as composting, recycling, and reusing crop residues, farmers can reduce their dependence on conventional disposal methods that contribute to greenhouse gas emissions. Circular economy principles promote a closed-loop system that promotes sustainability by transforming crop residues into valuable resources.

Bioenergy Production from Crop Residues:
Converting crop residues into bioenergy can be a sustainable approach to both residue management and carbon reduction. Biomass from crop residues and organic residue can be used to generate biofuels or biogas. This not only provides an alternative energy source, but also prevents the release of methane – a potent greenhouse gas – which can be produced during the natural decomposition of organic residue.

Energy

On the global stage, the energy sector is one of the largest contributors to GHG emissions, mainly due to the burning of fossil fuels. However, in Brazil, the energy matrix comes mostly from renewable sources, such as hydroelectricity, ethanol mixed with gasoline and cogeneration with sugarcane bagasse. This, in a large part, reduces the GHG emissions associated with electricity generation in the country. In citriculture, electricity consumption is especially present in the processes of supervision, storage, and post-harvest processing of oranges. In the context of GHG emissions, it is crucial to assess how the production and use of this electricity are relevant to the environmental impact of citrus farming.
The practice adopted by the orange juice industry in Brazil of using sugarcane bagasse as a renewable energy source replaces, in part, fossil fuels in electricity generation, and contributes significantly to the reduction of GHG emissions in the orange juice processing phase. The use of agricultural residue as an energy source, as in the case of sugarcane bagasse, is considered an environmentally sustainable practice, since it takes advantage of materials that would otherwise be discarded. However, the research raises a possible concern about the increased production of second-

[8] Bordeaux mixture is a traditional agricultural fungicide created in the 19th century in Bordeaux, France, composed of copper (II) sulfate ($CuSO_4$), hydrated lime or quicklime and water, in a simple mixture. It has proven effectiveness against several fungal diseases, mainly infections resulting from Plasmopara viticola. Widely used on vines to combat mildew, in persimmon trees, citrus, orchids and other crops. It also has action against bacterial infections and certain pests.

generation ethanol in Brazil, which could reduce the supply of sugarcane bagasse for the orange juice industry. These strategies not only contribute to the reduction of GHG emissions but also promote the resilience of agroecosystems and the citrus sector in the face of climate change and increasing demands for sustainable practices.

In this context, it is evident that nitrogen fertilization, the use of diesel, the application of limestone, pesticide management and energy consumption are crucial points that require attention. Strategies such as the replacement of nitrogen fertilizers with more sustainable alternatives, the implementation of conservation management practices, the efficient use of limestone, the adoption of alternative management and the use of renewable energy sources are essential for the mitigation of GHG emissions. To provide a clear overview of the main sources of GHG emissions identified and suggested mitigation strategies, the topics are presented in a summary table:

Carbon sequestration options

Alongside efforts to minimize emissions, there is a pressing need for actions that facilitate carbon sequestration from the atmosphere. Orange orchards, sprawling across diverse climatic conditions worldwide, emerge as a strategic asset in mitigating greenhouse gas (GHG) emissions. Being tree crops, these expansive systems harbor substantial carbon reservoirs, presenting significant potential for carbon sequestration in both soil and aerial biomass. The sequestration of carbon in soil, in particular, stands as a pivotal element in mitigating GHG emissions linked to citriculture. Just as efforts to diminish emissions consider socioeconomic factors, actions directed at carbon sequestration must similarly account for these aspects to ensure practical applicability. The main strategies identified that can contribute to carbon sequestration in orange orchards are:

- Reduction of soil turning;
- Use of cover crops;
- Green manure;
- ICLF – Crop-Livestock-Forest Integration;
- SAF – Agroforestry Systems;
- Recovery of degraded areas on the property.

Reduction of soil turning

One key strategy to enhance carbon sequestration in orange orchards involves minimizing soil turnover. Conventional practices like plowing, harrowing, and subsoiling often lead to a decline in soil carbon stocks due to the mineralization process of soil organic carbon, releasing carbon dioxide into the atmosphere. The extent of these carbon losses is directly linked to the intensity of soil turnover.

In contrast, conservative management stands out as a highly effective alternative. This approach aims to minimize soil turnover, enabling the maintenance or even augmentation of soil carbon stocks. By doing so, it helps mitigate CO2 emissions resulting from soil manipulation while fostering the health and resilience of soil ecosystems.

Conservative management encompasses reducing the use of soil-disturbing agricultural implements, such as subsoilers and harrows, in favor of no-till planters and brush cutters. Additionally, techniques like mulching and minimum tillage are implemented to protect the upper layer of the soil.

Use of cover crops

Another efficient strategy to increase carbon sequestration in orange orchards involves maintaining green soil cover using green manures. These fertilizers consist of plants grown specifically to improve soil properties and contribute to carbon sequestration and biological nitrogen fixation. The agronomic benefits of this practice are wide-ranging and include improving the physical, chemical, and biological properties of the soil, as well as controlling erosion and providing essential nutrients to the orchard trees.

The use of green manures such as *Crotalaria, Crotalaria juncea* (suitable for sandy and sloping soils), *pigeon pea, Cajanus cajan* (recommended for compacted sandy soils in young orchards), and *Lab-lab, Lablab purpureus* or *jack bean*, *Canavalia ensiformis* (suitable for mature orchards with erosion problems) can result in a significant increase in nitrogen and carbon contents in the soil. This occurs as the aerial biomass and roots of these plants decompose, enriching the soil with carbon-rich organic matter.

It is crucial to note that at the time of full flowering, when they are at the peak of nutrient accumulation, they should be mowed, and their incorporation into the soil should be avoided. This is mainly aimed at maintaining the soil cover and its physical properties, as well as allowing the possible recovery of these plants. A foliar analysis of the nitrogen content of citrus leaves can guide the adjustment of mineral fertilization, reducing the need for synthetic nitrogen application and the consequent emission of N2O.

Green manure also provides a natural control of spontaneous competing vegetation, which reduces herbicide application and decreases GHG emissions.

Crop-Livestock-Forest Integration

The techniques of integration between agricultural, livestock, and forestry activities bring numerous benefits to the agroecosystem, with emphasis on increased income and employment, biodiversity enhancement, environmental services, and system resilience, along with GHG mitigation.

The Integrated Crop-Livestock-Forest (ICLF) and its variants (ICLF), ILF, and IPF are viable modalities for producers of all sizes, especially those already engaged in multiple crops on their properties. For citrus producers, these practices can be beneficial for those with diversified activities or idle areas.

In the context of this study focused on family farming and small orange producers, the following integration practices are noteworthy:

Crop-Livestock (CL) – Orange and Livestock: Involving dairy farming and sheep farming.

