RESEARCH ARTICLE

REVISED "« Coffee agroforestry business-driven clusters »: an innovative social and environmental organisational model for coffee farm renovation [version 2; peer review: 2 approved]

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Abstract

Background: Worldwide coffee production, especially Arabica coffee, is threatened by climatic change, plants diseases and vulnerability of smallholders. Meanwhile, consumers' demand for socially and environmentally sustainable products is steadily increasing, driving the engagement of stakeholders in agro-ecological and social initiatives. Here we present a new organizational model, the "Coffee agroforestry business-driven cluster" (CaFC), which aims at preserving ecosystems while offering producers a fair income. Based on an original local micro value-chain dedicated to sustainable production of high-quality Arabica coffee under agroforestry systems, the CaFC model stands out by addressing the issues around plantation renovation, a crucial process that requires considerable investments from producers.

Methods: Based on a pilot project in Nicaragua, we illustrate how the operational principles of CaFC can be applied in a real setting. Using data shared by key stakeholders involved in the project, we assess the profitability of the CaFC model by comparing different scenarios and applying sensitivity analysis. We then reflect on the reproducibility of the model in other contexts, building on lessons learned from ongoing implementations in Vietnam and Cameroon.

Results: For producers renovating their plantations, the CaFC model consistently outperforms other scenarios, offering high quality premiums coupled with capacity building, access to highly productive varieties that perform well under agroforestry systems and adapted credit with favourable repayment schemes. Implementation in Vietnam and Cameroon show that the model can be successfully

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replicated with some adaptation to local contexts. These cases also highlight the importance of mutual interests, trust and communication in enabling collaboration between stakeholders.
Conclusions: The CaFC model has great potential for positive environmental and economic impact and offers strong incentives for stakeholders involved in its resulting micro value-chain. The concept was initially developed in Nicaragua for coffee but could also be adapted in other countries or even to other commodities such as cocoa.

Keywords
Arabica coffee, agroforestry cluster approach, Nicaragua, Cameroon, Vietnam

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REVISED **Amendments from Version 1**

The title of the article was changed from "Local value-chains dedicated to sustainable production (coffee agroforestry business-driven clusters or CaFC): a new organizational model to foster social and environmental innovations through farm renovation" to "« Coffee agroforestry business-driven clusters »: an innovative social and environmental organisational model for coffee farm renovation". A number of small changes have been applied to the content of the article following comments and suggestions of reviewers in order to clarify and harmonize the content. Relevant references suggested by reviewers were added and cited in the text, others were removed. The structure of the article remains the same, with no sections added or removed. The associated data and figures also remain the same.

Any further responses from the reviewers can be found at the end of the article

Introduction

Arabica coffee (*Coffea arabica* L.) has established itself as a high-quality product, characterized by its superior organoleptic qualities and considered a social product in many countries where so-called 'specialty' coffees have flourished over the last ten years. Producing such coffees involves new specifications for all participants in the supply chain. As the market for specialty coffees is expanding, new issues such as climate change, low carbon food print (Hergoualc'h *et al.*, 2012; Nab & Maslin, 2020) and respect for the environment are emerging.

The objective is now to produce, within the framework of sustainable agriculture, high performing varieties (with high yeilds and high organoleptic quality potential) to guarantee farm profitability, adapted to local climates and respectful of the environment. To preserve biodiversity and limit the effects of climate change, coffee production systems must provide positive externalities to the environment. The changes in production practices ideally needed to achieve these goals often require replanting coffee farms with adapted and efficient varieties.

Although it is crucial to ensuring the sustainability of their activity, the plantation renovation process can be a huge financial burden for farmers. The investment required to replant one hectare of coffee is in the order of 3,500 to 7,000 USD/ha, depending on the type of planting material (BREEDCAFS survey, Matrice project, personal communications with stakeholders in Nicaragua). Moreover, bank rates available to smallholders through local credit schemes are generally high – between 15 and 25%. Lacking access to the required capital for investment, many producers and especially smallholders tend to postpone this operation. For most smallholders, renovating plantations with the highest performing planting material remains inaccessible.

When developing agroforestry systems, both the issues of plantation renovation and appropriate choice of coffee variety are often overlooked by the research and development community. We argue that these are essential components for improving the performance and sustainability of coffee production systems.

To address this issue, we propose an innovative mode of organization that involves close collaboration between multiple stakeholders, including a strong commitment from the roaster. Indeed, to secure a supply of quality coffee (refering especially to organoleptic quality), it is in the roasters' interest to support producers in renovating their plantations with high performing coffee varieties with high organloeptic quality potential and to therefore remunerate them fairly for implementing agronomic practices that are compatible with the values that they wish to communicate to their customers.

