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IMPACT FINANCE FOR CLIMATE-SMART AGRICULTURE: COST-BENEFIT ANALYSIS OF INITIATIVES IN LATIN AMERICA

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Abstract

This thesis investigates the systematic risk-reduction potential of an impact investment initiative aimed at enhancing climate resilience and socio-economic conditions of smallholder farmers in Latin America. By integrating Carbon Removal Units (CRUs) as collateral and increasing revenues to strengthen repayment capacity, the initiative seeks to mitigate credit risks effectively. Smallholder farmers in the region face significant financing gaps due to perceived risks and inefficient rural banking systems. This initiative addresses these challenges by linking plantation renewal with the adoption of Climate-Smart Agriculture (CSA) practices, which improve biodiversity, soil health, and productivity. Agroforestry systems implemented under the project generate CRUs, providing an innovative form of credit guarantee that improves farmers' access to financing while reducing risks for lenders. The research serves as a financial model for an investment vehicle from FairCapital, designed to provide a valuable risk-return profile, sustainable environmental benefits, and a strong social impact on smallholder farmers' conditions.

Using a mixed-methods approach involving two qualitative and quantitative case studies in coffee crops, the research provides a cost-benefit analysis and assesses credit risk, highlighting not only the economic benefits but also the essential risk mitigation strategies intrinsic to the project. The results show an increase of 9.3% in smallholder farmers' revenues over a 20-year period when the project is implemented. Moreover, the risk is significantly mitigated as the additional collaterals generated in the form of CRUs represent 39.8% of the loan amount – or 51% of the interest's value – while the increase in revenues strengthens beneficiaries' repayment capacity.

Overall, the thesis highlights the significance of capital provision in promoting sustainable agriculture and climate resilience in developing economies. The results indicate in favor of project adoption, as the economic, environmental, and risk mitigation benefits significantly outweigh those of current practices. These findings underscore the potential of innovative financing mechanisms to drive sustainable development in agriculture and address financing gaps in developing economies. Moreover, it equipped FairCapital to expand its knowledge and offerings beyond short-term harvest financing by demonstrating the financial benefits of integrating plantation renewal, CSA practices, and CRUs as collateral, enabling a pilot project and scaling plans.

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List of Abbreviations

CDM	Clean Development Mechanism
CRU	Carbon Removal Units
CSA	Climate-Smart Agriculture
ETS	Emission Trading Scheme
EU	European Union
EUR	Euros
FCAA	FairCapital Agroforestry Accelerator
GHG	Greenhouse Gas
H_0	Baseline scenario – Current land-use
H_1	Project scenario – Project sustainable land-use
Solidaridad	Fundación Solidaridad Latinoamericana
tCO2e	Tons of carbon dioxide equivalent
USD	United States Dollar

1 Introduction

The global community stands at a critical stage, with the challenge of feeding an ever-expanding population estimated at 9.7 billion by 2050, while simultaneously addressing the pressing need to mitigate and adapt to climate change (World Economic Forum, 2022). Climate-smart agriculture (CSA) emerges as a strong solution, especially in countries that are the cellars for food production to nourish the global population, and reduce greenhouse gas emissions (Rotondaro et al., 2020).

Smallholder producer organizations in Latin America face significant economic and environmental challenges that threaten their livelihoods and the long-term sustainability of their communities. The increase in temperatures directly affects crop viability, reducing the availability of suitable cultivation areas and increasing the sensitivity of existing crops to climate-related stressors (Iturrioz & Arias, 2010). Areas such as the Andean regions, Central America, and the Amazon basin are experiencing accelerated deforestation and biodiversity loss, with critical ecosystems threatened by agricultural expansion, climate-driven land conversion, and unsustainable farming practices (FAO, 2020).

Despite the growing global demand for agricultural commodities such as coffee and cocoa, smallholder farmers often face low returns. Aging plants, inefficient farming practices, and escalating input costs diminish productivity, keeping low-profit margins (Fundación Solidaridad Latinoamericana, 2022). Monoculture cropping exacerbates the problem by creating vulnerable agricultural landscapes. Without crop diversification, these systems are highly susceptible to disease outbreaks, leading to crop failures that result in soil degradation and leave farmers economically vulnerable. With limited alternatives, some farmers might abandon degraded lands, converting them into cattle pastures or seeking other unsustainable uses that further accelerate environmental issues such as deforestation and biodiversity loss (Fundación Solidaridad Latinoamericana, 2022).

In rural areas across Latin America, smallholder farmers face significant barriers to accessing capital. The local banking systems in these regions are often inefficient, particularly in remote agricultural areas where financial services and credit options for smallholder farmers are scarce. This creates a financing gap: farmers lack the resources to invest in necessary improvements like plantation renewal, soil fertility, crop diversification, agroforestry systems, or other CSA practices. Investors, in turn, perceive these markets as high-risk due to limited track records and lack of bankable projects (UNEP, 2020), but also factors like weather volatility, crop disease, and limited collateral options. As a result, financing for sustainable agriculture remains scarce, despite a growing global demand for climate-smart and sustainable food production.

Without adequate financing, these farmers are unable to address the issue and adopt CSA practices that could protect them against climate-induced stresses and regenerate the ecosystems on which they rely. Realizing the potential of CSA requires significant financial resources and innovative financing mechanisms that align the interests of investors with the needs of sustainable land use. Impact finance is a way to conduct capital into agriculture initiatives that put priority on environmental and social issues while keeping financial profitability. However, low-carbon investments, which are more capital-intensive, often have high risk. This is even more the case in developing countries. As private investment decisions are largely based on the risk-return profile, two central levers exist for climate policy; increase the returns or decrease the risk of low-carbon investments, also referred to as de-risking risks (Schmidt, 2014). In the case at hand, another central lever could lie in the potential increased impact of those investments.

This research aims to explore a specific response of the impact investing sector to the capital expenditure needs of smallholder farmers in developing economies. It investigates how an impact investment solution can practically encourage the implementation of strategies that not only enhance financial sustainability but also catalyze the growth of CSA projects, by examining the following research question:

How does the addition of carbon credits impact the risk-return profile of Climate-Smart Agriculture investments?

By examining the FairCapital Agroforestry Accelerator (FCAA) example, the research offers practical insights into how specific investments can respond to the above-mentioned financing gap. The FCAA offers an effective approach to address this gap by reducing investment risk, while simultaneously creating a positive social and environmental impact. It will be implemented as a dedicated financial vehicle designed to support smallholder farmers in Latin America in renewing their plantations while transitioning to CSA, with a strong focus on the implementation of agroforestry systems. This aims at increasing smallholder farmers' revenue and economic stability, promoting soil conservation, preventing land degradation, and enhancing local biodiversity. Moreover, agroforestry systems not only improve climate resilience and adaptation but also act as a climate mitigation mechanism by sequestering carbon from the atmosphere, generating Carbon Removal Units (CRUs) that offer an additional income source and strengthen financial stability (FAO, 2023a).

By leveraging CRUs as collateral, the FCAA decreases risk and cost of capital, making sustainable agriculture investments in rural Latin America more attractive to investors and increasing farmers' access to finance. This system allows producers to both increase productivity and earn alternative income by trading CRUs, helping them combat climate risks and access sustainable financial resources.

2 Literature review

2.1 Carbon Markets Overview

2.1.1 Internalizing an Externality

Reducing greenhouse gas (GHG) emissions is increasingly prioritized in the global fight against climate change. Pricing carbon emissions has been widely discussed as a tool in climate policy over recent decades (Boyce, 2018). Previously, GHG emissions were not factored into the cost of production for corporations, resulting in no economic incentives to reduce them. However, as the impact of the greenhouse effect became better understood, efforts to control and reduce emissions grew. The introduction of carbon markets establishes a financial cost for emitting GHGs, aligning with the polluter pays principle (Vitelli, 2023).

Before the 1960s, controlling excessive pollution mainly relied on Pigou's tax on polluters for each unit of emissions (Calel, 2013). Coase (1960) proposed establishing property rights, allowing market mechanisms to set prices based on competition among buyers and sellers (Dales, 1968). Subsequent developments, such as flexible regulations through the Clean Air Act in the 1970s and various protocols in the 1980s and 1990s, paved the way for carbon markets in the 21st century (Calel, 2013).

Businesses operating under carbon markets face a financial tradeoff between emitting GHGs and investing in emission reduction to avoid costs (World Bank Group, 2023). Meeting the Paris Agreement objectives often involves carbon dioxide (CO_2) removal to limit climate change, compensating for temporary carbon budget exceeds, and offsetting expensive-to-abate GHG emissions (Boyce, 2018).

2.1.2 Compliance Markets

Various flexibility mechanisms under the Kyoto Protocol enabled emission reductions globally. The first period 1997-2004 operationalized the Clean Development Mechanism (CDM) and Joint Implementation, which gave rise to pilot activities in different areas by the public sector, and the official approval of baseline and monitoring methodologies

(Michaelowa et al., 2019). It allowed to use credits from emission reduction projects in developing countries to meet developed countries' commitments under the Kyoto Protocol (Hepburn, 2007).

From 2005, carbon markets expanded significantly, with mechanisms like Cap-and-Trade systems becoming prominent under national or international law. These approaches aim to limit total GHG emissions, with the Cap-and-Trade concept setting quantified emission reduction targets and issuing allowances accordingly (Anjos et al., 2022). The fundamental concept of a Cap-and-Trade system is to set a quantified target to reduce GHG emissions. From this specific target, a number of emissions allowances – or permits – is derived and firms must compete to obtain the legal permission to emit GHG. The transition to auctioning is taking place progressively intending to come to an end by 2030 in all industries (Vitelli, 2023). This contributes to incentivizing investment in low-carbon alternatives, the finality of the system being its disappearance as GHG emissions reach zero (Ellerman, 2009).

2.1.3 Voluntary Markets

In addition to these markets, there has been an explosion of interest in offsets that are traded voluntarily and on a separate market (Kreibich & Hermwille, 2021). Carbon credits, which can be bought by anybody, but mainly corporates, represent a reduction made in one place which can counterbalance the GHG emissions made somewhere else. Most scenarios for meeting the Paris Agreement objectives include CO2 removal as a necessary tool to limit climate change, which can compensate for temporary carbon budget overflow and offset GHGs that are costly to reduce (IPCC, 2022). Unlike the Cap-and-Trade markets, there is no limit to the number of credits that can be generated. Corporate buyers aim to reduce their emissions by buying credits based on voluntary and unilateral targets, but compliance demand could become more important (World Bank Group, 2023). The best-practice scenario aims at offsetting only after internal reductions have been made and to compensate for any inevitable reductions. As voluntary markets enable more direct finance of small community projects, they may be a valuable alternative solution for encouraging sustainable development (Hepburn, 2007).

Projects are calculated following precise methodologies dictated by international standards. Those are responsible for establishing precise methodologies governing the parameters of projects and assessing the GHG emission reductions. The projects also go through an independent auditing process to calculate the reductions.

In the current conditions, pricing is based on market dynamics obeying supply and demand, on project cost, and on the value delivered (Gold Standard, 2023). Yet, the high heterogeneity found in the characteristics of carbon credits is reflected in pricing. The type of the underlying project is determinant, along with the volume of credits traded, the project geography, its vintage, and the delivery time. Removal credits are usually traded at a premium compared to avoidance credits, reflecting a higher level of investment required but also a higher demand (Favasuli & Vendana, 2021). The prices of carbon credit should "mirror the true social cost of carbon and the economic value provided in additional impacts while using the power of markets to help deliver this most cost-effectively" (Gold Standard, 2023). Currently, the price of a carbon credit can widely differ, from a few U.S. Dollars (USD) per tCO2e to USD 15-50 per tCO2e for afforestation or reforestation projects, to USD 100 or even USD 300 per tCO2e for tech-based removal projects (Favasuli & Vendana, 2021).

2.1.4 Future & Challenges

Carbon markets have gained more and more importance in the past two decades. Voluntary markets are especially getting value in the corporate world, where companies are targeting a clear positioning on environmental matters, while compliance markets are spreading geographically, and getting increasingly constraining for companies lately.

2.1.4.1 Global-Scale Market

A central prerequisite for the viability of carbon credit markets to tackle climate change is its uniformity on a multinational level. Anjos et al. (2022) find that establishing a common carbon credits market could reduce significantly global GHG emissions while upholding national autonomy and setting national policies. Such markets help motivate corporates to maintain sustainable standards if emissions are not voluntarily reduced by altering their operations, governments could enforce the obligation through national policies and increase the costs of carbon emissions, thus making the bridge with compliance markets (Anjos et al., 2022).

2.1.4.2 Carbon Pricing

Yet, the future development of carbon markets is highly dependent on their effectiveness and consequently on their price. The fight against climate change can only be effective if the cost of internalizing the externality created by GHG emissions is high enough. Bakker et al. (2007) projected that the potential for GHG reductions through carbon credits supply until 2020 is large under the CDM in developing countries. Its potential however still depends strongly on future eligibility criteria, such as for avoided deforestation, and the adoption rate of technologies (Bakker et al., 2007). The demand side is also growing at a fast rate but to a lesser extent, which derives a market with a higher supply and the partial explanation for the relatively low carbon credit price (Vitelli, 2023).

When a global-scale carbon market exists, the goal reached, that is, the achievement of the net zero emission pledge, also highly depends on the price level of carbon (Verbruggen, 2021). A higher carbon pricing is determinant to scale up carbon reduction and removal. Currently, the majority of the mechanisms are undervalued and pay too little to induce portfolios of low and negative carbon projects to support the achievement of net zero (Hickey et al., 2023). Carbon trading in its current state inclines financial flows to the cheapest emission reductions (Hepburn, 2007).

2.2 Investing for Impact

2.2.1 Driving Change

A growing interest in impact investments has been observed in recent years, reaching USD 1 trillion under management in 2022 (GIIN, 2022). The underlying motivating factors are multiple, from the fighting against inequalities to the elimination of gender gaps, passing by the fight against climate change which is raising more and more concerns, and thus interest (WEF, 2024). Yet, the investment range proposed by financial institutions is wide, but their impacts largely differ. It is therefore central to evaluate the underlying investments and reallocate capital efficiently based on transparent information on its social value creation (Green & Roth, 2021).