Crop-Forest (CF) – Orange and Forest: Involving tree species such as Teak (*Tectona grandis*), Eucalyptus (*Eucalyptus*), and African Mahogany (*Khaya ivorensis*).

Large producers of milk and citrus benefit mutually – the composted residue from cows serves as fertilizer for orchards, leading to savings in synthetic fertilizer acquisition. The citrus pulp generated from orange processing serves as feed for lactating cows, contributing to increased milk production.

Similar benefits apply to small and medium-sized producers engaged in sheep farming for milk and/or meat production. Composted animal residue fertilizes orchards, and citrus pulp serves as animal feed. Additionally, some of this residue can be converted into electricity using the biogas produced.

Finally, intercropping orange production with timber tree cultivation presents an excellent opportunity for the agroecosystem. In the medium and long term, this practice can contribute to carbon sequestration during the vegetative growth period of the trees. Combined with proper planning and compensation through other activities, it can maintain at least emission neutrality when these trees are eventually harvested.

Agroforestry Systems – AFS

Agroforestry systems (AFS) can be considered a type of Integrated Crop-Livestock-Forest (ICLF), but AFS offers distinct advantages, including a) a higher degree of species diversification, leading to a variety of income sources; b) increased labor and time commitment to productive activities, contributing to job creation and supporting the local economy; and c) greater biodiversity within the agroecosystem, enhancing resilience and aiding in climate change mitigation.

Sustainable Agroforestry (SAF) involves planting native trees alongside annual crops (such as cassava, corn, beans, pumpkin) and fruit species (bananas, guavas, avocados, lemons, oranges, coffee). This approach aligns food diversity with income generation, contributing to increased food production in the short, medium, and long term, as well as supplementing family income, fostering autonomy for individuals, families, and communities.

The diversification of activities in AFS, in addition to promoting carbon sequestration and emission reduction, creates opportunities for job generation. Depending on the region, there can be increased exchange and services between producers, enhancing employment levels and contributing to the local economy. This dynamic strengthens interpersonal relationships and perpetuates community understanding.

Furthermore, research indicates that shaded citrus in AFS can yield equal to or more than citrus in full sun, potentially generating higher income per unit area (Bezerra, L. *et al*, 2021). The presence of trees not only provides an additional income source but also offers protection to the system during extreme weather events, such as frosts.

Recovery of degraded areas

The carbon stock in each area varies based on factors such as soil type, climate, geological material, and, crucially, land use and management practices. The ability of an area to sequester carbon depends on the quantity of organic matter in the soil.

Human activities often impact the surface layers of soil, reducing its organic content. As organic matter decreases, biodiversity, humidity, and the system's long-term sustainability are compromised. This leads to the loss of successive soil layers and erosive processes. Degraded areas not only result in reduced productivity but also fewer environmental services, diminished sustainability, limited opportunities for communities, and increased greenhouse gas (GHG) emissions. The imperative for recovery is evident, not only to lower emissions and mitigate climate change effects but also to promote social justice and improved opportunities for people.

Recovery efforts involve knowledge, planning, and an understanding of the origin or degradation process to formulate effective strategies. Often, collective action is required due to the extensive nature or significant impact of the recovery. Techniques commonly employed for recovery include vegetative propagation of native species, natural regeneration management, and planting through seedlings or seeds. These practices aim to establish a resilient ecosystem in the area and require ongoing monitoring and adaptation for optimal results. While these recovery processes may be slow, expensive, and bureaucratic, finding a balance between environmental and financial interests is a key challenge in managing these areas.

In summary, strategies like reducing soil turnover, utilizing green manures, and engaging in recovery activities in degraded or areas implementing CLI, CFI, or AFS present significant potential for soil carbon sequestration in orange orchards. The implementation of these practices not only contributes to GHG emissions mitigation in citriculture but also fosters healthier, more resilient, and productive soils, along with more robust and equitable communities.

Feasibility of Carbon Credits as a tool for income diversification

In addition to the positive impact on agroecosystems, the proposed actions for carbon reduction and sequestration can lead to the acquisition of carbon credits. These credits represent the avoidance of one ton of carbon emitted into the atmosphere, contributing to mitigating the greenhouse effect. Carbon credits serve as the currency in the carbon market, where companies with high emissions but limited reduction options can purchase credits to offset their carbon footprint. This mechanism finances climate change adaptations and rewards practices that are proven to sequester or reduce carbon emissions, indirectly supporting projects to reduce emissions or mitigate and/or adapt to climate change, thus contributing to the sustainable development of vulnerable communities.

Carbon credits offer an opportunity for income diversification, transitioning from a conceptual idea to a tangible resource. Properties adopting low-emission methods not only gain from the credits generated but also improve agroecosystem health, enhance environmental services, and boost productivity and quality, directly increasing income from production.

However, the journey to obtaining credits is extensive. It begins with initial studies, like the present one, defining baseline emission estimates. After implementing necessary adjustments in production processes, subsequent assessments demonstrate emission reductions due to the adopted practices, leading to carbon neutralization and sequestration. Once measured, these achievements can be translated into carbon credits for trade.

Given that this study is in its preliminary phase, it is premature to determine the full extent of the expected impact in the coming years and production cycles regarding credit generation. Even with the conclusion of the study in 2023 and feedback sessions with producers, the exact impact remains uncertain, contingent on numerous variables evolving over time. Key questions that still lack answers include:

- What will be the perceptions of the producers involved in the proposed changes?
- How will you accept the recommendations?
- How soon will you implement these measures?
- What support will they have in this implementation?
- What will be the reduction in emissions?
- How many credits will be generated?
- What amounts will producers receive?

These questions will only find answers over time as the planned actions, in collaboration with Fairtrade, CLAC, Cooperatives, and producers, are implemented.

It is accurate to assert that if the recommended actions are executed, they will yield numerous benefits. These extend beyond the potential generation of carbon credits for future commercialization, reaching into the daily lives of producers. The benefits include the improvement of agroecosystem conditions and enhanced resilience to climate change.

Conversely, the rejection of the proposed recommendations by producers and cooperatives, leading to a failure to alter the current framework, would heighten risks concerning the sustainability of the agroecosystem in the face of extreme weather events and climate change. This is especially true for prolonged droughts and a significant increase in temperatures.

To prevent such situations, there is a need for educational and awareness-raising actions among producers and cooperatives. Often, these actions are available free of charge and provided by the state, such as agricultural training courses offered by SENARA.

Estimated water footprint and opportunities for water management

Concurrently with the estimation of emissions and carbon footprint, the water footprints of farms and cooperatives were assessed using the Cool Farm Tool. Within the majority of sampled properties, water usage is predominantly confined to activities like spraying or human consumption, resulting in a minimal water footprint. Conversely, in properties equipped with irrigation systems, the footprints are notably larger and more impactful, as evidenced by the findings presented below:

As the activity adopted in Cool Farm Tool was "Tree Crops" it was not allowed to estimate de water footprint.