The CaFC (coffee agroforestry business-driven clusters) concept was developed to meet this objective (Bertrand *et al.*, 2019), initially within the framework of a project in 2017 (MATRICE project led by CIRAD), then within the framework of the EU/BREEDCAFS H2020 project initiated in 2019. The aim is to establish agroforestry clusters according to specifications jointly defined by all partners and local actors.

In this article, we first describe the general concept of the CaFC model, its vision and objectives. Based on the pilot project in Nicaragua, initiated in 2016, we illustrate how the CaFC model can be implemented in real conditions and show evidence of its potential. Using data shared by key stakeholders of the Nicaragua project – ECOM (coffee-buyer), the Moringa partnerships fund, NicaFrance (foundation), CIRAD (research institution) and Nespresso (roaster) – as well as data from a similar project in Peru, we assess the profitability of the CaFC model by comparing realistic scenarios and applying sensitivity analysis. We then discuss the model's reproducibility in other socio-economic contexts, building on lessons learned from the pilot project in Nicaragua and ongoing applications of the model in Vietnam and Cameroon.

The concept of coffee agroforestry Business driven Clusters (CaFC)

History and main components of a CaFC. Coffee agroforestry Business driven Clusters (CaFC) are defined as local micro value-chains dedicated to sustainable production under agroforestry systems of high-quality Arabica coffee with locally adapted and improved coffee planting material. The principles of these clusters are based on three pillars:

1) The creation of a specific micro-value chain, involving a limited set of actors, makes it possible to maximize gross margin per ha for the benefit of all stakeholders, including farmers. This short and simplified value chain also offers better coffee traceability, an important selling point for the "specialty coffee" market.

2) The use of high performing and resilient coffee varieties that guarantee high yields under agroforestry production systems and high organoleptic quality.

3) Agroforestry management that stabilizes production (over a longer period than full sun plantations), improves and

homogenizes coffee quality and provides valuable ecosystem services – through limited use of inputs, increased soil protection, and buffering effects on climate change. It also allows producers to diversify their income by combining the cultivation of coffee with fruit trees or timber trees, depending on local demand and markets.

Innovation platform and creation of a micro value-chain. The CaFC model is based on an original organization orchestrated by a network of six types of stakeholders forming an Innovation and Dialogue platform: producers, roasters, brokers, investors, government organisations and research-development actors. Through this Innovation and Dialogue platform, specifications are agreed upon between stakeholders regarding the varieties of coffee planted, agricultural management, coffee processing as well as purchase prices throughout the chain. Research and development organizations act as third parties in the coordination of the innovation platform, where the objective is to develop an equitable distribution of added value throughout the value chain. Of course the balance between the stake holders is delicate and requires a sincere and transparent dialogue.

One key point of the CaFC model is that a purchasing price, significantly above that of world market price, is initially accepted by the roaster, guaranteeing all actors downstream to share a significant quality price premium – including participating producers. This reduces risks and allows for the various investments required to develop a system that produces a consistent supply of high-quality coffee. Such a system includes i) renovating plantations with high-quality and high performing locally adapted Arabica plant material, ii) developing agroforestry systems, iii) providing extension services through various means, such as private service providers or digital agriculture information services, to ensure that farmers have the capacity to implement quality-enhancing and agroforestry management practices and adapted processing equipment and services. Eventually for roasters, this commitment enables them to secure a stable supply of quality coffee that is highly differentiated with a high added value potential.

Plantation renovation at the heart of the concept. In order to avoid a decline in productivity, a coffee plantation must be replanted after some years of production. While this renovation process is crucial to ensuring the sustainability of coffee production, it can be a huge financial burden for farmers.

The cost of replanting itself lies in the order of 3500 to 7000 USD/ha for the first two years according to a 2020 survey implemented by CIRAD in Nicaragua. The majority of coffee is currently produced by smallholders managing less than five ha of coffee (Jha *et al.*, 2011). For these smallholders, generating the capital required to invest in plantation renovation can prove difficult, and local credit mechanisms typically available are not adapted due to excessive interest rates.

Decisions taken during plantation renovation will impact socio-economic and environmental outcomes for years to come. For producers, this process is not only paramount in ensuring the long-term profitability of their farms, it also represents a tremendous opportunity to redefine their production practices, adopt new technologies, and switch to higher quality coffee varieties. Recognizing plantation renovation as a steppingstone in the implementation of sustainable practices, the CaFC model stands out by integrating this process within a tailored and locally adapted sustainable production system, a starting point for which is agroforestry.