Impact investing is primarily concerned with the positive, quantifiable outcomes it creates in addition to a financial return (Clivaz, 2022). The impact of an investment is a function of (1) the impact of the asset supported, typically the impact a company has on a world issue, and (2) the contribution made by the investor to achieve an impact, typically the impact of new capital contributions from the investor on a company (IMP, 2023). Yet, a central challenge is the measurement of the effects, as those are not always precisely quantifiable, and because the impact of a factor on a certain outcome can only be inferred, and on this basis future similar impacts predicted (Kölbel, 2023).

Several distinct strategies are commonly pursued by impact investors. The objective is to support the achievement of specific societal or environmental goals for businesses or organizations. The most popular forms of change through the allocation of capital are either by targeting companies and activities contributing significantly to the United Nations Sustainable Development Goals (UN SDGs), and enabling their growth, or by encouraging companies to do better where there is room for improvement in their activities, either by engaging actively or divesting (Robeco, 2022) (Heeb & Kölbel, 2020). Both strategies can thus be pursued with different mechanisms; signaling that impact matters, active engagement, the growth of new or undersupplied capital markets, and the provision of flexible capital, each of which can be used individually or in combination (IMP, 2023). The next section will emphasize the provision of flexible capital mechanisms in developing markets, as a relevant focus of this thesis.

2.2.2 Flexible Capital Provision

2.2.2.1 A Need for Smallholder Agribusiness in Developing Economies

Smallholder Agribusinesses in developing economies are often faced with a financing gap and typically have little access to international or local financing possibilities (Rotondaro et al., 2020). The insufficient availability of collateral and weak institutional framework, which affects the enforceability of security against credit, the land and property rights, and the high administrative costs make such businesses suffer from a lack of credit access (Nekesa & Mukabi, 2019). Those are generally confronted with high upfront capital expenditures to scale up production and increase revenues, and thus need access to flexible financing to counter the inhibiting effect on their activities. Impact finance is a way to conduct capital into agriculture initiatives that put precedence on solving environmental and social issues while keeping financial profitability.

Changing the financing conditions of those businesses that typically require up-front and seasonal financing is therefore a must to enable their growth. On the one hand, they should be given access to finance, while on the other they should be provided capital with better conditions than the ones that could be obtained from preference-neutral investors (Kölbel et al., 2020).

2.2.2.2 In Climate-Smart Agriculture

Private investments combining land restoration with sustainable production activities are still limited due to high perceived risks, limited track record, and lack of bankable projects (UNEP, 2020). Climate change adds a layer of complexity for smallholder farmers in immature markets but could also be an opportunity for them to ensure food security in a changing climate, and for impact investors to provide impactful capital.

CSA aims at transforming current agricultural practices and reorienting systems to ensure food security considering climate change effects (FAO, 2023b). Three main objectives are pursued by CSA; sustainably increase agricultural productivity and incomes, adapting activities and building resilience to climate change, and reducing and/or removing GHG emissions (FAO, 2023b). The adoption of CSA practices as reforestation projects, agroforestry, or transformation to organic production needs impact investing in innovative investment setups as it requires upfront capital expenditures and a first-mover approach mindset (Rotondaro et al., 2020).

Forestry

Forestry projects are central elements in the fight against deforestation and climate change as a nature-based solution to capture carbon from the atmosphere (Vitelli, 2023). Reforestation is the establishment of forest on land that was deforested since a certain point in time, usually for a period of 10 years, while afforestation refers to the planting of forest on land that has not been forest previously (FAO, 2008). Forestry initiatives allow additional income streams for smallholder farmers, as those projects are eligible for carbon credit generation, while the timber production derived from forestry systems also represents long-term profitability and further income, in addition to its ability to hedge against inflation (Rotondaro et al., 2020).

Agroforestry

Agroforestry refers to a land-use system where trees or shrubs are intentionally used on the same land as crops in a specific spatial arrangement. It aims at diversifying and sustaining crop production for increased social, economic, and environmental benefits for land users, especially crucial to smallholder farmers as it can enhance their food supply, income, and health (FAO, 2023a).

The monoculture at a large scale has been stressing out the soil and negatively impacting micro-climates and land profitability. Compared to conventional agriculture, the production output is less volatile and less exposed to some risks such as diseases or natural hazard events, but also potential future environmental legal requirements when it comes to local climate-change risks (Rotondaro et al., 2020). Furthermore, it enables a higher revenue stream from land cultivation thanks to the higher profitability of a more diversified and rich soil in the long term. It also includes the same benefits of reforestation projects, namely complementary income streams from carbon credits under the same eligibility criteria, and from timber production, in addition to its inflation hedge ability.

Transformation to organic production

Organic production is an agricultural system that relies on ecosystem management rather than external agricultural inputs and considers the potential environmental and social impacts by eliminating the use of synthetic inputs, such as synthetic fertilizers and pesticides, veterinary drugs, genetically modified seeds and breeds, preservatives, additives, and irradiation (FAO, 2023c).

Transformation of agriculture practices to organic production aims at maintaining soil fertility and preventing pests and diseases, thus decreasing the volatility of income, and increasing productivity in the long term. While not directly eligible for carbon credit generation for additional income, transformation to organic production is sometimes encouraged by certain standards as the Fairtrade Climate Standard in comprehensive projects involving activities eligible for carbon credit generation, through the use of the Fairtrade premium to support the transformation (Fairtrade International, 2015).

2.2.2.3 Risks

One of the biggest challenges of impact investing is to overcome the higher risk for preference-neutral investors. Low-carbon investments are more capital-intensive, and the likelihood of a negative financial impact associated with the occurrence of a negative event is therefore higher (Schmidt, 2014). This is even more the case in developing countries. As private investment decisions are largely based on the risk-return profile, two central levers exist for climate policy; increase the returns or de-risk low-carbon investments (Schmidt, 2014).

The main risks identified by Rotondaro et al. (2020) when investing in CSA in developing economies have been clustered into five groups; environmental and climate change risk, infrastructure and supply-chain risk, financial risk, political, legal, and governance risk, and the “H factor” or human capital risk. Those can all harm investment and should be minimized.

In our case, environmental and climate change risk is central as the unpredictability of weather events, rainfall, or the increased aridity of land increases the risk of bad harvests (Rotondaro et al., 2020). The financial risk related to high upfront disbursements is also important and even increased for long-term loans in our case. The long-term character of the credits (6-9 years) translates into a higher financial risk and loss probability in subsequent years due to crop volatility and the lack of collateral compared to a single-period investment for harvest. What is more, agribusinesses in developing economies generally suffer from the non-enforceability of security against credit (Nekesa & Mukabi, 2019).

2.2.2.4 De-Risking

To address the above-mentioned types of risks, different de-risking strategies can be adopted with the objective of re-directing financial flows in CSA in developing economies. De-risking lowers the financing costs in two ways; financial and policy de-risking (Schmidt, 2014). Financial de-risking transfers large portions of the impact of a negative event to other parties, typically with risk insurance or the use of collaterals, which could address the risk of bad harvests and the medium-term financial risk of high upfront disbursement in our case. On the other hand, policy de-risking aims to remove barriers in the investment environment and improve local institutions, which in our case could serve to address the enforceability issue.

2.3 An Innovative Solution to De-Risk

2.3.1 The FairCapital Agroforestry Accelerator

Even though growing interest is shown by investors to drive positive change, revealing that the risk-return profile is not the only basis for private investors' decisions and that prosocial preferences play a role (Riedl & Smeets, 2017), some investors are more reluctant to trade lesser risks or higher returns for positive impact. In this case, a risk-return investment profile competing with traditional investments is needed. The FCAA aims to tackle this issue by lowering the risks associated with providing flexible capital in developing economies while enhancing financial sustainability for investees and advancing the goals of CSA by building resilience to environmental challenges.

The FCAA project seeks to support smallholder farmers in Latin America and Africa while combating climate change. Coffee producers are particularly impacted by climate change as coffee trees are extremely sensitive to temperature increases. The FCAA provides long-term loans to Fairtrade-certified farmer organizations for plantation renewal and transformation to CSA with an agroforestry approach, accompanied by reforestation projects. The program enables farmer organizations to provide loans to their members for these initiatives. The project improves their productivity while new plantations and an agroforestry approach contribute to fighting climate change by generating more carbon removal capacity, permitting the generation of CRUs.

The FCAA's investment thesis is that risk can be further reduced by using CRUs as loan collateral. The probability of loss with long-term agricultural investments increases in subsequent years due to crop volatility and the lack of collateral compared to single-period financing for harvest. While the long-term nature of the loans usually contributes to higher risk, the FCAA demonstrates their viability for plantation renewal and crop transformation despite the inherent risks of crop volatility and external factors. The generation of CRUs allows producers to receive alternative income by trading them, in addition to improved productivity, meeting the needs of rural communities. With the project's implementation, the generated CRUs are used as collateral, decreasing investment risk and thus, the cost of capital.

2.3.2 Structure

The structure of the financing facility is represented in Figure 1. The financing operates as follows:

1. Investors place funds in an investment compartment for each FCAA project, for a period of 6 to 9 years. FairCapital acts as a financial intermediary and grants long-term loans to Fairtrade-certified producer cooperatives after in-depth due diligence.

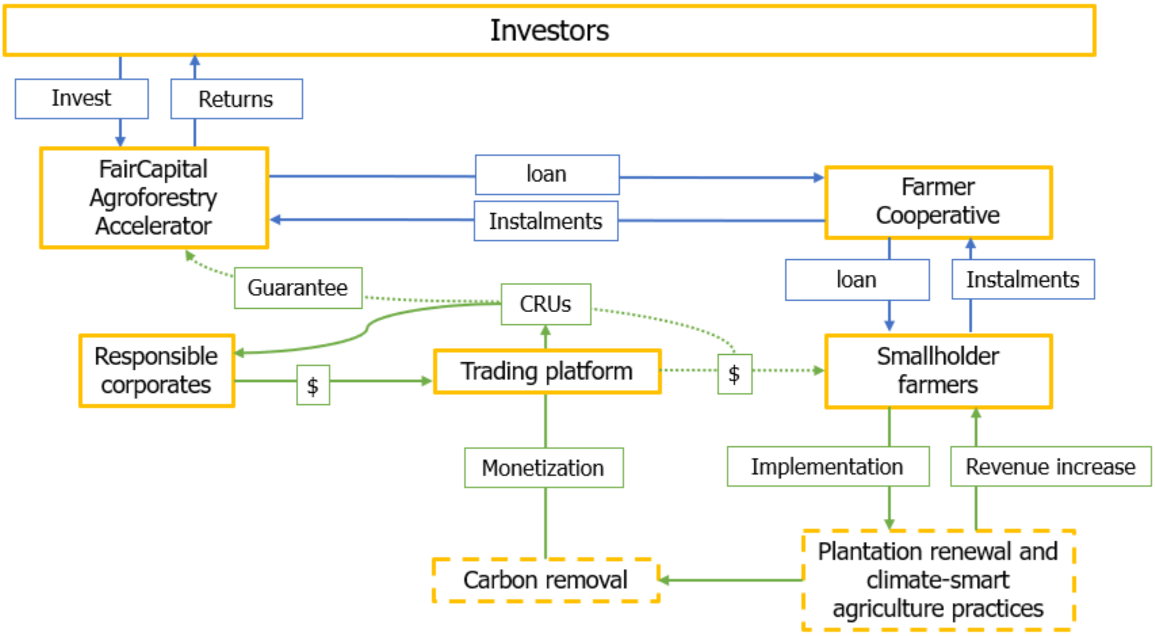
2. The cooperatives further lend the capital to its producer members, who implement the projects by using the funds to finance the land transformation. This encompasses the renewal of plantations and the implementation of CSA practices, typically the adoption of organic production and agroforestry systems implementation, as well as reforestation projects. This allows greater productivity and revenues from harvests and increased land health, while additional income is created by the production of timber and fruit products, along with organic premiums arising from the newly adopted practices.

3. The agroforestry and reforestation projects allow the removal of carbon from the atmosphere. After going through a verification process and a quantitative assessment of the amount of carbon sequestered, CRUs will be generated. The rights to payment remain with the producers, but they are used as collateral for loan repayment.

4. Producer organizations reimburse the FCAA based on an agreed repayment plan. The first three years of the loan are subject to a grace period, where amortization is not required as monetary benefits from project implementation arise at a later stage.

5. When the installments are paid according to the repayment schedule, the CRUs are generated and monetized via a trading platform, where responsible corporates are given the opportunity to balance their emissions. The end buyer previously reported all carbon emissions produced and provided a carbon reduction plan. He pays the CRU price on the platform, which ultimately reaches the producers after a commission for the platform and the project implementor is deducted. In the case of non-repayment of the loans, the rights to payment are transferred to the FCAA.

Figure 1. Vehicle Structure - FairCapital Agroforestry Accelerator. *Self-made figure (2024)*



3 Methodology & Data

3.1 Research Questions

The empirical part of this thesis is concerned with the answering of the following research question:

How does the addition of carbon credits impact the risk-return profile of Climate-Smart Agriculture investments?

3.2 Research Design

This exploratory research adopts a mixed-methods approach that involves a qualitative and quantitative case study. An innovative financing solution – the FCAAA – using CRUs generated by investees to mitigate credit risk and over-indebtedness, is studied. Two case studies are selected to assess the implementation of the project financed via the investment vehicle. Communications with key stakeholders (cooperatives in CSA projects and service providers for implementation) provide insights into the project impact, due diligence, and risk mitigation strategies.

The goals are to:

- Identify solutions to climate- and economic vulnerability among smallholder farmers provided by long-term financing.
- Examine the monetary benefits of a specific initiative for smallholder farmers.
- Investigate how innovative financing solutions can be used to decrease risks of investments for impact and attract capital for low-carbon investments.

3.3 Research Methods

The analysis is undertaken in three key steps:

3.3.1 Carbon Removal Units Estimation

To conduct CRU estimations for specific projects, the carbon methodologies from the United Nations Framework Convention on Climate Change (UNFCCC) "CDM AR-AMS0007 A/R

Small-scale methodology: Afforestation and Reforestation Project Activities Implemented on Lands Other Than Wetlands-Version 03.0" is employed as the foundational basis for calculating the CRUs generation of projects (UNFCCC, 2013).