For the producers that declared to use irrigation, the table below presents the quantity of used water.

Table 27 - Water used in irrigation

Cooperative	Producer	Water used (l)	l/ha	mm
Cooperative B	ID2_8	390,000	32,500.00	3,25
Cooperative C	ID3_6	5,914,350	642,864.13	64,28
	ID3_8	30,816,000	880,457.14	88,05
	ID3_10	299,952	21,425.14	2,14
	ID3_11	60,720,000	3,584,415.58	358,44
	ID3_12	33,600,000	4,200,000	420,00

However, despite the challenges presented by climate change affecting all surveyed properties and regions, the impact is evident. Producers and their families are already experiencing the consequences of increased local temperatures and reduced water availability throughout the year. It is imperative to implement mitigation actions promptly, as some of these actions have medium and long-term effects on agroecosystems.

A notable example of these challenges is observed in Cooperative B, which has grappled with successive periods of drought in recent years within its operational area. These droughts have led to significant losses in orange productivity and quality, resulting in a subsequent decrease in the income of producers.

Several opportunities exist to mitigate the effects of these extreme events, particularly the increasingly frequent droughts. Key strategies include the reduction of irrigation consumption through practices such as managing vegetation between rows without turning the soil and implementing green manure. Additionally, measures such as preventive maintenance of pumps and records, along with the calibration of sprayers, can aid in reducing water usage.

Other impactful strategies involve enhancing water retention by constructing and maintaining reservoirs, as well as capturing and reserving rainwater. Furthermore, the recovery of springs and water bodies through reforestation initiatives is crucial for effective water management.

In summary, based on the findings, the identified main strategies that can significantly contribute to water management, expand water retention, and mitigate the impacts of droughts and other extreme events in orange orchards include:

- Rainwater harvesting on the roofs of existing infrastructures and installation of cisterns or reservoirs.
- Construction of dams and reservoir on farms.
- Regularization of grants.
- Identification, Mapping, and Recovery of springs and water bodies.
- Preventive maintenance of pipes, pumps, and irrigation registers.
- More efficient spraying with the regulation of nozzles and sprayers.
- Extensive use of mulches in production areas.

Rainwater harvesting

Rainwater is a plentiful natural resource available at certain times of the year, sorely missed during long months of increasingly frequent drought. Capturing rainwater and reserving it through cisterns, for example, can provide autonomy to the families of producers and ensure their consumption needs are met.

Having more water available enables the planning and expansion of production diversification. Many roofs of sheds, houses, and other structures on the properties can be adapted to capture rainwater. Simple systems ensure that the first rains wash the roofs, and only once cleaned of accumulated dust and other dirt, clean water begins to be reserved in cisterns.

Dams and reservoir

The negative impacts resulting from the construction of reservoirs are generally negligible compared to the significant benefits they can offer. Encouraging and facilitating the establishment of dams on rural properties is highly relevant for water and soil conservation. It enhances aquifer recharge, sustains water flow throughout the year, and facilitates irrigation projects, leading to increased food production and job opportunities.

Augmented water supply in river basins also enables the extension of water use rights to a broader spectrum of users, enhancing the effective fulfillment of diverse water needs. This consistent availability of water ensures increased autonomy and stability, fostering higher productivity within the agricultural ecosystem and promoting greater equity for rural populations.

Water Grants

Water resources, both surface and groundwater, are considered public goods, and according to Brazilian laws, every individual or legal entity has the right to access them. The Granting of the Right to Use Water Resources (Water Grant) serves as an instrument established by the National Water Resources Policy (PNRH), outlined in Federal Law No. 9,443, dated January 8, 1997. This instrument is essential for the quantitative and qualitative control of water usage, ensuring the effective exercise of the right to access it.

In essence, the Grant is an administrative act, authorization, or concession by which the government grants permission to the recipient to utilize water for a specific period. Besides facilitating the efficient management of water resources, the Grant has become a requisite for obtaining environmental licenses for certain projects. For instance, in the agricultural domain, the approval of rural credits by banks or credit unions necessitates the regularity of water resource usage in enterprises.

It is crucial to note that utilizing any water resource without the proper authorization from the granting public authority exposes the project to warnings, fines, and the potential for embargo. Therefore, the bureaucratic regularization of existing liabilities on properties or the regularization of future impoundment and catchment projects is indispensable to ensure legal access to water and enjoy the associated benefits of its use and availability.

Springs

Properties that have springs and other bodies of water must make special efforts in their conservation. Interventions are often necessary for their proper recovery.

Care must begin with the preservation of springs because they are the origins of rivers, serving as superficial manifestations of water stored in aquifers that initiate the formation of rivers. For the conservation of springs and water sources on rural properties, some measures can be adopted to protect the soil and vegetation, ranging from eliminating burning practices to enriching native forests.

Additionally, other precautions are essential for their preservation. For instance, avoiding the construction of corrals, pigsties, chicken coops, and cesspools near or above the springs is crucial. This is because, with rain, waste can contaminate these water sources. Similarly, deforestation around the springs and the accumulation of garbage in the regions near them also require attention.

Deforestation and irregular land occupation devastate headwaters or recharge areas, which are responsible for replenishing groundwater, aquifers, and springs. This devastation significantly contributes to reducing the quantity and quality of water available on the planet.

Preventive maintenance

The preventive maintenance of pipes, conduits, hydraulic pumps, and water distribution records is an essential activity to control waste and reduce consumption on rural properties.

The wastage of water in irrigation and other agricultural activities not only increases production costs but also incurs environmental costs by compromising the availability and quality of water. In this context, it can be inferred that many irrigation projects worldwide suffer from low economic and socio-environmental sustainability.

Achieving sustainability in irrigation projects requires effective actions from both farmers and public agencies. These actions should aim to minimize water waste during its capture, conveyance, and application to crops, preventing the degradation of surface and groundwater. In arid and semi-arid regions, special attention is needed to address salinization problems.

Sprays

Adjusting the nozzles of the sprayers or replacing outdated spraying equipment with electrostatic technology enables the optimal use of water as a carrier for the dispersion of molecules combating pests and diseases. This ensures increased process efficiency and minimizes resource wastage.

To achieve this, educational initiatives are essential for producers, their families, and employees, including specialized technical training for applicators. Awareness campaigns about the ideal spraying times, preferably during cooler hours of the day and in windless conditions, should also be an integral part of these efforts.

Agricultural management

The agricultural management practices adopted significantly impact the water availability within the agroecosystem. One of the key measures to preserve soil moisture is the promotion and upkeep of green roofs.