Adopting high performing coffee varieties adapted to agroforestry systems. Buyers and roasters are well aware that the choice of variety has a great importance on the sensory profile of the coffee and, ultimately, on its value and marketability. However, with very few exceptions, stakeholders upstream have limited control over the varieties they buy. Moreover, producers often have access to a limited diversity of coffee varieties. The CaFC concept offers a solution to this dilemma: roasters and farmers are given the opportunity to jointly choose a variety and a process tailored to the local production context and with specific characteristics. The decision taken on such an important economic and strategic factor in coffee production, and recognition of common interests between stakeholders is what defines the CaFC model as 'business driven'.

In Arabica, the types of varieties are pure line, clonally propagated F1 hybrid cultivars and F1 hybrid cultivars reproduced by seed (using male gene sterility).

The choice of genetic material is based on two considerations : i) the different agronomic performances between varieties, ii) the availability of large amounts of seeds. Today, 90% of the world's Arabica plantations (more than seven million hectares) are planted with line varieties derived from a narrow genetic basis (Montagnon *et al.*, 2021). Despite an effort of gene introgression, Setotaw *et al.* (2010) showed that the genetic bases of 121 cultivars released in Brazil between 1939 and 2009 were defined by only 13 ancestors. The major risk in using line varieties is that of uniformity as they present poor adaptability due to their narrow genetic base and are more prone to the attack of new diseases (Bertrand *et al.*, 2021).

In the majority of Arabica producing countries, there are no controlled or certified seed production bodies, putting farmers at risk that the seeds for new trees are not of consistent quality, genetic purity and variety standards (Pruvot-Woehl *et al.*, 2020). Moreover, there is no strict autogamy with Arabica and a certain rate of cross-fertilisation leads to a 'degenerative effect' of the variety after a few generations. With an allogamy rate of 4% to 10%, the percentage of off-types is estimated to be between 12 and 20% after three generations (Gallais, 1989).

The lack of certified seed and seedling producing schemes results sometimes in poor-quality plants or seeds and fraudulent seed sales, which lowers productivity at the farm level. It is therefore necessary to guarantee the quality of planting material with reliable traceability and introduce quality control.

We based our study on the high performing variety 'Starmaya', an F1 hybrid produced by seeds (Georget *et al*., 2019). A Starmaya plant coming out of the nursery and ready to be planted costs about 1.2 times the cost of a plant produced by the producer with pure line seeds. Starmaya F1 hybrids were shown to have better agronomic characteristics in terms of vigor, bean size, and yield than the Marsellesa® cultivar or the Caturra red as control (Georget *et al*., 2019; Marie *et al*., 2020). The Starmaya also had a higher cup quality than the traditional cultivars, such as Marsellesa® and Caturra red.

Through the CaFC model, high performing and locally adapted varieties such as Starmaya are developed based on specifications agreed upon between stakeholders of the Innovation platform. Moreover, the quality of the planting material provided through the CaFC cluster is guaranteed through a certification system developed by World Coffee Research – a partner organization in the initiative.

Offering a fair price. Voluntary sustainability standards (VSS) such as Fair Trade, which are becoming a requirement for access to specialty coffee markets, face increasing criticism from academics and stakeholders of the coffee sector. VSS have been the subject of many studies in the past decades, especially in coffee value chains, and contradicting results have been reported regarding their impacts on various elements of sustainable livelihoods. Whereas some studies show positive effects for at least some environmental, social or economic sustainability indicators, many find no or even negative impacts (Akoyi & Maertens, 2017; Baake *et al*., 2018; Dietz & Grabs, 2022; Fort & Ruben, 2017; Minten *et al*., 2018; Mithöfer *et al*., 2017; Oya *et al*., 2017; Vanderhaegen *et al*., 2018). Specialty coffees are usually certified by one or several of these VSS as a communication tool to consumers regarding their sustainability. While they often result in higher prices at the farm gate, questions remain about the extent to which the benefits of higher retail prices translate into higher revenues for farmers and rural communities (Rueda & Lambin, 2013). As a novel organizational model, CaFC strives to overcome these short-comings. Through transparent collaboration between producers, roasters and other stakeholders, the CaFC model is designed to guarantee shared added value of high quality coffee and fair prices to producers regardless of the size of their farm and volume of coffee delivered.

Promoting agroforestry systems for increased environmental sustainability. The CaFC model addresses one of the most significant threats to coffee production: the shift from diversified shade coffee to simplified shade or unshaded coffee (Goodall *et al*. 2015; Harvey *et al*., 2021; Jha *et al.* 2014).