The Clean Development Mechanism (CDM) operates under the Kyoto Protocol, enabling developed countries committed to carbon emissions reduction to implement projects sequestering a limited amount of greenhouse gases (max 16,000 tCO2eq/year) in developing countries (UNFCCC, 2019). These projects involve low-income communities, aiming to contribute to sustainable development. The advantage of small-scale CDM lies in simplified methodologies, expecting the generation of CRUs for a crediting period of 20 years, renewable two times (UNFCCC, 2005).

The number of CRUs issued is determined by the net anthropogenic greenhouse gas (GHG) removals by sinks during the crediting period in tCO_2-e, the baseline net GHG removals by sinks, and leakage (GHG emissions outside the project boundary but attributable to the project activities), as expressed in Equation 1:

$$tCRU_{t_2} = \sum_{1}^{t_2} (\Delta C_{ACTUAL,t} - \Delta C_{BSL,t} - LK_t) \qquad \text{Equation 1}$$

Where:

$tCRU_{t_2}$	=	Number of units of temporary CRUs issuable in year t_2
$\Delta C_{ACTUAL,t}$	=	Actual net GHG removals by sinks, in year *t*; t CO_2-e
$\Delta C_{BSL,t}$	=	Baseline net GHG removals by sinks, in year *t*; t CO_2-e
LK_t	=	GHG emissions due to leakage, in year *t*; t CO_2-e
t_1, t_2	=	The years of the start and the end, respectively, of the verification period

Assumptions:

1. In the cases at hand, there is no leakage expectation as the agroforestry design is based on the idea that it has minimal adverse effects on coffee production. Participants are unlikely to shift their practices to areas beyond their farmland because they acknowledge the advantages of the agroforestry system, which

efficiently utilizes the current land by incorporating a mix of crops and trees. Displacement is not expected due to the long traditional roots to the land, and the legal system usually prevents unapproved tree-cutting.

2. The baseline net removal of GHGs by sinks is considered zero due to the anticipated long-term degradation of the soil. This degradation is expected to result from the overexploitation of lands, leading to a reduction in carbon stock both in the soil and in the living biomass (Fundación Solidaridad Latinoamericana, 2022) .

Three distinct tree species are under consideration within the project, encompassing both nutritional and wood-producing varieties, namely Erythrina Fusca, Cedrella Odorata, and Tabeuia Rosea. Solidaridad considered a planting density of 188 trees per hectare established for the land renewal, along with new coffee plantations. Baseline assessments account for existing trees within the parcels. The survival rates of newly planted trees are subject to reductions, factoring in losses during the initial year, genetic defects in subsequent years two and three, and thinning during the eighth and ninth years. Consequently, a survival rate of 58.5% beyond the eighth year is established, thereby adapting the carbon sequestration calculations based on total losses.

3.3.2 Cost-Benefit Analysis

3.3.2.1 Additionality

To evaluate the impact of project implementation, a comparative cost-benefit analysis is carried out at the smallholder farmers' level. The additional monetary benefits and costs from projects are weighed against current land use by the producers. It investigates the project and the conversion of coffee crops into agroforestry eligible under the CDM from the Kyoto Protocol. The cash flows over the project period will be calculated by estimating the revenues and costs of both scenarios over time. Potential benefits are expressed as:

$$H_1 - H_0 > 0 \quad \text{Equation 2}$$

Where:

H_0	=	Baseline scenario – Current land-use
H_1	=	Project scenario – Project sustainable land-use

The analysis is carried out over 20 years and thus is based on the present value of costs and benefits of the projects and current land use, using the appropriate discount rate.

The impact of proposed projects is compared with the baseline outputs from Fairtrade-certified producers' cooperatives. Due to its singular form and the practice of maximizing redistributions to its members as costs of goods sold, as well as commodity price volatility, the impact on the net income of cooperatives makes little sense. Rather, H_1 scenario will be weighed against H_0, representing the net present value of the past average gross sales, projected over the project implementation period. To erase any price volatility element in the comparison, the output volumes and the Fairtrade minimum price will be used. It thus allows to consider productivity gains and losses from the project scenario H_1. This demonstrates the scale of projects benefits, and when $H_1 - H_0 > 0$, it should be taken as a strong indicator for project adoption. Thus,

$$H_0 = \left\{ \sum_{S=1}^{n} S_0 \times P_0 \right\} \times q^{-1} \quad \text{Equation 3}$$

Where:

H_0	=	Expected net present value of sales without project implementation
S_0	=	Average past gross sales, kg
P_0	=	Coffee price paid to members at time 0, USD
q	=	Discount factor
n	=	Project implementation period, years

And:

$$H_1 = H_0 + \left\{ \sum_{S=1}^{n} (B_1 - K_1) \right\} \times q^{-1} \qquad \text{Equation 4}$$

Where:

H_1	=	Expected net present value of sales in project implementation scenario
n	=	Project implementation period, years
B_1	=	Net present value of benefits from project implementation, USD
K_1	=	Net present value of costs from project implementation, USD

3.3.2.2 Benefits

For the additional benefits, considering data from Solidaridad, the productivity gain derived from agroforestry, plantation renewal, and organic production, and additional revenues from the sale of CRUs, and the additional organic premium, are taken into account. Formally represented in Equation 5:

$$B_1 = (PG_A + \frac{RR_1}{RR_0} - 1 + PG_O) \times P_0 \times S_0 + tCRU_{t_2} \times P_{CRU} + S_{conv.} \times P_{OP} \qquad \text{Equation 5}$$

Where:

PG_A	=	Productivity gain from additional coffee tree life span from agroforestry practices
$RR_{1,0}$	=	Replacement rate from plantation renewal scenario, respectively from baseline scenario
PG_O	=	Productivity gain from organic production and capacity building according to the baseline
P_0	=	Coffee price paid to members at time 0, USD
S_0	=	Past gross sales, kg
$tCRU_{t_2}$	=	Number of units of temporary CRUs issuable in year t_2
P_{CRU}	=	Net price of carbon removal unit to be sold (COGS 20%), USD
$S_{conv.}$	=	Sales of conventional (non-organic coffee), kg
P_{OP}	=	Organic premium, USD/kg

Productivity gain

For agroforestry, an increased coffee tree life span over the conventional years of normal productivity before degradation is considered. Before project intervention, coffee cultivated in full sun necessitates greater fertilizer use and has a shorter lifespan. On the other hand, implementing a shade system reduces fertilizer requirements and extends the plant's longevity, ultimately boosting productivity (Fundación Solidaridad Latinoamericana, 2022). Yet, a cautious approach is adopted, and the benefits of minimizing fertilizer usage are not considered here. Moreover, the increased lifespan of coffee trees under agroforestry systems is factored in by considering the cost savings on future plantation renewal costs.

Regarding plantation renewal, the productivity gain from new plants, depending on the baseline health of current active coffee trees is considered. In the following years after renewal, respectively when young plantations become fertile, the output gradually increases when compared to the baseline (Wintgens, 2008). In the case at hand, the replacement rate from current land use, respectively considering renewal on an 8-year rolling basis of a quarter of the land suitable for production, and the one from the project scenario, or a one-time renewal of a quarter of land after 5 years, are considered.

The transition to organic production accompanied by capacity-building processes, especially in the development and application of organic inputs that respond to fertility plans and soil analysis, can significantly improve the yields when switching to organic practices (Fundación Solidaridad Latinoamericana, 2022). This is also considered depending on the baseline, respectively if producers have been traditional, meaning there was no usage of fertilizer and the output increase is major, organic, or using conventional practices with fertilizers.

Additional monetary benefits

Various additional monetary benefits arising from project implementation are considered in the cost-benefit analysis.

Agroforestry and reforestation practices allow the generation of CRUs from the fourth year of project implementation. A time following project implementation, and after the verification is carried out by the auditor on carbon capture measurements, smallholder farmers receive monetary compensation via CRUs selling.

Tree reduction also represents an additional revenue for smallholder farmers, considered according to tree type and growing rate pattern. While it lowers CRUs generation potential, it does represent an additional revenue for smallholder farmers. Apart from timber, fruit trees also represent a further generation of revenues. In the analysis, additional revenues from timber products and fruits are not considered, as their quantification is uncertain, and they are often intended for self-use. However, it is important to note that these products further strengthen the producers' value chain.

Finally, the transition to organic production allows the sale of organic certified coffee. Depending on the baseline, correspondingly the already-certified practices allowing a differentiated coffee price, an organic premium over conventional coffee price is considered.

3.3.2.3 Additional costs

The project scenario H_1 produces additional costs, and loss of earnings and productivity in the short term for the producer, represented in Equation **6**.

In the short term, cultivation under shade may result in a production reduction (Fundación Solidaridad Latinoamericana, 2022). Despite the potential slight decrease in coffee production under shade compared to full sun at the beginning, the resulting coffee will be of higher quality, as it will be spared from UV damage (Wintgens, 2008). The latter, however, is hardly quantifiable and will not be considered in the analysis. It should nonetheless be noted that the increase in quality strengthens the producers' value chain.

The implementation costs of projects in the first years are considered and vary from project to project depending on cooperatives' internal costs.

The loss of earnings due to the portion of plantations to be renewed is considered. Depending on the project and area renewed, those represent a partial loss of earnings in the first years related to newly planted coffee trees' unproductivity.

$$K_1 = (PL_A + PL_R) \times S_0 \times P_1 + IC \qquad \text{Equation 6}$$

Where:

K_1	=	Additional costs from project H1
PL_A	=	Short-term productivity loss from agroforestry implementation
PL_R	=	Short-term productivity loss from unproductive plants being renewed
S_0	=	Past gross sales, USD
P_0	=	Coffee price paid to members at time 0, USD
IC	=	Implementation costs of projects in years 1 to 3

3.3.3 Credit risk

In the context of long-term agricultural credits in developing countries, overcoming increased risks poses a significant challenge for investors seeking neutrality in preferences. Unlike short-term financing typically employed in agriculture, which is less capital-intensive, long-term investments present obstacles to producers with short-term orientations, potentially jeopardizing their capacity for credit repayment. This heightened risk is attributed to factors such as crop volatility and the absence of collaterals, which increase the probability of financial loss in subsequent years compared to single-period investments focused on harvest only.

To analyze the de-risking potential of the project, an analysis of the risk reduction elements from project implementation is provided. Respectively, this includes a simulation of the payback chronogram and its burden on smallholder farmers, the additional collateral in the form of pledged CRUs, and the increased revenues strengthening smallholder farmers' repayment capacity. Additionally, qualitative elements such as the smallholder cooperative's role in risk-buffering, the stable prices from the Fairtrade system, and the role of agroforestry in reducing climate risk on plantations are discussed.

3.3.4 Data Used

To evaluate the income generated by project implementation, calculations consider the additional monetary benefits as well as productivity gains from implemented practices. This includes CRU incomes from the estimation of GHG sequestration directly linked to tree growth rates, organic premiums, timber products, and productivity gains from agroforestry and organic practices. The costs are evaluated considering implementation costs and productivity losses from unproductive coffee plants being renewed and the short-term reduced productivity from agroforestry. In addressing these aspects, IPCC guidelines are followed, while data on CRU, organic premiums, timber, implementation costs, and productivity changes are sourced from local data providers. The qualitative assessment of credit risk is undertaken with data from FairCapital and local partners.

The data considered can be found in the tables below. Values are indicative and are adapted for each case study with project-specific data according to the organization's specificities. The complete data can be found in the appendix of this research.

Table 1. Time variables used in the cost–benefit analysis.

Variable	Unit	Value
Time until full productivity (renewal)	years	3
Productive life span coffee tree	years	25
Additional life exp. agroforestry	years	4
Time for shade trees to be effective	years	5
Start payment CRU	years	4

Table 2. Productivity & revenues and costs variables used in the cost-benefit analysis.

Variable	Sub-variable	Sub-variable	Value
Productivity gain agroforestry		%	20.0
Plantation renewal	Baseline productivity	%	70.0
	Project productivity	%	73.2
	Productivity gain	%	3.3
Productivity gain organic production	Baseline practice (non-organic area)	Traditional (%)	30.0
		Conventional (%)	10.0
Productivity loss agroforestry	After year 25	%	15.0

Table 3. Economic variables used in the cost-benefit analysis.

Variable	Sub-variable	Unit	Value
Coffee	Fairtrade price Arabica seeds	US$/pd	1.80
	Organic differential	US$/pd	0.40
	Fairtade Premium	US$/pd	0.20
CRU	Price (Acorn)	EUR/tCO2eq	35.00
		US$/tCO2eq	37.45
	Commission selling platform	%	10%
	Commission project implementor	%	10%
	Net price for producer	US$/tCO2eq	29.96
EUR/USD rate			1.07
Financial interests	Cooperative	%	9.00
	Member (discount rate)	%	13.00

Table 4. Project costs of plantation renewal and climate-smart agriculture implementation per ha (USD)

Type	T1	T2	T3	Total
Seedbed and nursery	**442.54**			**442.54**
Workforce	*339.03*			*339.03*
Material and supplies	*103.51*			*103.51*
Establishment	**685.19**			**685.19**
Workforce	*399.01*			*399.01*
Material and supplies	*286.18*			*286.18*
Maintenance		**658.65**	**764.64**	**1'423.29**
Workforce		*203.42*	*240.00*	*443.42*
Material and supplies		*455.23*	*524.64*	*979.87*
Total	**1'127.73**	**658.65**	**764.64**	**2'551.02**

4 Analysis – Case Study

4.1 Project Description

4.1.1 Objective

Smallholder farmers in Nicaragua face significant challenges due to climate change, as the increase in temperatures directly affects crop viability and reduces suitable cultivation areas. This threat has led them to consider the transition to CSA practices. But despite high commodity prices, the profits of farmers are reduced by low productivity due to plants aging and increased production costs, exacerbated by shortages in agricultural inputs. Consequently, they find themselves barely breaking even and do not invest in their climate resilience.