The soil management and agricultural practices recommended for carbon reduction and sequestration also hold relevance for water management on farms. Optimizing mechanized activities, avoiding soil disturbance and adopting no-till practices, and incorporating green cover are viable options that contribute to maintaining higher humidity levels in the agroecosystem over time.

Costs of mitigation opportunities

Economic aspects

In business, every decision carries both a cost and an opportunity, and these factors are not always immediately apparent, extending beyond mere financial considerations. This economic principle is encapsulated in the concept of "opportunity cost," which holds significant sway in the decision-making processes of enterprises.

Opportunity cost can be defined as the value of the best alternative forgone when a decision is made. It represents what is sacrificed by choosing one option over another. This concept is especially crucial for small and medium-sized enterprises, including agricultural businesses, operating with limited resources, necessitating careful allocation for maximizing returns over time.

Understanding this concept is fundamental for effective business management, providing a framework for making sound decisions. By considering opportunity cost, companies can assess all available options and make choices that optimize the value of their resources. For instance, if a farm invests in new equipment, the opportunity cost might be the potential gain that could have resulted from hiring a new employee. Furthermore, opportunity cost is not confined to financial decisions but extends to other valuable resources like time and manpower. If a company chooses to dedicate time to developing a new product, the opportunity cost is what could have been achieved by utilizing that time differently, such as improving an existing product or training staff.

Calculating opportunity cost involves comparing the potential returns of different options to determine the one that offers the most value. While a straightforward concept in theory, its practical application can be challenging as it requires evaluating alternatives that may not be easily comparable. Exploring concrete examples within the context of small and medium-sized enterprises can enhance understanding.

Investment Decisions

A farm finds itself with a surplus capital of $100,000 and faces a decision between two investment options:

a) Expand Production Facilities:
Anticipated Return: 10% per year
Surplus Capital: $100,000
b) Invest in Another Company's Stock:
Projected Return: 15% per year
Surplus Capital: $100,000

If the farm opts to allocate its funds towards expanding its production facilities (Option a), the incurred opportunity cost will be the potential 15% return it could have garnered by investing in the stock market (Option b). In other words, the farm foregoes the higher return from the stock investment by choosing to enhance its production facilities.

Time Alocation

A farm engages in the production and sale of two distinct products. However, the time allocated to the production of one product directly diminishes the available time for producing the other.

In the scenario where the farm chooses to increase its focus on producing Product A, the associated opportunity cost is represented by the potential revenue that could have been generated through the production of Product B. In essence, the farm foregoes the income it could have earned from Product B by allocating more time to Product A.

Recruiting Choices

In this scenario, a farm possesses the resources to hire a new employee but faces a decision between two options: hiring a general tractor driver specializing in brush cutters and soil preparation or hiring a tractor driver with additional skills in pesticide application.

Should the farm opt to hire the general tractor driver, the opportunity cost would encompass the additional value that the tractor driver with pesticide application skills could have contributed to the company. In essence, by selecting the general tractor driver, the farm foregoes the potential benefits that could have been provided by the pesticide-application expertise of the alternative candidate.

Pricing Decisions

A company selling a popular product may confront the decision of whether to increase the price of the product. If the company decides to raise the price, the opportunity cost could manifest as the potential loss of customers unwilling to pay the higher price.

These examples highlight the presence of opportunity cost in various facets of business operations. In each scenario, the company must carefully evaluate the benefits and costs associated with each option, taking into account the value of the best alternative not chosen. Through this analysis, businesses can make well-informed decisions that optimize the utilization of their resources and contribute to sustained long-term growth and profitability.

To facilitate this process, here are some general steps that can be taken to calculate and consider opportunity cost:

Identify the Alternatives

The initial step in calculating opportunity cost involves identifying the various alternatives available. This may encompass diverse investment strategies for money, alternative approaches to time allocation, or various options for utilizing other resources.

Evaluate the Potential Return of Each Alternative

Subsequently, the company should assess the potential returns for each alternative. This process may entail scrutinizing historical data, conducting thorough market research, or seeking insights from industry experts.

Compare Returns

After evaluating the potential return for each alternative, the company can compare the returns to determine which option provides the most value. Typically, the alternative with the highest potential return becomes the preferred choice.

Consider Opportunity Cost

If the company opts for the alternative with the highest potential return, the opportunity cost would be the return that could have been achieved with the second-best alternative.

Thus, we can summarize the impacts of opportunity costs on business decisions as follows:

Impact on Investment Decision

Opportunity cost plays a crucial role in investment decisions. When evaluating various investment options, businesses should consider the opportunity cost associated with each option. Typically, the option with the lowest opportunity cost is considered the optimal choice.

Impact on Business Strategy

Opportunity cost can significantly influence a company's overall business strategy. When assessing different strategies, businesses should consider the opportunity cost associated with each one. Typically, the strategy with the lowest opportunity cost is deemed the most favorable choice.

Impact Performance Assessment

Finally, opportunity cost can be employed to evaluate a company's performance. Comparing the actual return on a decision to the opportunity cost enables businesses to assess the soundness of their choices and identify areas for improvement in the future.

Climate Finance

Climate disasters are notorious for causing catastrophic material and economic damage. As the planet warms, the anticipation is that climate events will become increasingly intense and challenging to predict, posing a significant risk to the productive and financial sectors.

It is evident that the economic benefits of proactive disaster preparedness far outweigh the costs of dealing with their aftermath. According to the Global Commission on Adaptation (GCA), the benefits of investing in resilience surpass the costs by up to four times.

Considering this, it appears to be an opportune moment for various productive, financial, and political sectors to come together for a global effort to address the following challenges:

- Understanding the financial impacts of climate change.
- Determining the overall benefits of preventive action.
- Identifying the best allocation of financial capital to manage risks and seize opportunities.

The implementation of mitigation, adaptation, and resilience measures can present opportunities rather than just risks. For instance, the economic recovery post the coronavirus pandemic offers a significant opportunity for businesses and governments to commit to climate adaptation and resilience, potentially generating new jobs and stimulating economic growth.

Key initiatives include:

- Developing a long-term vision focused on opportunities.
- Increasing stakeholder awareness about climate-related risks.
- Enhancing climate risk disclosure processes.
- Sharing insights and lessons learned with a broader audience.
- Taking proactive measures to seize opportunities.

However, achieving the required levels of investment in financial and climate resilience demands a substantial increase in both public and private capital allocation.

Socioenvironmental Aspects

The justification for conducting opportunity cost analysis is grounded in the recognition that investment decisions driven solely by profit motives and market prices often result in outcomes that may be socially undesirable. Conversely, when a project's inputs, outputs (including intangibles), and external effects are assessed based on their social opportunity costs, the resulting calculated return provides a more suitable measure of the project's impact on social welfare. This approach ensures a more comprehensive and socially responsible evaluation, taking into account the broader implications for the community and the environment.

Opportunity costs for producers and cooperatives in this study

Cost of Inaction: Losses from the Impacts of Climate Change:

- What happens if you don't reserve water? Agricultural production and family life on the property may become unfeasible.
- If you neglect to keep the soil covered and moist? Water needs will increase, along with the incidence of pests and diseases.
- If you skip implementing Integrated Pest Management (MIP)? You might end up spending more than necessary, leading to an imbalance in the agroecosystem and additional costs in trying to restore its lost balance.
- If you avoid diversification? You could face the economic consequences of a crisis in the citrus sector.

Environmental Socioeconomic Cost: Losses Caused by Ignorance and Lack of Information:

- What if you don't take the time to inform yourself? Adapting to and mitigating climate change may become unfeasible, impacting economic sustainability.
- If you neglect monitoring and recording? You may incur unnecessary expenses and be at the mercy of decisions made by other agents.
- If you don't allocate resources to change? It might become economically unviable.
- Values of the Mitigation Actions Proposed by KS

During the study period, the values for some proposed activities were verified in the Brazilian market. Additionally, actions requiring organization and planning, without imposing financial burdens on the producer, were identified, such as the free learning activities offered by SENAR.

SENAR offers free courses, such as:

Line of action: agriculture - Orange

a) Pest and disease inspection
b) Setting-up of the crop
c) Cultural management and farming care
d) Harvest
e) Harvesting and marketing

Line of action: Agro-silvopastoral support activities - Pesticides

a) Application with manual backpack sprayer
b) Application with motorized backpack sprayer
c) Application with a low-volume backpack sprayer
d) Application with tractor-mounted spraying
e) Turbo spray application
f) Correct and safe use for workers in a family economy regime
g) Control of leaf-cutting ants

Line of action: Agro-silvopastoral support activities - Farm machinery

a) Maintenance of farming tractors
b) Operation of farming tractors
c) Operation of farming tractors s - soil conservation techniques

The SENAR (National Service for Rural Learning) provides free courses and training across the country through its Rural Vocational Training program.

However, not all recommended actions come without cost. Some demand significant investments, such as the replacement of tractors, for which the producer must seek partnerships with cooperatives, banks, etc. On the other hand, there are actions with low to moderate costs, allowing the producer to invest independently on behalf of their organization. Looking specifically at this study, we present information on some of the costs of the proposed mitigation actions:

Environmental remediation:

Regarding the costs associated with environmental recovery, data from The Nature Conservancy (2020) suggests an average expenditure per hectare of approximately US$ 2,000 in the Amazon, US$ 2,100 in the Atlantic Forest, and US$ 3,000 in the Cerrado. For our illustration, we adopted the pattern of the Atlantic Forest, given that the majority of cooperatives are situated in this biome.

Mitigation actions	Unit	Values	Financing
Environmental remediation*	ha	€1,901.70 EUR	Banks

Soil conservation and Green Manure – Coats of implementation

NOTE: A budget was carried out remotely, in the week of December 11 to 15, in a green manure seed store in Piracicaba/SP. These values are presented below.
NOTE 2: The costs of soil preparation, planting and cultivation were not budgeted, as they may vary according to the agricultural practices adopted (mechanized vs. manual), as well as whether the operations will be combined or individualized.

Green Manure	Values (€/Kg of seed)	Kg of seed / ha (recommended)	Coast (€/ha)	Financing
Pigeon pea (*cajanus cajan*)	3,50	40 to 50	140,00 to 175,00	Banks; cooperative
Jack bean (*canavalia ensiformis*)	3,70	100 to 120	370,00 to 445,00	Banks; cooperative

Source: https://pirai.com.br/

Water Security and Water Reservation – Budget for the project to install a 25m^3 cistern and 80 m^2 multipurpose roof

NOTE: Budgets were made remotely, in the week of December 11 to 15, in construction materials stores and related stores in the states of São Paulo, Paraná and Rio Grande do Sul. An average of the budgeted amounts has been established and is presented below.

Average Project Cost

Improvements	Total Average Value (€)	Financing
Cistern (25m^3)	2,460.00	Banks; cooperative
Automatic device for water quality protection	72.70	Banks; cooperative
Shed roof	866.00	Banks; cooperative
Shed (80 m^2)	2.878.50	Banks; cooperative
Total	**6,277.20**	

For more details see the Appendix 6.

Evolution Indicators

In the calculation of the Cool Farm Tool (excluding biases), analyze the predominant indicator(s) that significantly contribute to the estimate, such as fertilizers, energy, etc.
Specify the key components within each indicator—such as types of fertilizers, sources of energy, and more—that exert the most substantial influence on the estimate.
Set a baseline for these indicators to facilitate future assessments of progress in critical areas during subsequent time points or in other studies.

Workshops Fairtrade

As a fundamental part of the strategy of this study, after data collection, treatment and analysis, meetings were held with the technicians of the cooperatives and associated producers in order to present the results of the study. In these meetings, the results were presented in Power Point and, soon after, a round of discussion took place with the associates and technicians, on the following dates and places:

Cooperative / Data / Attendance in the meeting

- Cooperative C 27/11 – 2 cooperative technicians and 9 producers
- Cooperative B 28/11 – 4 cooperative technicians and 6 producers
- Cooperative A 05/12 – 3 cooperative technicians
- Cooperative D 06/12 – 3 cooperative technicians and 1 producer

The first three workshops took place following the presentation on the Project "Intercitrus 2 – Elaboration of Climate Change Adaptation Plans for Small Producer Organizations in Brazil" where the results of the study of climate change perception among the cooperative members were presented, as well as the local adaptation plans elaborated. The fourth workshop took place only with the cooperative's technicians and the KS team.

The necessary actions emphasized by the Intercitrus project reflect the actions recommended by KS in the present study, with emphasis on the use of green cover in the orchards as well as the use of controlled-release fertilizers. Alternatives such as the use of green manures, greater use of organic matter and expansion of the use of biological products are also worth mentioning.

During the discussion round, the producers who gave their opinion (3 or 4 in each of the cooperatives that had producers present) understand the importance of adopting good agricultural practices, especially those mentioned above, although many still do not adopt them in practice on their properties.

The producers reported that the practices already used by them are:

- use of green cover,
- use of organic matter,
- adjustment of sprayers,
- preventive maintenance in the machines and,
- modernization of the fleet.

There is an experience with SAF at Cooperative B that is at the beginning and from the report,

The suggested practices that caught the attention of the group of producers and technicians are:

- use of controlled-release fertilizers,
- use of green cover (brachiaria),
- use of green manure,
- use of organic matter/composting,
- use of biological products,
- Water reservation on the property

Regarding the possibility of generating credits and their subsequent commercialization, there is interest and curiosity on the part of producers and cooperatives. As it is still a new subject and the perspective is medium and long-term, it is a subject that is discussed, but there is no real notion of values, deadlines, etc.