Through the project, investors provide long-term financing for a period of 6 to 9 years, to two smallholder farmer organizations. The financing is used to invest in the renewal of plantations and transformation to CSA with an agroforestry approach. The implementation of those activities is supported by Solidaridad, who has extensive expertise in the field. The farmers will generate CRUs, that can be traded via "Acorn", a carbon credits selling platform created by Rabobank in a preferred partnership with Solidaridad. The CRUs generated represent additional revenue for farmers and are used as collateral, granting a further guarantee for the lender. Smallholder farmers also receive an organic premium, representing additional income. This incentive enables a stronger commitment to long-term CSA, as agroforestry systems and plantation renewal address the economic challenges by sustainably increasing the productivity of coffee trees. Those additional revenues enable farmers to adopt sustainable practices despite economic challenges.

Key actions for both climate change mitigation and adaptation while supporting smallholder farmers are expected to be achieved. Successful results will allow for scaling, based on the farmers' incentives to adopt targeted practices improving productivity and income, while creating additional guarantees for the lender in the form of pledged CRUs.

4.1.2 Capital Use

Long-term investments in agriculture within developing countries often carry higher perceived risks compared to short-term harvest financing due to their increased capital intensity. Individuals with limited financial resources may face difficulties in investing in efficient projects due to short-term orientations and capital constraints. Such challenges can translate into heightened financial risks and increased probability of losses in subsequent years, particularly given the volatility of crop yields and the absence of collateral, as opposed to single-period investments focused solely on harvest.

Under the framework of project financing, meticulous attention is devoted to ensuring the accurate execution of proceedings. Project implementation and guidance are overseen by an expert field partners. Through targeted capacity-building efforts, it facilitates the adoption of sustainable practices, thereby contributing to carbon sequestration and biodiversity preservation.

4.1.3 Investment Procedure & Due Diligence

The process of selecting investees and conducting comprehensive analysis holds high importance in the risk mitigation strategy of the FCAA in practice. As FairCapital serves as the investment manager for the project financing, it adheres to an extensive procedure to assess the investment risk associated with smallholder cooperatives.

Initially, a pipeline database featuring promising Fairtrade smallholder cooperatives is established. Following an initial screening process, those demonstrating significant potential are approached for further engagement. Subsequently, an analysis is conducted wherein the investment team performs a preliminary assessment based on the information furnished by the cooperative and their financial statements. Any arising uncertainties are addressed through virtual interactions or on-site visits. Upon determination of continued interest in the investment, an exhaustive due diligence process ensues. The assessment encompasses an analysis of the company's activities, mission, social and environmental impact, operational framework, financial health, and legal standing, but also a financial simulation of project adoption with the implementor.

4.2 Partners

4.2.1 Solidaridad

Solidaridad is an international non-profit organization with over 50 years of experience in developing inclusive and sustainable value chains. It founded the Max Havelaar Foundation in 1988, pioneering the first fair trade label for sustainable coffee. Solidaridad has a strong expertise in implementing CSA in developing countries, helping local farmer organizations to produce in harmony with the environment, and contributing to local communities' prosperity.

4.3 Description of case studies areas

The project methodology is applied to two different smallholder farmer's cooperatives in Nicaragua. The country relies extensively on coffee production, being its first export product and employing 330'000 people in 2021, or about 15% of the national labor market. Considering the importance of the coffee sector for the Nicaraguan economy, solutions to face lowering yields and changing climate conditions are being sought by actors along the value chain. For confidentiality reasons, the names of the two case-study cooperatives have been replaced with pseudonyms.

The organizations receiving financing will allocate the funds by extending loans to their members who seek to undertake plantation renewal and transition to climate-smart practices. To adapt to potential defaults, a predetermined spread will be applied to these microloans extended to members. The cooperatives directly assume responsibility towards the lenders, thus offering a significant advantage by further mitigating investment risk and serving as a protective barrier against non-payment.

Even though the risk remains the same as with the baseline in the case at hand, this approach presents a notable advantage in mitigating the investment risks, as the revenues generated by the cooperatives are not solely dependent on the project itself. Additional sales proceeds may be allocated towards credit repayment, thereby providing an added layer of risk buffering for investors in comparison to exclusive project-based financing arrangements.

4.3.1 Cooperativa Río Verde

The Cooperativa Río Verde is a union of cooperatives based in Nicaragua, which has brought together 472 small coffee producers. Since 1993, Cooperativa Río Verde has focused on the production and commercialization of organic coffee, aiming to support the socio-economic development of its members while fostering entrepreneurial vision. Cooperativa Río Verde provides a range of services including credit, technical assistance, training, and marketing of organic coffee to enhance the living standards of all participating producers.

The study area involves the participation of 200 small-holder farmers, representing almost half of the cooperative's members. Farmers participating in the project will allocate 25% of their land to plantation renewal and CSA adoption, including agroforestry systems. Producers hold an average area of 5.86 hectares, from which 89% is cultivated organically, the rest following conventional methods. In 2023, 40'242 quintals (1 quintal = 45.36 kg) of fairtrade-certified coffee were sold to the cooperative from participant members, for a price of USD 214 per quintal.

Table 5. Producer cooperative data (*Source: Cooperativa Río Verde)*

Variable	Unit	200 producers
Members		445.00
Organic certified land	%	89%
Average land size /member	ha	5.86
Coffee bought from members	%	60%
Coffee bought from member(s)	qq	89'425.86
Price paid to members	USD/qq	214.00
Sales from members	USD	19'137'133.21
Land size participants	ha	1'173.47

Table 6. Project variables - Cooperativa Río Verde

Variables	Unit	200 producers
Portion of producers participating	%	45%
Portion of land for project	%	25%
Effective land participation	%	11%
Sales participants	USD	8'611'709.94
Project area (renewal and CSA)	ha	293.37

4.3.2 Cooperativa Tierra de Café

Cooperativa Tierra de Café is a cooperative that originated as a group of coffee producers in 2001 in Nicaragua, with 174 founding members. By 2023, Cooperativa Tierra de Café has expanded to 204 members, including 75 women and 129 men. The cooperative's mission is to facilitate the international commercialization of organic coffee produced by its members, while also promoting the cultivation of organic banana and honey to diversify income sources. Cooperativa Tierra de Café encourages its members to improve their incomes and living standards.

The study area involves the participation of 102 small-holder farmers from Cooperativa Tierra de Café, representing 50% of the cooperative's members. Farmers participating in the project will allocate 25% of their land to plantation renewal and CSA adoption, including agroforestry systems. Members hold an average area of 5.6 hectares, from which 82% is cultivated organically, the rest following conventional methods. In 2023, 21'706 quintals of Fairtrade-certified coffee were sold to the cooperative from participant members, for a price of USD 185 per quintal.

Table 7. Producer cooperative data (*Source: Cooperativa Tierra de Café*)

Variable	Unit	102 producers
Members		204.00
Organic certified land	%	82%
Average land size /member	ha	5.60
Coffee bought from members	%	75%
Coffee bought from member(s)	qq	43'411.20
Price paid to members	USD/qq	185.00
Sales from members	USD	8'031'072.00
Land size participants	ha	571.20

Table 8. Project variables - Cooperativa Tierra de Café

Variables	Unit	102 producers
Portion of producers participating	%	50%
Portion of land for project	%	25%
Effective land participation	%	13%
Sales participants	USD	4'015'536.00
Project area (renewal and CSA)	ha	142.80

5 *Findings & Results*

5.1 Carbon Removal Estimation

The estimation of carbon removal is a central aspect of the analysis. By quantifying the amount of CO2 sequestered by the agroforestry systems, key variables in terms of revenues from the derived CRU generation, and valuable insights into the environmental impact can be gained. This section provides an examination of the outcomes obtained regarding carbon removal estimation.

The results from the carbon removal calculation can be found in Table 9, expressed in tCO2 sequestered per hectare and year. Net CRU revenues per hectare for producers are derived through the multiplication of annual carbon removal by the CRU price from ACORN, adjusted for platform selling and project implementor's commissions of 10% each. CRU price is considered at EUR 35 per tCO2 and converted to USD, even if the price is expected to reach a potential EUR 40 in 2024 (ACORN, 2024). A total of USD 3'553 per hectare is expected to reach the producer over the 20-year crediting period, which can be extended to up to 50 years according to the applied standard (Plan Vivo, 2022). The revenues per hectare from CRUs generation represent 1.83% of average sales per hectare from the cooperatives' members, and in the case at hand increments sales by 0.457%, considering the partial land coverage of the project. While representing a decent gain for producers, this highlights further the potential of agroforestry systems expansion over the whole producers' land in terms of monetary benefits from CRUs.

Table 9. Carbon sequestration per hectare of project over time ***(Source: Solidaridad, 2024)***

y	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Total
Carbon removal (tCo2/ha)	0.0	0.0	0.0	4.0	4.0	6.7	4.0	6.7	6.7	1.3	6.7	6.7	9.3	9.3	6.7	10.6	9.3	8.0	9.3	9.3	**118.6**
Net CRU revenue (USD)	0	0	0	120	120	201	120	201	201	39	201	201	279	279	201	318	279	240	279	279	**3553**

5.2 Cost-Benefit Analysis

In evaluating the feasibility and desirability of the proposed alternatives, a comprehensive cost-benefit analysis is undertaken. This analysis considers the financial implications of each alternative over a specified crediting period, thus enabling a comparison of economic viability. The resulting discussion elaborates on the cash flows associated with the respective scenarios and presents an assessment of their economic benefits.

Considering the financial implications of each scenario, an economic evaluation over the stipulated crediting period is conducted. The base scenario presents the incomes of participant producers, assuming consistent annual sales from existing activities throughout the observed period. Conversely, the project scenario adds to the base scenario by integrating additional costs associated with project implementation, as well as the benefits derived from productivity gains and additional monetary benefits. Figure 2 provides a visual overview of the annual flows from both scenarios and the net additional income generated. The most striking element emerging from the difference in both scenarios is the increased income between years four and six, derived from the increased productivity from the renewal of the plantation. During the peak productivity of those four years, the project scenario generates on average a 35.3% increase in revenues compared to the baseline, principally thanks to plantation renewal. Yet, the other elements derived from the implementation of CSA practices provide a long-lasting, sustainable benefit.

Figure 2. Annual flows derived from baseline and project scenario - Cooperativa Río Verde

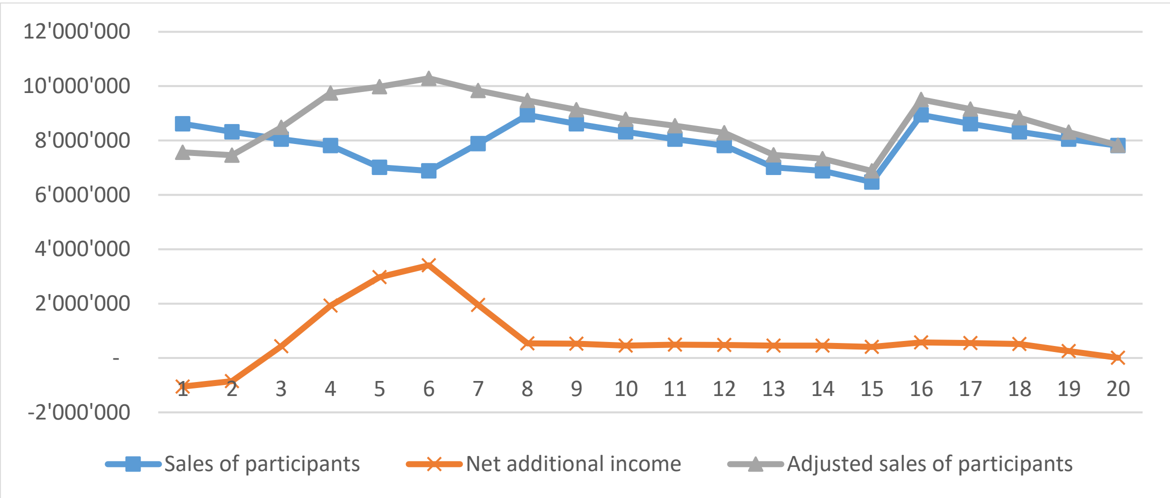


Table 10 presents the net present value per hectare of costs and benefits from both scenarios and its average over 20 years, as determined through the applied methodology in the context of the two case study cooperatives. While average coffee sales from the baseline scenario amount to USD 52’784 per hectare, the project scenario yields additional revenues of USD 7’380. alongside extra costs of USD 2’453, resulting in a net additional income of USD 4’926. Consequently, the adjusted sales after project implementation stands at USD 57’710 per hectare, reflecting a 9.3% increase compared to the baseline scenario. This increase represents a central finding from the analysis and speaks in favor of project adoption. The most striking factor contributing to the revenue increase arises from plantation renewal (+9.5%) and CSA practices (+3.3%). Yet, additional revenues derived from CRU generation (+0.4%), organic premiums (+0.3%), and increased lifespan of coffee trees (+0.5%) are also important, but influence the NPV to a lesser extent, as they arise continuously over the 20 years study period. Productivity gains from plantation renewal, on the other hand, occur between years 3 and 6, thus having a bigger weight on the NPV calculation. Conversely, additional costs also arise mainly at the beginning of the study period.