Suggestion: It is important to expand CLAC-Fairtrade's relationship with cooperatives to facilitate the possibility of more in-depth and constant practical studies, which present continuity and tangible results to producers and their families. Direct and indirect forms of remuneration are an incentive for their participation.

8. Conclusions

To consolidate the key outcomes and insights of the study, it is essential to summarize the findings:

- **Climate Change Impact on Farmers:** The study reveals that farmers and their families are already experiencing the tangible effects of climate change and extreme weather events.
- **Carbon Emission Impact:** Crop residue management, fertilizer use/production, diesel, and pesticides are identified as the primary contributors to carbon emissions in orange production.
- **Carbon Footprint Variation:** Notably, Cooperative C exhibits the largest overall carbon footprint due to its higher proportion of technified producers and more extensive orchard renewal. In contrast, Cooperative B demonstrates the lowest carbon footprint, attributed to a higher number of organic producers.

In summary of the study objectives:

- **Diversification in Family Farming:** Considering the unique context of Brazilian family farming, there is an opportunity to broaden the focus beyond primary production. Embracing diversified crops and activities, such as integration with animal farms, biodigesters, biogas power generation, solar panels installation, recovery of degraded areas, pasture restoration, and reforestation, could enhance efforts to reduce carbon emissions effectively.
- **Beyond Carbon and Water Footprints:** The study underscores considerations beyond production-related footprints. Oranges, known for exporting significant water, contribute to a substantial water footprint in agroecosystems, especially in orange juice production. Additionally, while the carbon footprint of orange agricultural production can be optimized, significant emissions occur in subsequent stages, emphasizing the impact of fuel usage in juice processing and energy needs for transportation and refrigeration.

<table>
<tr><th colspan="2">ECONOMIC ASPECTS</th></tr>
<tr><td rowspan="2">Objective: To estimate the costs of compliance (with FT standards and legal requirements) and the advantages of scaling up and extending agroecological practices, biodiversity criteria, and the use of the Cool Farm Tool or other appropriate tools for local farmers to improve livelihoods.</td><td>Hypothesis: The implementation of agroecological practices and biodiversity criteria may result in reduced costs and increased profitability for farmers.</td></tr>
<tr><td>Conclusion: It is possible and very likely that the introduction and implementation of agroecological practices can result in better productivity per area, and increased profitability for farmers. However, it is necessary to have a follow-up over time to confirm this hypothesis with certainty.</td></tr>
</table>

ECONOMIC ASPECTS	
Objective: Is there a willingness at the level of Producer Organizations (POs) or farmers to address carbon reductions or evaluate the option of producing carbon credits, for example, in order to diversify income? If not, what are the reasons?	**Hypothesis**: The willingness of producers to participate in carbon reduction initiatives may depend on economic incentives and technical support.
	Conclusion: The study reveals that most producers have a keen awareness of the evolving impacts of climate change, particularly its direct implications on orchard phytosanitary conditions. While many employs empirical measures to address these challenges, the agricultural sector encounters significant hurdles in embracing changes to production systems that may not yield immediate financial gains. The citrus industry, in particular, grapples with substantial market fluctuations and the pervasive threat of greening disease, leading some producers within the study sample to contemplate orchard eradication. Consequently, initiatives aimed at reducing greenhouse gas emissions pose a formidable challenge and necessitate a precursor in the form of heightened awareness among producers, coupled with insights into prospective business opportunities. Addressing the carbon issue should adopt a holistic approach, encompassing projects or actions that extend beyond individual orchards to encompass entire properties and even cooperative endeavors. This broader perspective is essential, shifting the focus from solely orange production to a more comprehensive strategy for sustainable agricultural practices.
DECARBONIZATION	
Objective: What is the amount of carbon emissions estimated with the Cool Farm Tool?	**Hypothesis**: The use of the Cool Farm Tool may reveal the amount of carbon emissions associated with orange production in southern and southeastern Brazil.
	Conclusion: With the use of the Cool Farm Tool, it was possible to estimate emissions per hectare and ton of oranges in the four cooperatives that were part of the study. It is important to remember that the Cool Farm Tool does not offer (at the time of the study) an assessment focused on oranges and that "tree crop" was used. An alternative to make this data more realistic is to update this information when there is a possibility of making specific estimates for citrus/oranges.
Objective: Are there possibilities for carbon reduction and sequestration in the selected cooperatives and in what quantity?	**Hypothesis**: Producer cooperatives can implement measures to reduce carbon emissions and sequester carbon, contributing to climate change mitigation.
	Conclusion: It is possible to raise awareness and adopt better agricultural practices with carbon reduction and sequestration in mind, as described in this study. Once again, we emphasize that the opportunities can be expanded if we look at the properties as a whole and not just at the production of oranges.

DECARBONIZATION	
Objective: What would be the estimated costs of all the interventions/instruments mentioned above for smallholder farmers/cooperatives?	**Hypothesis**: The implementation of carbon reduction and water management practices may involve costs that need to be estimated to assess economic viability.
	Conclusion: It is evident from the beginning of this study that the cost of inaction outweighs any investment made to improve recommended agricultural practices and agroecosystems. This underlines the urgency and importance of proactive measures, highlighting that the potential losses associated with neglecting necessary improvements far outweigh the initial investments required. Some of the costs raised by KS and commented in the previous chapter show that the implementation of some practices such as green manure and water reservation require low to moderate investment and producers can have access to bank financing.
COOL FARM TOOL	
Objective: To evaluate potential and possibilities for reducing carbon emissions.	**Hypothesis**: The use of the Cool Farm Tool may identify opportunities to reduce carbon emissions in orange production.
	Conclusion: The Cool Farm Tool serves as a valuable instrument for pinpointing emission reduction opportunities. However, it is essential to acknowledge certain limitations, as outlined in biases. Additionally, the Cool Farm Tool currently lacks a dedicated option for citrus cultivation. Moreover, there is a crucial need to enhance the tool's capability to estimate emissions resulting from changes in land use with a higher level of granularity. The existing tool permits the input of only one change in land use, whereas many growers undergo multiple changes over time. Addressing these aspects would contribute to a more comprehensive and nuanced assessment of emissions in the context of citrus cultivation.
Objective: To evaluate carbon sequestration opportunities and whether it would be possible to use carbon sequestration as an opportunity to generate carbon credits.	**Hypothesis**: The identification of carbon sequestration opportunities can pave the way for the generation of carbon credits, creating a new source of income for producers.
	Conclusions: Embracing the recommended actions for carbon reduction and sequestration is a feasible and viable path for all producers. However, success on this journey requires meticulous planning, technical oversight, investment, and a dedicated timeframe. The essence lies in consistently gathering inputs throughout the year and maintaining commitment to ongoing improvements. This approach lays the groundwork for realizing reductions, sequestration, and the potential to generate carbon credits over time.

COOL FARM TOOL	
Objective: To analyze the water footprint and opportunities for water management, water retention, and other opportunities to mitigate the effects of frequent droughts in Brazil.	**Hypothesis**: Water footprint analysis may reveal ways to better manage water and address the challenges of frequent droughts.
	Conclusion: the water footprint was not generated by Cool Farm Tool, as this data is not available for "Tree Crops". Despite not having numerical data of water footprint, the perception of this study regarding field visits, conversations with producers and irrigation quantification is that although the perception of changes in the water system, the producers, in general, are still not dependent on irrigation to produce. Thus, actions aimed at maintaining water availability, more efficient use of water and the possibility of retaining water in the soil and rainwater retention, is well accepted by producers and has more accessible cost for implementation.
Objective: What is the estimated water footprint and what opportunities for water management, water retention or other ways to mitigate the effects of frequent droughts in Brazil exist?	**Hypothesis**: Estimating the water footprint will provide valuable information for effective water management and mitigation of drought impacts.
	Conclusion: the water footprint was not generated by Cool Farm Tool, as this data is not available for "Tree Crops". Despite not having numerical data of water footprint, the perception of this study regarding field visits, conversations with producers and irrigation quantification is that although the perception of changes in the water system, the producers, in general, are still not dependent on irrigation to produce. Thus, actions aimed at maintaining water availability, more efficient use of water and the possibility of retaining water in the soil and rainwater retention, is well accepted by producers and has more accessible cost for implementation.

Recommendations

Based on the findings and conclusions presented in the study, the KS team recommends the following future actions to enhance and broaden the process of emissions reduction. It is essential to note that these recommendations are general and need to be assessed for each cooperative, considering its specific context and feasibility:

- **Expand Information and Educational Processes:**
  - Facilitate access to information on emissions, climate change, and mitigation actions through the creation of booklets, pamphlets, mobile applications, field days, dynamics, exchanges of experiences, case studies, and other accessible formats.
- **Stimulate and Showcase Participation:**
  - Find innovative ways to motivate producers and their families, emphasizing the importance of their involvement in cooperative and partner sustainability initiatives.
- **Practical Engagement for Technical Staff and Producers:**
  - Engage technical staff and producers in practical demonstrations showcasing the benefits of implementing recommended actions and maintaining necessary information (field notebook, invoices, complete notes, etc.).

- **Promote Documentation and Record-Keeping:**
  - Encourage farmers and their families to maintain a detailed field notebook recording all operations and products used throughout the year. Emphasize the importance of keeping a folder with invoices for pesticides, fertilizers, equipment, and energy bills.
- **Highlight Economic Viability and Benefits:**
  - Demonstrate the economic viability of recommended actions, emphasizing their role in income diversification, job creation, sustaining rural families, and maintaining agroecosystem balance.

In addition, Fairtrade has already initiated promising programs, as reported in the Fairtrade Juice Bulletin of March 2019. This program, funded by Fairtrade's Strategy for Juices, involved 16 properties from four Fairtrade cooperatives: Cooperative C (SP), Cooacipar and Cooperative A (PR), and Cooperative B (RS), in collaboration with the company FARMATAC. The program included georeferencing the properties, monitoring all activities, and annual planning of activities and expenses. Post-pilot, eight properties continued to follow the annual plan and maintained records, demonstrating positive outcomes, especially in families where women and children actively participated in the project.

As evident, producers and cooperatives can extend such collaborative efforts to involve other producers within their networks or different regions, fostering the reduction of production costs and an increase in profits. Numerous actions and strategies proposed throughout this chapter need not only dedicated time but also financial resources for effective implementation. As previously highlighted, specific lines of credit are available for low-carbon agriculture. Therefore, it is imperative to build partnerships and establish connections with local public financial institutions, ensuring the effective dissemination and broadening of access to the credit lines provided by the ABC Plan.

A concluding recommendation pertains to the Cool Farm Tool methodology. To enhance its applicability and accuracy for Brazilian family producers in future studies, consider the following adjustments:

Adjust Cool Farm Tool Parameters for Citriculture:

- Incorporate parameters within the Cool Farm Tool that specifically differentiate citriculture from general "tree crop," recognizing the unique characteristics and emissions profiles associated with citrus cultivation.

Expand Cool Farm Tool Evaluation to the Entire Scope of the Farm:

- Introduce an option within the Cool Farm Tool to assess the entire farm rather than focusing solely on the orange production area. This adjustment would be particularly valuable for small family farms, which often feature diversified and integrated productions. Such an approach could serve as a more comprehensive measure, considering the counterbalancing effects of emissions across various agricultural activities within the farm.

Strategies

The KS team suggests the following potential strategies to mitigate the carbon and water footprint in orange juice production. It is crucial to underscore that the strategies outlined below are general, and their practical suitability for each specific case should be thoroughly evaluated by farmers, their families, and cooperative technicians.

Footprint or Emissions	Activity	Recommended strategy	Investment Grade
Carbon	Decrease diesel consumption	Preventive maintenance and adjustment of machines and implements	Low
		Staff training	Low
		Equipment Replacement	High
		Systematize the productive areas (paths, carriers, contour farming, water drainage, etc.)	High
		Planning and systematization of activities	Low/Moderate
	Mitigating emissions	Establish Integrated Pest Management (IPM)	Low
		Replace pesticides to organic products	Low/Moderate
		Implement no-till (direct seeding)	Low/Moderate
		Improve crop residues management	Low/Moderate
	Increase carbon sequestration	Offer possibilities for integrating crops, livestock, and forestry, such as combining orange cultivation with teak trees. Explore intercropping options with timber tree species like Jequitibá (Cariniana legalis), Ipê (Handroanthus heptaphyllus), Peroba (Aspidosperma polyneuron), and Louro (Laurus nobilis), and consider incorporating service species like Ingá (Inga edulis), Mulungú (Erythrina verna), Eucalyptus, and Gliricidia.	Moderate
		Implement agroforestry systems	Moderate
Nitrous oxide	Decrease the consumption of urea and other nitrogen fertilizers	Replacement of normal nitrogen fertilizers with slow-release encapsulated fertilizers	Moderate
		Green manure *cajanus cajan and canavalia ensiformis*).	Low/Moderate
		Biological nitrogen fixation	Low
Water	Minimize Water Wastage	Preventive maintenance of pumps and faucets	Low
		Sprayer adjustment	Low
	Decrease water consumption	Renovation of the orchard with varieties resistant to water stress	Moderate/High
	Increase water reserves	Construction of dams and reservoirs	High
		Rainwater harvesting and construction of cisterns	Moderate
	Maintain soil moisture	Use of vegetation cover (e.g. brachiaria)	Moderate
	Reduce pollution	Installation of biodigester septic tanks	Low/Moderate

Some of these recommended actions have their own lines of credit and financing, and producers can access them through banks and credit unions, etc. We highlight:

- The credit lines of the ABC Plan for the recovery of degraded areas, BNF – Biological Nitrogen Fixation, ICLF – Crop-Livestock-Forest Integration, etc.
- Lines of credit for the modernization of the fleet of tractors and machines – Moderfrota Program.