Table 10. Net present value per hectare of cash flows from project scenario (20 years)

NPV per hectare	Cooperativa Río Verde	Cooperativa Tierra de Café	Average	
Sales of participants	$ 53'917.94	$ 51'649.89	$ 52'783.91	100.0%
Coffee	*$ 53'917.94*	*$ 51'649.89*	*$ 52'783.91*	100.0%
Productivity gain	$ 6'857.84	$ 6'600.77	$ 6'729.30	12.7%
Plantation renewal	*$ 5'120.89*	*$ 4'905.48*	*$ 5'013.18*	9.5%
Climate-smart practices	*$ 1'736.95*	*$ 1'695.30*	*$ 1'716.12*	3.3%
Additional Revenues	$ 348.30	$ 406.40	$ 377.35	0.7%
CRUs	*$ 236.04*	*$ 236.04*	*$ 236.04*	0.4%
Organic Premium	*$ 112.26*	*$ 170.36*	*$ 141.31*	0.3%
Costs savings from agroforestry	$ 277.06	$ 268.75	$ 272.91	0.5%
Increased life-span coffee trees	*$ 277.06*	*$ 268.75*	*$ 272.91*	0.5%
ADDITIONAL INCOMES	**$ 7'483.20**	**$ 7'275.93**	**$ 7'379.56**	14.0%
INCOMES	**$ 61'401.14**	**$ 58'925.81**	**$ 60'163.47**	114.0%
Productivity loss	$ 484.89	$ 464.50	$ 474.70	0.9%
Agroforestry	*$ 484.89*	*$ 464.50*	*$ 474.70*	0.9%
Additional costs	$ 2'008.68	$ 1'948.47	$ 1'978.57	3.7%
Project implementation costs	*$ 577.36*	*$ 577.36*	*$ 577.36*	1.1%
Loss of earnings	*$ 1'431.32*	*$ 1'371.11*	*$ 1'401.22*	2.7%
ADDITIONAL COSTS	**$ 2'493.57**	**$ 2'412.97**	**$ 2'453.27**	4.6%
Net additional income	**$ 4'989.62**	**$ 4'862.96**	**$ 4'926.29**	9.3%
Adjusted sales of participants	**$ 58'907.56**	**$ 56'512.85**	**$ 57'710.20**	109.3%

5.3 Sensitivity Analysis

The sensitivity analysis aims to assess the robustness of the model in response to changes in input variables. It involves systematic varying of defined inputs and observing the corresponding changes in the results. The investigated input variables include coffee price, CRU price, project implementation area, baseline organic land certification, discount rate, and productivity gain from implemented agroforestry systems, as being the most significant ones. The corresponding results are reported in Table 11. This analysis helps to identify which input variables have the most importance on the outcomes and how sensitive the model or system is to changes in those variables.

All explored input variables in the project scenario yield positive outcomes when compared against the baseline, with some exerting greater influence on results. When variables remain constant, the project scenario generates a revenue 9.3% higher than the baseline scenario.

The coffee price level emerges as the most impactful variable on producers' incomes, showing a very high correlation with the results of both scenarios. However, its importance is limited when comparing both scenarios, and a variation in coffee price level does not speak against nor for project adoption. Notably, a 40% price increase results in a mere 0.44% sharper increase in incomes for the project scenario against the baseline scenario, thus reaching 9.4%, a 0.2% increase compared to the coffee price level being constant.

The discount rate is the next most sensitive variable, significantly impacting revenues when increased. Nevertheless, the changing results between scenarios are limited, with a 2.5% disadvantage for the project scenario observed with a 38% increase in the discount rate, and a 0.5% decrease in revenues when considering the original discount rate. This discrepancy is linked to the fact that additional costs and benefits mainly occur in the initial years of project implementation, after which both project cash flows move similarly, thus limiting the impact on project outcomes.

The remaining variables, inherent to project implementation activities, hold significant importance in the comparative sensitivity analysis, although they do not impact the baseline scenario. Project size, representing the portion of land dedicated to project activities, emerges as the most sensitive variable to potential changes in inputs in terms of scenario comparison. A 1.7% comparative increase is noted for the project scenario against the baseline when land coverage increases by 60%, reaching an 11.1% increase in revenues. While greater land coverage yields substantially higher outcomes, significant variation is unlikely as punctual and regular land renovation is crucial for ensuring stable revenues.

Productivity gains from the implementation of CSA practices also bear importance, being fundamental for long-term marginal benefits. While the variable considered for increased productivity is not expected to change significantly, it results in notable changes, with a 1.4%

increase in revenues for the project scenario for a 10% increase in productivity from agroforestry systems, reaching 10.8% advantage of the project scenario against the baseline.

Table 11. Sensitivity analysis - Cooperativa Río Verde

Variables	Variation (%)	Value	Unit	H0	H1	Comparative analysis H1-H0	Comparative analysis H1/H0	H1/H0 difference
			USD/ha	53'918	58'908	+4'990	1.093	0.000
			%	0	9.3	9.3		
			Results					
Coffee price	+40	300	USD/ha	75'485	82'575	+7'090	1.094	0.001
			%	40.0	40.2	0.2		
	-50	128	USD/ha	32'351	35'240	+2'889	1.089	0.003
			%	-40.0	-40.2	-0.2		
CRU price	+57	50	USD/ha	53'918	59'009	+5'091	1.094	0.002
			%	0.0	0.2	0.2		
	-57	20	USD/ha	53'918	58'806	+4'888	1.091	0.002
			%	0.0	-0.2	-0.2		
Project size	+60	40	USD/ha	53'918	59'916	+5'998	1.111	0.019
			%	0.0	1.7	1.7		
	-60	10	USD/ha	53'918	57'899	+3'981	1.074	0.019
			%	0.0	-1.7	-1.7		
Organic certification members (baseline)	+12	100	USD/ha	53'793	58'771	+4'978	1.093	0.000
			%	-0.2	-0.2	0.0		
	-12	78	USD/ha	54'043	59'044	+5'001	1.093	0.000
			%	0.2	0.2	0.0		
Discount rate	+38	18	USD/ha	43'052	46'733	+3'681	1.086	0.007
			%	-20.2	-20.7	-0.5		
	-38	8	USD/ha	71'801	78'686	+6'884	1.096	0.003
			%	33.2	33.6	0.4		
Productivity gain CSA	+10	30	USD/ha	53'918	59'748	+5'830	1.108	0.016
			%	0.0	1.4	1.4		
	-10	10	USD/ha	53'918	58'067	+4'149	1.077	0.016
			%	0.0	-1.4	-1.4		

CRU prices and baseline practices in terms of organic production are less important compared to sales levels but still represent valuable long-term sustainable monetary benefits. Both variables influence results when comparing the two scenarios. Specifically, a 57% increase in CRU prices leads to a 0.2% increase in project scenario outcomes, reaching 9.4% augmentation comparing scenarios. A 12% increase in members' organic certification from the baseline reduces the attractiveness of the project scenario by 0.2%, reaching 9.0%.

5.4 Credit Risk

5.4.1 Repayment Capacity

The investigation reveals that the structure of the financing projects holds benefits in terms of augmenting revenue streams and mitigating climate-related risks. Additional income generated from productivity enhancements, CRUs, organic premiums, timber and fruit yields, as well as cost savings, serves to enhance credit repayment capacity and diversify revenue sources. Moreover, the adoption of climate-smart agricultural practices fosters greater resilience to climatic events among producers by protecting their plantations from adverse weather conditions and temperature extremes.

Table 12 provides a simulation of the repayment schedule for project implementation on a per-hectare basis, with a portion of land undergoing transformation with a 75% project financing scheme for smallholder farmers over 8 years. Initially, cooperative funds and the productive coffee land of participating producers, which are not being renewed, cover credit interests. A grace period for amortization is granted in the initial years, with CRUs anticipated to cover an important part of interest payments from the fourth year onward. Concurrently, renewed coffee plants become productive, boosting former farmers' incomes, and facilitating amortization. From the cost-benefit analysis, it was found that the cash flows generated result in positive net additional benefits from the fourth year on, and that from the fifth year, they cover the principal and loan interests. The medium-term benefits thus enable credit repayment without compromising the financial stability of smallholder farmers. In the event of external adversities, the consistent long-term incomes derived from climate-smart agricultural practices and associated financial benefits provide a buffer, enabling gradual repayment within an extended grace period.

Table 12. Amortization table (per ha) – Cooperativa Río Verde

Year	Credit balance	Interest	Principle	Total Payment	Closing balance	Loan paid by				CRU income / Interest	CRU income / Credit size
						other farm/area cultivated	new hectare / prod. gain	CRU income	CRU income		
1	1'913	249		249	1'913	x					
2	1'913	249		249	1'913	x					
3	1'913	249		249	1'913	x					
4	1'913	249	383	631	1'531		x	x	120	48.2%	6.3%
5	1'531	199	383	582	1'148		x	x	120	60.2%	6.3%
6	1'148	149	383	532	765		x	x	201	134.5%	10.5%
7	765	99	383	482	383		x	x	120	120.5%	6.3%
8	383	50	383	432	-		x	x	201	403.5%	10.5%
Total		**1'492**	**1'913**	**3'406**					**761**	**51.0%**	**39.8%**

5.4.2 Collaterals

The investment thesis of the FCAA revolves around risk mitigation through the pledging of CRUs. Carbon sequestration resulting from newly planted trees is assessed, monitored, and certified by the Plan Vivo Foundation, allowing the annual generation of CRUs three to four years after the implementation of agroforestry systems.

When CRUs are generated on behalf of smallholder producer cooperatives and pledged to lenders against interest and capital repayments, they offset a significant portion of the ensuing payments. For one hectare, exemplified by the case study with Cooperativa Río Verde, the cumulative CRUs generated over eight years, corresponding to the credit repayment duration, constitute 51% of the interest value or 39.8% of the loan amount, representing a substantial risk mitigation component for the loan. In repayment difficulties, the CRUs generated cover the outstanding loan balance before the 14th year, encompassing both capital and interest payments accrued over the preceding eight-year period by the 18th year.

While similar investments for plantation renewal or transition to CSA are available, the consolidation of these approaches and the integration of CRUs as collateral significantly diminish credit risk, rendering the investment substantially de-risked and more competitive.

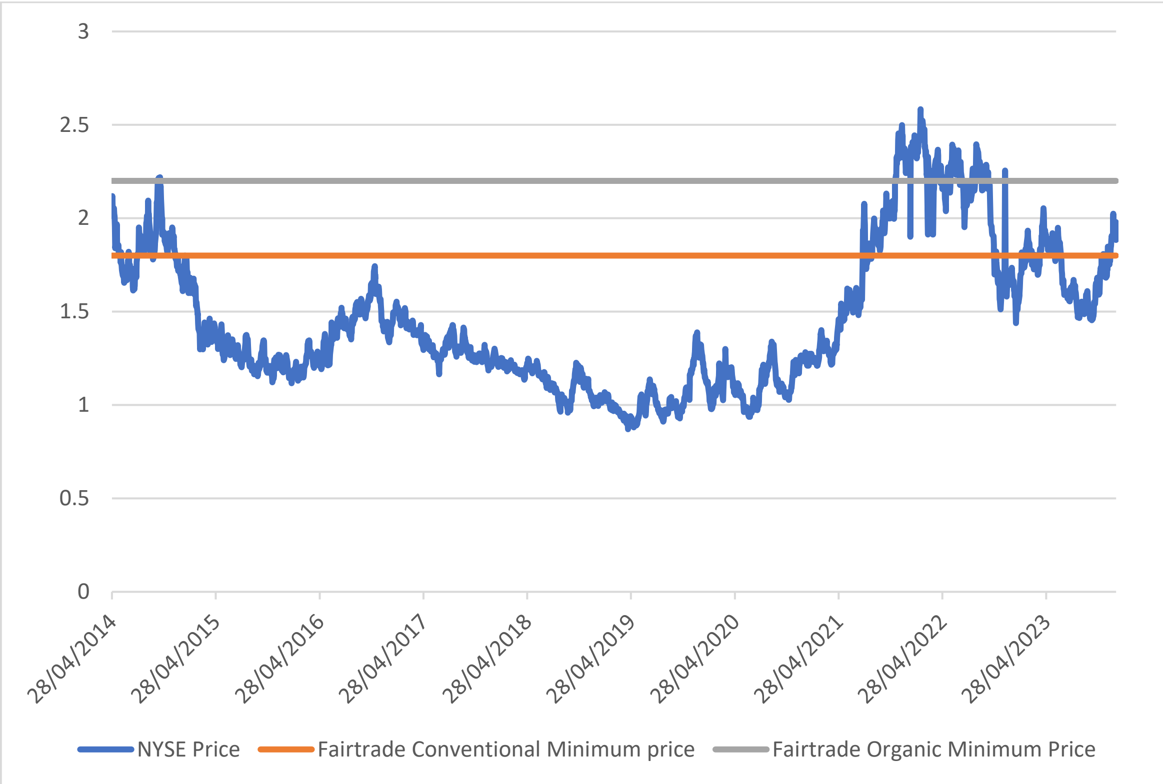
6 Discussion

6.1 Additional Considerations and Implications

6.1.1 Price Risk

The price of coffee, like other commodities, is subject to fluctuations driven by supply and demand, often influenced by speculation. These fluctuations can significantly impact small-scale producers, either positively or negatively. However, established mechanisms such as the Fairtrade system allow to anticipate and mitigate price volatility, providing producers with stable and sustainable revenues, in addition to fair prices. The Fairtrade certification serves as a robust tool to mitigate price risk for both producers and investors, while also ensuring the production of high-quality coffee. Some consumers are willing to pay a premium for Fairtrade-certified coffee, enabling direct investments into cooperative businesses or community projects. In recent years, coffee prices have exhibited notable fluctuations. Figure 1 provides an overview of coffee prices negotiated on the NYSE, alongside the Fairtrade and organic Fairtrade minimum prices. These fluctuations pose significant risks for producers, both in scenarios of price increases and decreases. In the event of substantial price hikes, cooperatives may struggle to compete and procure coffee from their members at pre-established prices, potentially leading to financial difficulties. Conversely, in the event of price declines with fixed contracts, cooperatives may incur significant losses, being obligated to purchase coffee from members at prices higher than those at which they can subsequently sell. While such fluctuations have a central influence on producers and cooperative revenues, this risk can be mitigated by implementing minimal price guarantees. This is a practice in Fairtrade certification standards, which in addition to minimal prices, reward producers with a Fairtrade premium, intended to be used as a communal fund for workers and farmers to improve their social, economic, and environmental conditions (Fairtrade Foundation, 2023). The minimum price allows greater control on the supply side, protecting cooperatives while ensuring equitable prices for producers. Consequently, FCAA investments are exclusively directed towards Fairtrade-certified cooperatives, thereby mitigating the impact of price fluctuations. Moreover, the adoption of climate-smart practices enables producers to receive a price differential, further reducing the vulnerability to price volatility. Figure 3. Price per Pound of Green Washed Arabica Coffee Beans provides a representation of historical coffee price fluctuations, compared to the minimum Fairtrade and Fairtrade organic price. The Fairtrade premium of USD 0.2 per pound is not included but is further enhancing Fairtrade farmers' resilience to price volatility while representing an essential extra income for the development of their conditions.

Figure 3. Price per Pound of Green Washed Arabica Coffee Beans



6.1.2 Comparative Analysis

The comparative analysis depicted in Table 10 reveals a favorable economic outlook for the project scenario, suggesting its potential as a lucrative investment opportunity compared to current land use practices. Moreover, the implementation of these projects is anticipated to yield sustainable additional benefits extending beyond the observed period, thereby strengthening the producers' value chain. Notably, the introduction of agroforestry systems is expected to yield multiple benefits, encompassing productivity gains, cost efficiencies from fertilizers savings, and financial gains from CRUs, timber, fruit products, and additional organic premiums (Fundación Solidaridad Latinoamericana, 2022). Additionally, these practices contribute to the enhancement of coffee quality and strengthen producers' resilience in terms of climate change adaptation and sustainable production practices. Despite certain benefits being challenging to monetarily quantify and internalize, such as quality improvements and enhanced resilience, they substantially augment the overall producer's position. Furthermore, the adoption of CSA practices produces environmental benefits by reducing fertilizer usage, enhancing soil quality, and sequestering atmospheric carbon. Ultimately, this integrated approach enables producers to diversify their revenue streams, thereby mitigating dependence on irregular harvests and volatile coffee prices.

6.1.3 Climate Change Risk Adaptation

Coffee producers face significant exposure to climate change risks and extreme weather events, given the sensitivity of coffee plantations to rising temperatures, which can potentially limit suitable cultivation areas. Investments directed toward supporting plantation renewal and transitioning to CSA practices play a pivotal role in helping producers adapt to climate resilience.

These investments encompass initiatives such as transitioning to sustainable production methods and the introduction of agroforestry systems. By adopting such practices, producers not only improve soil health but also utilize natural fertilizer sources, thereby reducing reliance on external inputs. Agroforestry systems serve as robust climate adaptation mechanisms by providing shade to plantations, thereby regulating temperature increases that could otherwise impede productivity over the long term. Moreover, they help prevent the risk of crop abandonment due to land degradation induced by global warming, a pressing concern in numerous Latin American regions.

In the absence of these interventions, escalating input costs could render soil unsuitable for cultivation, heightening the risk of disease outbreaks within monoculture systems and leading to abandonment and conversion of land to cattle pastures. Furthermore, these practices contribute to climate mitigation efforts by enhancing local biodiversity and sequestering carbon from the atmosphere. The incorporation of diverse tree species within agroforestry systems provides habitat for wild fauna and flora, while concurrently countering the historical decline in forest cover and biodiversity. This holistic approach fosters resilience to climate change and mitigates the risk of biodiversity loss associated with land-use changes, thus promoting sustainable agricultural practices in the face of evolving climatic challenges.

6.2 Limitations

The findings in this thesis provide insights into the financial and environmental impacts of project adoption. However, several limitations must be acknowledged, which could affect the generalizability, accuracy, and applicability of the results. These limitations highlight the need for caution when interpreting the findings and for further research to build on these results.

6.2.1 Price Changes and Volatility over Time

The data used for financial projections rely on estimates and model assumptions. The coffee prices, CRU prices, and other economic variables used in the cost-benefit and sensitivity analyses (e.g., Table 10 and Table 11) are subject to market fluctuations and may not accurately represent future values. This limitation impacts the accuracy of revenue forecasts, potentially underestimating or overestimating the financial benefits. Still, a relatively conservative approach has been adopted, and the usage of NPVs for future results diminishes the uncertainty of future cash flows.

The time period of 20 years for the cost-benefit analysis simplifies the complexity of long-term impacts. Factors like evolving carbon market standards, uncertainty and volatility of harvests, and potential technological advancements in land-use practices could alter the projected outcomes over time. The assumption of a constant discount rate, also affects the economic analysis, potentially influencing the NPV results.

Fluctuations in CRU prices and coffee sales could substantially alter income projections, yet this study does not explore the correlation between these variables and risk diversification fully. The CRU prices are expected to act against the volatility of harvests and coffee prices, generating an uncorrelated revenue over time. Still, future analyses should assess how price variations in both coffee and CRUs could impact the economic stability and resilience of producers participating in such projects.

The reliance on Fairtrade certifications and CRUs as a stabilizing factor for coffee price volatility and credit collateral introduces some dependency. Fluctuations in CRU prices and demand for certified coffee could affect both income and repayment rates, potentially altering the benefits projected in this analysis. Furthermore, while Fairtrade minimum price guarantees offer some protection, they do not entirely eliminate market risks, especially during extreme price shifts.

6.2.2 Uncertainty

The analysis relies on a baseline scenario that assumes periodic plantation renewal every 8 years for comparison. However, changes in baseline practices, such as a move to faster or slower replacement cycles, could influence the observed productivity gains and should be paid attention to. Yet, the replacement cycle taken is a rather conservative approach, as many smallholder farmers struggle to invest in plantation renewal and usually do not invest in renewal before this period. Still, it is central to consider the baseline land practice for project implementation. Moreover, benefits from plantation renewal appear in the short term. For an even larger revenue increase apart from those from improved land use and CRUs generation, continuous investments in plantation renewal are recommended, typically by adopting optimal renewal cycles every 5 years.

The analysis does not address certain environmental risks associated with long-term credit financing. Factors such as climate variability, pest infestations, or socio-economic shocks were not modeled. These elements could significantly impact both the productivity and financial stability of participating farmers, particularly in developing regions with limited access to adaptive resources. Still, the adoption of CSA practices acts as a climate adaptation mechanism and allows sustainable land use which increases climate resilience. Moreover, the CRU income should allow a stable revenue uncorrelated with harvest cycles.

6.2.3 Generalizability of Results

Given the potential benefits observed, scaling up the FCAA approach appears promising; however, several factors should be considered. This thesis focuses on projects implemented by specific cooperatives, which may limit the generalizability of findings. Variability in local contexts, such as soil conditions, cooperative governance, and member practices, may influence the outcomes differently. Consequently, the results may not be fully applicable to other regions or cooperatives without adaptation to local conditions.

6.3 Contribution to Existing Knowledge

This study contributes to the literature on agriculture financing by evaluating the feasibility of combining plantation renewal financing with the implementation of climate-smart agricultural (CSA) practices and the generation of Carbon Removal Units (CRUs) as collateral. This integrated approach appears to be novel in agricultural financing, representing an innovative solution for risk mitigation when providing long-term capital for smallholder plantation renewal investments. The findings demonstrate how combining CRUs with productivity gains from CSA practices can enhance producer incomes while promoting environmental sustainability. By reducing credit risk and supporting revenue diversification, this model offers a robust framework for private actors as impact investors to develop risk-resilient financing solutions, potentially applicable across various agricultural sectors.

In the context of FairCapital's operations, which will apply the results in practice, this research has provided valuable insights that build on pre-existing knowledge. Before this study, FairCapital recognized the need for long-term financing for smallholder farmers but primarily focused on short-term harvest financing due to the perceived risks of long-term investments. This thesis expanded that understanding by demonstrating the financial benefits of integrating plantation renewal and CSA practices, supported by CRUs as additional collateral to mitigate risks. These findings facilitated the approval of a pilot project and established a foundation for scaling, equipping FairCapital with a clearer framework for implementing innovative, risk-reducing financing mechanisms.

7 Conclusion

This master thesis has explored an impact investment initiative aiming at enhancing climate resilience and socio-economic conditions of smallholder producers in developing economies. Serving as the core of an investment vehicle, this initiative links plantation renewal and CSA practices to systematically mitigate investment risks and enhance the socio-economic conditions of beneficiaries facing low returns, restricted access to capital and financing, and challenges posed by changing climate conditions. Throughout a mixed-methods approach involving two qualitative and quantitative case studies for project implementation in coffee crops, the investigation – encompassing a cost-benefit analysis and credit risk assessment – highlights not only the economic benefits but also the risk mitigation components intrinsic to the project.

A central element of the underlying project lies in the innovative approach to financing climate resilience, characterized by the generation of CRUs through agroforestry practices combined with plantation renewal, which are necessary to sustain productivity for smallholder farmers. The financial instrument not only yields an additional, sustainable revenue stream for producers but also incentivizes environmentally friendly practices, positioning smallholder farmers as active contributors to climate change mitigation. Moreover, the thesis underscores the significance of climate change adaptation measures through the adoption of sustainable agriculture practices to build the resilience of smallholder farmers against the adverse impacts of climate change.

The findings of this thesis show the positive economic benefits for smallholder farmers and support the investment risk reduction claims for the investment vehicle. Quantitatively, farmers are able, through project adoption, to increase their NPV revenues by 9.3% compared to the baseline scenario over a period of 20 years. Risk is significantly reduced with additional collaterals in the forms of CRUs, which represent 51% of the interest value and 39.8% of the loan amount. Moreover, the sustainable increase in revenues generated by project implementation also strengthens the repayment capacity of beneficiaries, further increasing credit security.

The directing of impact investments in the project is expected to act as a significant catalyst for sustainable agriculture and climate resilience in Latin America. Through innovative financing mechanisms supporting the adoption of CSA practices, the initiative not only generates economic benefits but also creates substantial environmental and social value. The adoption of CSA practices improves biodiversity, soil health, and climate resilience while fostering sustainable agricultural practices in resource-constrained regions. By combining these financing mechanisms with tangible environmental and socio-economic outcomes, the initiative serves as a model for leveraging impact investments to address challenges like low returns and limited capital availability in the agricultural sectors of developing economies.

While the thesis highlights promising results, certain limitations must be acknowledged. Financial projections rely on assumptions such as constant coffee sales and CRU prices, which could affect the accuracy of revenue forecasts, especially over the long term. Additionally, the 20-year period and fixed discount rate simplify the complexity of evolving market conditions and environmental factors. The analysis also assumes periodic plantation renewal every 8 years, but variations in renewal cycles and environmental risks, such as climate variability or pest infestations, were not accounted for. Lastly, while the findings suggest the potential for scaling up, the results are based on specific cooperatives, crops, and regions, limiting their generalizability to other regions or contexts. This typically requires a careful assessment of the baseline for replicability.

The thesis contributes to the current literature by demonstrating the economic, environmental, social, and risk benefits of a novel investment vehicle, and aims at fostering and scaling up such craved initiative. It underscores the potential to drive sustainable agriculture, climate resilience, and inclusive development. This research provided FairCapital with critical insights to expand from short-term harvest financing to long-term investments. By demonstrating the financial benefits of integrating plantation renewal and CSA practices, supported by CRUs as collateral, the findings enabled the approval of a pilot project and set the stage for scaling innovative, risk-reducing financing mechanisms. By cultivating a favorable ecosystem for impact investments and developing partnerships across various actors, a more resilient, sustainable, and equitable agricultural landscape is envisioned.

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Appendix

Appendix A. Data used

A.1 Carbon Removal Units Generation

A.1.1 Agroforestry Design, Tree Thinning and Reduction

Coffee & Agroforestry System for promotion in Nicaragua 2024-27: Source data, Fundación Solidaridad Latinoamericana.

Tree type	Tree species	No. planted / ha	No. surviving / ha from yr 8 on	No. surviving / ha as %	
Nutrition	Erythrina Fusca	40	25	61.44%	21%
Precious wood	Cedrella Odorata	88	49	55.25%	47%
Hardwood	Tabeuia Rosea	60	37	61.44%	32%
	Total	**188**	**110**	58.54%	100%

	Density/ha			
	Baseline (yr 0)	No. trees to add with project	Total no, trees yr 1	Total no trees yr 7
Coffee plants	4'600	0	4'600	4'600
Banana/plantain	100	0	100	60
Fruit trees	10	0	10	10
Existing Shade trees (12 Forestry and 40 "service") trees	52	188	240	152

	Tree species					
Nutrition	**Erythrina Fusca** / Bucaro (Alternatives: guaba rosada/negra)	44	40	84	55	25
Precious	**Cedrella Odorata** / cedro real. Alternatives: mahogany / caoba, cedro macho, nogal, gavilan	5	88	93	54	49
Hardwood	**Tabeuia Rosea** / Roble Macuelizo. Alternatives: laurel, palo de agua (Waslala), guayabon, nispero, cortes	5	60	65	42	37
	Total	**54**	**188**	**242**	**150**	**110**
						59%

Agroforestry management plan: Summary	yr 1 (loss)	Yr 2 (genetic defect)	Yr 3 (genetic defect)	Thinning yr 7 / 8
% reduction	10.0%	10.0%	10.0%	20%
No. trees reduced	19	17	15	27
	169	152	137	110
No. and % trees remaining from total planted	90%	81%	73%	58%
Detail				
Erythrina fusca loss	4%	7%	7%	26%
No. Erythrina fusca reduced	2	3	2	9
No. Erythrina fusca remaining	38	36	33	25
Cedrella Odorata loss	17%	14%	14%	10%
No. Cedrella Odorata reduced	15	10	9	5
No. Cedrella Odorata remaining	73	63	54	49
Tabeuia rosa loss	4%	7%	7%	26%
No. Tabeuia rosa reduced	2.4	4	4	13
No. Tabeuia rosa remaining	58	54	50	37
Total no. trees reduced	19	17	15	27
Total no. trees remaining	169	152	137	**110**
check	0	0	0	0
Detail of existing trees				
Existing trees				52
Existing Service trees thinned in yr 7	25%			10
Total no. trees remaining / ha				42
Grand total no. trees / ha (existing + new)				152

PLAN 1	**381'081**	**La Cumplida**	**PACSA**	**Otro vivero**	**Total**	**No hectares**	**No. producers**
Erythrina Fusca	**81'081**				**0**		
Bucaro / Guaba				81'081	**81'081**		
Cedrella Odorata	**178'378**				**0**		
Cedro real o Caoba del Atlantico		148'378	30'000		**178'378**		
Tabeuia Rosea	**121'622**				**0**		
Roble macuelizo, Laurel Negro, Cortes (solo PACSA) , Guayabon (Solo PACSA).		101'622	20'000		**121'622**		
Total	**381'081**	**250'000**	**50'000**	**81'081**	**381'081**	2'027	1'448