In addition to the recommendations mentioned earlier, it is advisable for properties and cooperatives to consider obtaining certifications demanded by the market, such as Rainforest Alliance, SAI-Platform, and Organic certifications. This approach is designed to enhance their comprehension of sustainability issues, fortify their management systems, refine operational procedures, and widen the array of options for mitigating environmental impacts through reductions and sequestration.

More robust and complex systems aimed directly at carbon certification, such as the “Gold Standard”, also require the support and organization of the cooperative to be obtained, as they require considerable areas to be economically viable. To make projects with small producers viable, the ideal is to form groups of several producers until the estimated credit generation reaches a minimum limit of economic viability.

Certification costs[9] vary depending on the type, scale and complexity of the project. Fees paid to Gold Standard include an emission fee for products such as carbon credits or renewable energy labels, plus a flat fee for tracking in the public Impact Register.

Additional costs come from project implementation, third-party reviews by approved validation and verification bodies, and certification review fees paid to SustainCERT, the official certification provides the Gold Standard for the Global Goals.

Finally, another point to highlight for the reality of small orange producers is to think about the property as a whole, as many production actions are already carried out in an integrated manner by them. Regenerative agriculture finds an ally at this point and producers, in addition to being able to obtain other relevant certifications, can open new markets for their products. Added to this, the recovery of degraded areas and the reforestation of priority areas can, in addition to guaranteeing the resilience of the agroecosystem, ensure that REED projects are integrated.

It is essential to acknowledge that this study does not exhaust the subject, and there may be existing possibilities that haven't been identified, along with potential developments over time as advancements in the state of the art continue. Complementing the strategies proposed earlier, various actions developed by the private sector or initiated by Fairtrade itself have been identified. These actions are presented below as potential examples to be considered for replication.

Examples of possible strategies developed by Fairtrade itself in Brazil

EXAMPLE 1: Embracing Regenerative Agriculture and Organic Production in Fairtrade Coffee Farming

In the region of Paraguaçu/MG, the Mixed Agricultural Cooperative of Paraguaçu (COOMAP) has embarked on an innovative initiative within the crops of its cooperative members – the transition to regenerative agriculture. Recognizing the escalating environmental concerns and the growing demand within the Fairtrade market for environmentally conscious practices, the cooperative enlisted the expertise of a consultant to guide the implementation of this sustainable approach, particularly in response to the suspension of glyphosate usage.

The adopted management strategy involves intercropping forage plants amid the main crop and employing biological products. This approach aims to enhance plant resilience against pests and diseases, optimize the effectiveness of applied fertilizers, and foster less compacted soil.

With a membership of approximately 850 farmers, of which 60% to 70% have already embraced this regenerative management, COOMAP anticipates a surge in productivity, cost reduction, increased organic matter, soil coverage, minimized water stress, and improved weed control. Leveraging funds from the Fairtrade Premium, COOMAP subsidizes the acquisition of cover crop seeds. The implementation cost per hectare ranges from R$ 300 to R$ 400, with the cooperative covering around 50% of this amount.

[9] Further details and information can be found at: https://www.goldstandard.org/take-action/certify-project

EXAMPLE 2: The Fairtrade Award Stimulates Innovative Projects in Brazilian Coffee and Citrus Farming

From planting and cultivating to harvesting and marketing, completing the production cycle presents challenges for Brazilian farmers at each stage. While family farming faces disadvantages compared to larger producers, those involved in agro associations or cooperatives experience a different reality. Orange and coffee production organizations within the Fairtrade network in Brazil benefit from guidance in planting, production, and marketing.

Supported by the Association of Fairtrade Producer Organizations of Brazil (BRFAIR) and the Latin American and Caribbean Coordinator of Small Producers and Fairtrade Workers (CLAC), small farmers receive assistance in enhancing productivity and product quality. They gain access to international markets and additional benefits, significantly improving the quality of life in rural areas.

One notable advantage is the Fairtrade Premium, an extra amount paid for certified products. Organizations receive this award for Fairtrade-marketed products, and it is collectively invested in improving living conditions for families and communities where these foods are produced. The utilization of this resource varies across organizations, with decisions made collaboratively by cooperative members and associates.

Fairtrade promotes fair and equitable trade relations among all stakeholders – producers, buyers, and consumers. To achieve these goals, Fairtrade certification ensures a minimum price for the product, covering production costs and providing decent remuneration for those involved in the system.

The Agricultural Cooperative of Organic Producers of Nova Resende and Region (COOPERVITAE), with the received award, constructed photovoltaic plants. The solar-generated energy is distributed among cooperative members and philanthropic entities in Nova Resende (MG). The project, costing € 118,339, can expand with an increasing number of cooperative members. Without the award, executing this and other cooperative projects would be challenging.

On average, each cooperative family saves € 16.13 per month on energy bills, and each entity receives a credit of about € 112.90.

Examples of possible strategies developed by the Private Sector

EXAMPLE 1: Citrus Sustainability Program by Cooperative C in Partnership with Citrosuco – Nurturing a Thriving Citrus Industry

Cooperative C's collaboration with Citrosuco aims to fortify family farming and uphold Fairtrade-certified production through the Trilha Program – Together for Sustainable Citriculture. Launched in 2016, this program focuses on concrete actions to enhance sustainability across the entire value chain. Guided by the path to sustainable certification and dedicated support for family farming, the program strives to ensure that 100% of the third-party supply aligns with international standards.

The partnership with Citrosuco actively promotes the adoption of sustainable production practices among citrus growers of various scales. This comprehensive program provides guidance to partners on international best practices, emphasizing increased productivity, superior fruit quality, responsible utilization of natural resources, and the establishment of conducive working conditions. The journey began with the Agrochemical Monitoring Program in 2012, reinforcing dialogues with citrus growers to ensure product safety and consumption. By 2014, the program achieved Fairtrade certification for the initial farms.

To expedite the progress of citrus growers, Cooperative C receives funds from the Fairtrade Premium. These funds are allocated for enhancing productivity, managing and legally adapting properties, ensuring the health and safety of workers, environmental conservation, and other crucial aspects. The system's design facilitates the retention of family farmers in the industry through cooperative efforts. In total, the certification encompasses 159 properties in the Bebedouro region (SP), guaranteeing families a minimum price for their citrus fruits.

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