PLAN 2	**316'297**	**La Cumplida**	**PACSA**	**Otro vivero**	**Total**	**No hectares**	**No. producers**
Erythrina Fusca	**67'297**						
Bucaro / Guaba			8'500	58'797	67'297		
Cedrella Odorata	**148'054**						
Cedro real o Caoba del Atlantico		123'154	24'900		148'054		
Tabeuia Rosea	**100'946**						
Roble macuelizo, Laurel Negro, Cortes (solo PACSA) , Guayabon (Solo PACSA).		84'346	16'600		100'946		
Total	**316'297**	**207'500**	**50'000**	**58'797**	**316'297**	**1'682**	**1'202**

PLAN 3	**216'297**	**La Cumplida**	**PACSA**	**Otro vivero**	**Total**	**No hectares**	**No. producers**
Erythrina Fusca	**40'240**						
Bucaro / Guaba	0	0	8'500	31'740	40'240	0	0
Cedrella Odorata	**97'992**						
Cedro real o Caoba del Atlantico	0	73'092	24'900	0	97'992	0	0
Tabeuia Rosea	**50'887**						
Roble macuelizo, Laurel Negro, Cortes (solo PACSA) , Guayabon (Solo PACSA).	0	34'287	16'600	0	50'887	0	0
Total	**189'119**	**107'379**	**50'000**	**31'740**	**189'119**	**1'006**	**719**

A.1.2 Carbon removal units generation over 20 years per hectare

YR	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	TOTAL
CRUs				4.0	4.0	6.7	4.0	6.7	6.7	1.3	6.7	6.7	9.3	9.3	6.7	10.6	9.3	8.0	9.3	9.3	8.0	126.4

A.2 Cost Benefit Analysis

A.2.1 Data

Table 13. Producer cooperative data (*Source: Cooperativa Río Verde)*

Variable	Unit	200 producers
Members		445.00
Organic certified land	%	89%
Average land size /member	ha	5.86
Coffee bought from members	%	60%
Coffee bought from member(s)	qq	89'425.86
Price paid to members	USD/qq	214.00
Sales from members	USD	19'137'133.21
Land size participants	ha	1'173.47

Table 14. Project variables - Cooperativa Río Verde

Variables	Unit	200 producers
Portion of producers participating	%	45%
Portion of land for project	%	25%
Effective land participation	%	11%
Sales participants	USD	8'611'709.94
Project area (renewal and CSA)	ha	293.37

Table 15. Producer cooperative data (*Source: Cooperativa Tierra de Café)*

Variable	Unit	102 producers
Members		204.00
Organic certified land	%	82%
Average land size /member	ha	5.60
Coffee bought from members	%	75%
Coffee bought from member(s)	qq	43'411.20
Price paid to members	USD/qq	185.00
Sales from members	USD	8'031'072.00
Land size participants	ha	571.20

Table 16. Project variables - Cooperativa Tierra de Café

Variables	Unit	102 producers
Portion of producers participating	%	50%
Portion of land for project	%	25%
Effective land participation	%	13%
Sales participants	USD	4'015'536.00
Project area (renewal and CSA)	ha	142.80

Table 17. Time variables used in the cost-benefit analysis (years).

Variable	Value
Time until full productivity (plantation renewal)	4
Productive life span coffee tree	20
Additionnal productive life due to agroforestry	5
Time for shade trees to be effective	5
Start payment CRU	4

Table 18. Productivity & revenues and costs variables used in the cost-benefit analysis (%).

Variable	Sub-variable	Sub-variable	Value
Productivity gain agroforestry			20.00
Plantation renewal	Baseline productivity		63.27
	Project productivity		68.96
	Productivity gain		8.99
Productivity gain organic production	Baseline practice (non- organic area)	Traditional	30.00
		Conventional	10.00
Costs saving from agroforestry	Increased life-span coffee trees		20.00
Productivity loss agroforestry	After year 25		15.00
Productivity loss ageing coffe trees	After year 25		2.50

Table 19. Economic variables used in the cost-benefit analysis.

Variable	Sub-variable	Unit	Value
Coffee	Fairtrade price Arabica seeds	US$/pd	1.80
	Organic differential	US$/pd	0.40
	Fairtade Premium	US$/pd	0.20
CRU	Price (Acorn)	EUR/tCO2eq	35.00
		US$/tCO2eq	37.45
	Commission selling platform	%	10%
	Commission project implementor	%	10%
	Net price for producer	US$/tCO2eq	29.96
EUR/USD rate			1.07
Financial interests	Cooperative	%	9.00
	Member (discount rate)	%	14.00

Table 20. Project costs of plantation renewal and climate-smart agriculture implementation per hectare (USD)

Type	T1	T2	T3	Total
Seedbed and nursery	**442.54**			**442.54**
Workforce	*339.03*			*339.03*
Material and supplies	*103.51*			*103.51*
Establishment	**685.19**			**685.19**
Workforce	*399.01*			*399.01*
Material and supplies	*286.18*			*286.18*
Maintenance		**658.65**	**764.64**	**1'423.29**
Workforce		*203.42*	*240.00*	*443.42*
Material and supplies		*455.23*	*524.64*	*979.87*
Total	**1'127.73**	**658.65**	**764.64**	**2'551.02**

Table 21. Land productivity base scenario (10 years interval renewal)

y	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Replacement rate
25%	0.31	0.28	0.25	0.23	0.00	0.00	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	
25%	0.73	0.66	0.59	0.53	0.48	0.43	0.39	0.35	0.31	0.28	0.25	0.23	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	
25%	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.81	0.73	0.66	0.59	0.53	0.48	0.43	0.39	0.35	0.31	0.28	0.25	0.23	
25%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.81	0.73	0.66	0.59	0.53	
baseline H0	**0.76**	**0.73**	**0.71**	**0.69**	**0.62**	**0.61**	**0.70**	**0.79**	**0.76**	**0.73**	**0.71**	**0.69**	**0.62**	**0.61**	**0.57**	**0.79**	**0.76**	**0.73**	**0.71**	**0.69**	**0.6996**

Table 22- Land productivity project scenario (baseline scenario and renewal after 5 years)

y	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	Replacement rate
25%	0.00	0.00	0.50	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.81	
25%	0.73	0.66	0.59	0.53	0.48	0.43	0.39	0.35	0.31	0.28	0.25	0.23	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	
25%	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.81	0.73	0.66	0.59	0.53	0.48	0.43	0.39	0.35	0.31	0.28	0.25	0.23	
25%	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.90	0.81	0.73	0.66	0.59	0.53	
renewal H1	**0.68**	**0.66**	**0.77**	**0.88**	**0.87**	**0.86**	**0.82**	**0.79**	**0.76**	**0.73**	**0.71**	**0.69**	**0.62**	**0.61**	**0.57**	**0.79**	**0.76**	**0.73**	**0.69**	**0.64**	**0.7325**

Appendix B. Results.

B.1.1 Annual Cash Flows from Projects

Cooperativa Río Verde

200 producers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sales of participants	8'611'710	8'316'575	8'050'954	7'811'896	7'014'033	6'878'666	7'888'909	8'939'637	8'611'710	8'316'575	8'050'954	7'811'896	7'014'033	6'878'666	6'473'818	8'939'637	8'611'710	8'316'575	8'050'954	7'811'896
Coffee	*8'611'710*	*8'316'575*	*8'050'954*	*7'811'896*	*7'014'033*	*6'878'666*	*7'888'909*	*8'939'637*	*8'611'710*	*8'316'575*	*8'050'954*	*7'811'896*	*7'014'033*	*6'878'666*	*6'473'818*	*8'939'637*	*8'611'710*	*8'316'575*	*8'050'954*	*7'811'896*
Productivity gain	-	-	706'521	2'195'096	3'334'576	3'327'640	1'891'805	458'045	441'242	426'121	412'511	400'262	359'382	352'446	331'702	458'045	441'242	426'121	398'010	372'710
Plantation renewal	-	-	*695'697*	*2'182'728*	*2'830'183*	*2'830'183*	*1'415'091*	-	-	-	-	-	-	-	-	-	-	-	-	-
Climate-smart practices	-	-	*10'824*	*12'368*	*504'393*	*497'457*	*476'714*	*458'045*	*441'242*	*426'121*	*412'511*	*400'262*	*359'382*	*352'446*	*331'702*	*458'045*	*441'242*	*426'121*	*398'010*	*372'710*
Additional Revenues	-	-	21'648	59'894	59'521	82'917	58'184	81'014	80'202	32'010	78'814	78'222	99'100	98'765	74'911	115'292	103'054	90'898	100'966	99'744
CRUs	-	-	-	*35'157*	*35'157*	*58'888*	*35'157*	*58'888*	*58'888*	*11'426*	*58'888*	*58'888*	*81'740*	*81'740*	*58'888*	*93'166*	*81'740*	*70'314*	*81'740*	*81'740*
Organic Premium	-	-	*21'648*	*24'737*	*24'364*	*24'029*	*23'027*	*22'126*	*21'314*	*20'584*	*19'926*	*19'334*	*17'360*	*17'025*	*16'023*	*22'126*	*21'314*	*20'584*	*19'226*	*18'004*
Costs savings from agroforestry	168'135	136'904	30'941	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	39'037	74'170
Increased life-span coffee trees	*168'135*	*136'904*	*30'941*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*39'037*	*74'170*
ADDITIONAL INCOMES	**168'135**	**136'904**	**759'109**	**2'254'990**	**3'394'097**	**3'410'557**	**1'949'990**	**539'058**	**521'444**	**458'130**	**491'325**	**478'484**	**458'481**	**451'210**	**406'613**	**573'336**	**544'297**	**517'018**	**538'012**	**546'624**
Productivity loss	-	-	104'355	327'409	424'527	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Agroforestry	-	-	*104'355*	*327'409*	*424'527*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Additional costs	1'218'979	992'553	224'320	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	283'018	537'735
Project implementation costs	*330'838*	*193'226*	*224'320*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Loss of earnings	*888'141*	*799'327*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*283'018*	*537'735*
ADDITIONAL COSTS	**1'218'979**	**992'553**	**328'674**	**327'409**	**424'527**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**283'018**	**537'735**
Net additional income	**-1'050'844**	**-855'649**	**430'435**	**1'927'581**	**2'969'570**	**3'410'557**	**1'949'990**	**539'058**	**521'444**	**458'130**	**491'325**	**478'484**	**458'481**	**451'210**	**406'613**	**573'336**	**544'297**	**517'018**	**254'994**	**8'889**
Adjusted sales of participants	**7'560'866**	**7'460'926**	**8'481'390**	**9'739'476**	**9'983'603**	**10'289'224**	**9'838'899**	**9'478'695**	**9'133'154**	**8'774'706**	**8'542'279**	**8'290'380**	**7'472'514**	**7'329'877**	**6'880'431**	**9'512'973**	**9'156'006**	**8'833'594**	**8'305'949**	**7'820'785**

Cooperativa Tierra de Café

102 producers	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Sales of participants	4'015'536	3'877'918	3'754'063	3'642'592	3'270'559	3'207'439	3'678'503	4'168'444	4'015'536	3'877'918	3'754'063	3'642'592	3'270'559	3'207'439	3'018'663	4'168'444	4'015'536	3'877'918	3'754'063	3'642'592
Coffee	*4'015'536*	*3'877'918*	*3'754'063*	*3'642'592*	*3'270'559*	*3'207'439*	*3'678'503*	*4'168'444*	*4'015'536*	*3'877'918*	*3'754'063*	*3'642'592*	*3'270'559*	*3'207'439*	*3'018'663*	*4'168'444*	*4'015'536*	*3'877'918*	*3'754'063*	*3'642'592*
Productivity gain	-	-	324'395	1'028'265	1'559'520	1'556'222	886'518	217'801	209'812	202'621	196'150	190'325	170'887	167'589	157'725	217'801	209'812	202'621	189'254	177'224
Plantation renewal	-	-	*324'395*	*1'017'779*	*1'319'680*	*1'319'680*	*659'840*	-	-	-	-	-	-	-	-	-	-	-	-	-
Climate-smart practices	-	-	-	*10'486*	*239'840*	*236'542*	*226'678*	*217'801*	*209'812*	*202'621*	*196'150*	*190'325*	*170'887*	*167'589*	*157'725*	*217'801*	*209'812*	*202'621*	*189'254*	*177'224*
Additional Revenues	-	-	-	38'085	37'769	49'037	36'636	47'423	46'734	23'012	45'558	45'056	54'506	54'222	42'249	64'108	57'858	51'677	56'088	55'051
CRUs	-	-	-	*17'113*	*17'113*	*28'665*	*17'113*	*28'665*	*28'665*	*5'562*	*28'665*	*28'665*	*39'788*	*39'788*	*28'665*	*45'350*	*39'788*	*34'226*	*39'788*	*39'788*
Organic Premium	-	-	-	*20'972*	*20'656*	*20'372*	*19'523*	*18'758*	*18'070*	*17'451*	*16'893*	*16'392*	*14'718*	*14'433*	*13'584*	*18'758*	*18'070*	*17'451*	*16'299*	*15'263*
Costs savings from agroforestry	79'334	64'382	15'061	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18'202	34'585
Increased life-span coffee trees	*79'334*	*64'382*	*15'061*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*18'202*	*34'585*
ADDITIONAL INCOMES	**79'334**	**64'382**	**339'456**	**1'066'350**	**1'597'289**	**1'605'258**	**923'154**	**265'224**	**256'546**	**225'634**	**241'708**	**235'382**	**225'392**	**221'810**	**199'974**	**281'909**	**267'670**	**254'298**	**263'544**	**266'860**
Productivity loss	-	-	48'659	152'667	197'952	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Agroforestry	-	-	*48'659*	*152'667*	*197'952*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Additional costs	575'169	466'772	109'191	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	131'968	250'739
Project implementation costs	*161'040*	*94'055*	*109'191*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Loss of earnings	*414'130*	*372'717*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*131'968*	*250'739*
ADDITIONAL COSTS	**575'169**	**466'772**	**157'850**	**152'667**	**197'952**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**131'968**	**250'739**
Net additional income	**-495'836**	**-402'389**	**181'606**	**913'683**	**1'399'337**	**1'605'258**	**923'154**	**265'224**	**256'546**	**225'634**	**241'708**	**235'382**	**225'392**	**221'810**	**199'974**	**281'909**	**267'670**	**254'298**	**131'576**	**16'121**
Adjusted sales of participants	**3'519'700**	**3'475'529**	**3'935'668**	**4'556'275**	**4'669'896**	**4'812'697**	**4'601'657**	**4'433'668**	**4'272'082**	**4'103'552**	**3'995'770**	**3'877'974**	**3'495'951**	**3'429'249**	**3'218'637**	**4'450'354**	**4'283'206**	**4'132'217**	**3'885'639**	**3'658'714**

B.1.2 Annual Net Present Value of Projects

Cooperativa Río Verde

200 producers	NPV1	NPV2	NPV3	NPV4	NPV5	NPV6	NPV7	NPV8	NPV9	NPV10	NPV11	NPV12	NPV13	NPV14	NPV15	NPV16	NPV17	NPV18	NPV19	NPV20
Sales of participants	8'611'710	7'359'801	6'305'078	5'414'035	4'301'838	3'733'464	3'789'189	3'799'888	3'239'380	2'768'462	2'371'717	2'036'543	1'618'179	1'404'379	1'169'667	1'429'365	1'218'525	1'041'384	892'145	766'066
Coffee	*8'611'710*	*7'359'801*	*6'305'078*	*5'414'035*	*4'301'838*	*3'733'464*	*3'789'189*	*3'799'888*	*3'239'380*	*2'768'462*	*2'371'717*	*2'036'543*	*1'618'179*	*1'404'379*	*1'169'667*	*1'429'365*	*1'218'525*	*1'041'384*	*892'145*	*766'066*
Productivity gain	-	-	553'309	1'521'312	2'045'158	1'806'110	908'669	194'697	165'978	141'849	121'521	104'347	82'911	71'957	59'931	73'237	62'434	53'358	44'104	36'549
Plantation renewal	-	-	*544'833*	*1'512'740*	*1'735'804*	*1'536'110*	*679'695*	-	-	-	-	-	-	-	-	-	-	-	-	-
Climate-smart practices	-	-	*8'477*	*8'572*	*309'354*	*270'000*	*228'974*	*194'697*	*165'978*	*141'849*	*121'521*	*104'347*	*82'911*	*71'957*	*59'931*	*73'237*	*62'434*	*53'358*	*44'104*	*36'549*
Additional Revenues	-	-	16'954	41'509	36'506	45'004	27'947	34'436	30'169	10'655	23'218	20'392	22'863	20'164	13'535	18'434	14'582	11'382	11'188	9'781
CRUs	-	-	-	*24'366*	*21'562*	*31'962*	*16'887*	*25'031*	*22'151*	*3'804*	*17'348*	*15'352*	*18'858*	*16'688*	*10'640*	*14'896*	*11'566*	*8'805*	*9'058*	*8'016*
Organic Premium	-	-	*16'954*	*17'144*	*14'943*	*13'042*	*11'060*	*9'405*	*8'017*	*6'852*	*5'870*	*5'040*	*4'005*	*3'476*	*2'895*	*3'538*	*3'016*	*2'577*	*2'130*	*1'765*
Costs savings from agroforestry	168'135	121'154	24'231	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4'326	7'273
Increased life-span coffee trees	*168'135*	*121'154*	*24'231*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*4'326*	*7'273*
ADDITIONAL INCOMES	**168'135**	**121'154**	**594'494**	**1'562'821**	**2'081'663**	**1'851'114**	**936'616**	**229'132**	**196'146**	**152'505**	**144'739**	**124'740**	**105'774**	**92'121**	**73'465**	**91'671**	**77'016**	**64'740**	**59'618**	**53'604**
Productivity loss	-	-	81'725	226'911	260'371	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Agroforestry	-	-	*81'725*	*226'911*	*260'371*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Additional costs	1'218'979	878'365	175'675	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	31'362	52'732
Project implementation costs	*330'838*	*170'996*	*175'675*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Loss of earnings	*888'141*	*707'369*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*31'362*	*52'732*
ADDITIONAL COSTS	**1'218'979**	**878'365**	**257'400**	**226'911**	**260'371**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**31'362**	**52'732**
Net additional income	**-1'050'844**	**-757'212**	**337'094**	**1'335'910**	**1'821'293**	**1'851'114**	**936'616**	**229'132**	**196'146**	**152'505**	**144'739**	**124'740**	**105'774**	**92'121**	**73'465**	**91'671**	**77'016**	**64'740**	**28'256**	**872**
Adjusted sales of participants	**7'560'866**	**6'602'590**	**6'642'172**	**6'749'946**	**6'123'131**	**5'584'578**	**4'725'805**	**4'029'020**	**3'435'526**	**2'920'966**	**2'516'456**	**2'161'283**	**1'723'953**	**1'496'501**	**1'243'133**	**1'521'036**	**1'295'541**	**1'106'124**	**920'401**	**766'937**

Cooperativa Tierra de Café

102 producers	NPV1	NPV2	NPV3	NPV4	NPV5	NPV6	NPV7	NPV8	NPV9	NPV10	NPV11	NPV12	NPV13	NPV14	NPV15	NPV16	NPV17	NPV18	NPV19	NPV20
Sales of participants	4'015'536	3'431'786	2'939'982	2'524'499	2'005'895	1'740'869	1'766'853	1'771'842	1'510'483	1'290'900	1'105'903	949'615	754'537	654'845	545'402	666'496	568'183	485'585	415'996	357'207
Coffee	*4'015'536*	*3'431'786*	*2'939'982*	*2'524'499*	*2'005'895*	*1'740'869*	*1'766'853*	*1'771'842*	*1'510'483*	*1'290'900*	*1'105'903*	*949'615*	*754'537*	*654'845*	*545'402*	*666'496*	*568'183*	*485'585*	*415'996*	*357'207*
Productivity gain	-	-	254'049	712'639	956'483	844'655	425'811	92'579	78'923	67'450	57'783	49'617	39'425	34'216	28'497	34'824	29'688	25'372	20'972	17'379
Plantation renewal	-	-	*254'049*	*705'372*	*809'384*	*716'269*	*316'933*	-	-	-	-	-	-	-	-	-	-	-	-	-
Climate-smart practices	-	-	-	*7'267*	*147'098*	*128'385*	*108'878*	*92'579*	*78'923*	*67'450*	*57'783*	*49'617*	*39'425*	*34'216*	*28'497*	*34'824*	*29'688*	*25'372*	*20'972*	*17'379*
Additional Revenues	-	-	-	26'395	23'165	26'615	17'597	20'157	17'580	7'660	13'421	11'746	12'575	11'070	7'633	10'250	8'187	6'471	6'215	5'399
CRUs	-	-	-	*11'860*	*10'496*	*15'558*	*8'220*	*12'184*	*10'782*	*1'851*	*8'444*	*7'473*	*9'179*	*8'123*	*5'179*	*7'251*	*5'630*	*4'286*	*4'409*	*3'902*
Organic Premium	-	-	-	*14'534*	*12'669*	*11'057*	*9'377*	*7'973*	*6'797*	*5'809*	*4'977*	*4'273*	*3'395*	*2'947*	*2'454*	*2'999*	*2'557*	*2'185*	*1'806*	*1'497*
Costs savings from agroforestry	79'334	56'976	11'795	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2'017	3'392
Increased life-span coffee trees	*79'334*	*56'976*	*11'795*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*2'017*	*3'392*
ADDITIONAL INCOMES	**79'334**	**56'976**	**265'844**	**739'034**	**979'647**	**871'270**	**443'408**	**112'736**	**96'502**	**75'110**	**71'204**	**61'363**	**51'999**	**45'286**	**36'131**	**45'075**	**37'874**	**31'843**	**29'204**	**26'169**
Productivity loss	-	-	38'107	105'806	121'408	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Agroforestry	-	-	*38'107*	*105'806*	*121'408*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Additional costs	575'169	413'072	85'512	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	14'624	24'588
Project implementation costs	*161'040*	*83'235*	*85'512*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Loss of earnings	*414'130*	*329'838*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	*14'624*	*24'588*
ADDITIONAL COSTS	**575'169**	**413'072**	**123'620**	**105'806**	**121'408**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**-**	**14'624**	**24'588**
Net additional income	**-495'836**	**-356'097**	**142'224**	**633'228**	**858'240**	**871'270**	**443'408**	**112'736**	**96'502**	**75'110**	**71'204**	**61'363**	**51'999**	**45'286**	**36'131**	**45'075**	**37'874**	**31'843**	**14'580**	**1'581**
Adjusted sales of participants	**3'519'700**	**3'075'689**	**3'082'206**	**3'157'727**	**2'864'135**	**2'612'139**	**2'210'261**	**1'884'578**	**1'606'986**	**1'366'010**	**1'177'107**	**1'010'979**	**806'536**	**700'131**	**581'532**	**711'570**	**606'058**	**517'428**	**430'577**	**358'788**

B.1.3 Total Value Generated from Project over 20 Years

Cooperativa Río Verde

200 producers	Total	Total per ha	Total NPV	NPV per ha
Sales of participants	158'400'807	134'986	63'270'816	53'918
Coffee	*158'400'807*	*134'986*	*63'270'816*	*53'918*
Productivity gain	16'733'475	14'260	8'047'431	6'858
Plantation renewal	*9'953'881*	*8'482*	*6'009'181*	*5'121*
Climate-smart practices	*6'779'593*	*5'777*	*2'038'250*	*1'737*
Additional Revenues	1'415'154	1'206	408'719	348
CRUs	*1'042'405*	*888*	*276'989*	*236*
Organic Premium	*372'749*	*318*	*131'730*	*112*
Costs savings from agroforestry	449'187	383	325'119	277
Increased life-span coffee trees	*449'187*	*383*	*325'119*	*277*
ADDITIONAL INCOMES	**18'597'816**	**15'849**	**8'781'270**	**7'483**
Productivity loss	856'291	730	569'006	485
Agroforestry	*856'291*	*730*	*569'006*	*485*
Additional costs	3'256'605	2'775	2'357'114	2'009
Project implementation costs	*748'383*	*638*	*677'509*	*577*
Loss of earnings	*2'508'222*	*2'137*	*1'679'605*	*1'431*
ADDITIONAL COSTS	**4'112'896**	**3'505**	**2'926'121**	**2'494**
Net additional income	**14'484'920**	**12'344**	**5'855'149**	**4'990**
Adjusted sales of participants	**172'885'727**	**147'329**	**69'125'965**	**58'908**

102 producers	Total	Total per ha	Total NPV	NPV per ha
Sales of participants	73'860'377	129'307	29'502'415	51'650
Coffee	*73'860'377*	*129'307*	*29'502'415*	*51'650*
Productivity gain	7'864'543	13'768	3'770'361	6'601
Plantation renewal	*4'641'374*	*8'126*	*2'802'008*	*4'905*
Climate-smart practices	*3'223'169*	*5'643*	*968'353*	*1'695*
Additional Revenues	805'067	1'409	232'135	406
CRUs	*507'405*	*888*	*134'828*	*236*
Organic Premium	*297'662*	*521*	*97'307*	*170*
Costs savings from agroforestry	211'564	370	153'513	269
Increased life-span coffee trees	*211'564*	*370*	*153'513*	*269*
ADDITIONAL INCOMES	**8'881'174**	**15'548**	**4'156'009**	**7'276**
Productivity loss	399'278	699	265'321	464
Agroforestry	*399'278*	*699*	*265'321*	*464*
Additional costs	1'533'839	2'685	1'112'966	1'948
Project implementation costs	*364'286*	*638*	*329'787*	*577*
Loss of earnings	*1'169'553*	*2'048*	*783'179*	*1'371*
ADDITIONAL COSTS	**1'933'117**	**3'384**	**1'378'287**	**2'413**
Net additional income	**6'948'057**	**12'164**	**2'777'722**	**4'863**
Adjusted sales of participants	**80'808'434**	**141'471**	**32'280'137**	**56'513**

B.1.4 Sensitivity Analysis of Project Implementation (Cooperativa Río Verde)

Variables	Variation (%)	Value	Unit	H0	H1	Comparative H1-H0	Comparative H1/H0	H1/H0 difference
			USD/ha	53'918	58'908	+4'990	1.093	0.000
			%	0	9.3	9.3		
			Results					
Coffee price	+40	300	USD/ha	75'485	82'575	+7'090	1.094	0.001
			%	40.0	40.2	0.2	1.004	
	-50	128	USD/ha	32'351	35'240	+2'889	1.089	0.003
			%	-40.0	-40.2	-0.2	1.004	
CRU price	+57	50	USD/ha	53'918	59'009	+5'091	1.094	0.002
			%	0.0	0.2	0.2		
	-57	20	USD/ha	53'918	58'806	+4'888	1.091	0.002
			%	0.0	-0.2	-0.2		
Project size	+60	40	USD/ha	53'918	59'916	+5'998	1.111	0.019
			%	0.0	1.7	1.7		
	-60	10	USD/ha	53'918	57'899	+3'981	1.074	0.019
			%	0.0	-1.7	-1.7		
Organic certification members (baseline)	+12	100	USD/ha	53'918	58'771	+4'853	1.090	0.003
			%	0.0	-0.2	-0.2		
	-12	78	USD/ha	53'918	59'044	+5'126	1.095	0.003
			%	0.0	0.2	0.2		
Discount rate	+38	18	USD/ha	43'052	46'733	+3'681	1.086	0.007
			%	-20.2	-20.7	-0.5	1.025	
	-38	8	USD/ha	71'801	78'686	+6'884	1.096	0.003
			%	33.2	33.6	0.4	1.012	
Productivity gain CSA	+10	30	USD/ha	53'918	59'748	+5'830	1.108	0.016
			%	0.0	1.4	1.4		
	-10	10	USD/ha	53'918	58'067	+4'149	1.077	0.016
			%	0.0	-1.4	-1.4		

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