Coffee agroforests may vary from a single shade tree species planted within the rows of coffee trees to traditional or rustic systems where coffee is planted under managed forests, where numerous tree species provide an almost complete shade cover through a multi-strata tree canopy (Perfecto *et al*., 2005). A modern version of the latter system is promoted through the CaFC model, where a variety of shade trees are pro-actively selected to provide a range of services to coffee trees. Such systems have been appraised for their services as refuge for biodiversity, including their role in biological corridors, where the productive system also serves to connect fragmented forested areas. Management of shade tree cover in coffee agroforests is also considered one of the key measures towards climate change adaptation (Vaast *et al*., 2016; Verburg *et al*., 2019). Shade trees in coffee agroforestry systems may serve two climate related purposes: i) adaptation, by buffering the expectedly increasing variability in temperature and rainfall and improving resilience to extreme weather events such as windstorms, frost or hail, and ii) mitigation, by capturing and storing carbon in the shade trees, below and above ground (Goodall *et al*., 2015; Pinoargote *et al*., 2017; Vaast *et al*., 2016; Verburg *et al*., 2019). Coffee agroforestry systems that have limited disturbance to the soil present a more organic matter-rich system than many other agricultural systems and – when coffee does not replace forests – are a step forward in climate change mitigation (Guillemot *et al*., 2018; Verburg *et al*., 2019).

Agroforestry systems also provide additional services or benefits to the producers. The shade trees, especially when consisting of flowering trees, may provide a habitat for pollinators and thus provide pollination services, not only to the coffee crop but to other crops in the vicinity (Boreux *et al*., 2013). The shade environment may also enhance biological control of certain pests and diseases, which otherwise are controlled through commercial or homemade inputs, which come at a cost to farmers. These different services associated with shade trees all contribute to the growth and development of the coffee trees, but the shade trees themselves also directly provide products to the farmers' households in the form of fuel wood, timber and other materials, as well as food products (Nguyen *et al*., 2020). Agroforest systems developed through the CaFC model are designed to incorporate native timber trees that increase their resilience to climate change and provide environmental services to neighboring communities. At the end of their life span, these timber trees should represent a significant capital for the producer.

However, the main shortcoming of coffee agroforests remains the associated reduction in coffee yield. Decades of breeding strategies and agricultural extension policies focusing on high yields have resulted in non-shaded coffee monocultures being the dominant production system and has undermined research in varieties adapted to shaded environments and able to perform well under agroforestry systems. This issue is at the core of the CaFC cluster, which renovates farm plantations with new improved Arabica varieties that provide high yield under shaded conditions.

Management of innovative agroforestry systems requires extensive knowledge not always accessible to smallholder farmers. The CaFC model integrates capacity building and training of farmers to overcome these challenges by enabling a central coffee farm to offer technical expertise to smaller farms joining the cluster, as well as an access to innovative processing

practices and equipment that can help tackle local sustainability issues.

Integrating and creating synergies with current certifications. CaFC shares similar objectives with other certification systems – e.g. Fairtrade, Rainforest Alliance, UTZ – offering smallholders access to differentiated markets and price premiums, reducing their vulnerability to price volatility, improving their livelihoods and promoting agricultural practices that are respectful of the environment. The organization in agroforestry clusters does not obliterate these certifications. On the contrary, it uses and reinforces them by increasing their reliability through the improved traceability of the CaFC's micro-value chain.

The pilot project in Nicaragua. The pilot project in Nicaragua is a great opportunity to illustrate how the CaFC model can be implemented in real life. The pilot cluster was established in two years from 2016 to 2017 in Nicaragua, where 1,300 ha of coffee trees are currently cultivated under agroforestry management in association with high value timber trees. Through this pilot project, coffee producers, ECOM (coffee-buyer), the Moringa partnerships fund, CIRAD and Nespresso (roaster), were all brought together within an Innovation and Dialogue platform coordinated by CIRAD.

The shade is composed of native species that have proven themselves in agroforestry systems, associated with coffee (*Cordia alliodora* 'Laurel', *Swietenia humilis* 'Caoba', *Juglans olanchana* 'Noga'l, *Platymiscium pleiostachyum* 'Coyote'), with densities between 250 and 400 trees per hectare at the time of replanting. During the first 5 years of development, thinning leads to real densities of 200 to 350 trees/hectare The percentage of shade at noon on a sunny day varies between 25 and 40% depending on the plots (exposure and age of trees).

Nespresso had initially expressed its interest in a stable supply of high-quality coffee produced by the pilot project in the Matagalpa region of Nicaragua. A cluster of large to medium producers (50 to 150 ha) – referred to as *out-growers* – has been developed around a central coffee estate owned by Nicafrance – La Cumplida. Through this central estate, training and assistance are provided by ECOM and Nicafrance to ensure farmers joining the cluster have the ability to adopt required practices and produce the highest quality coffee cherries. La Cumplida also provides other farms with high performing planting material and access to an innovative processing facility. This pilot project relies on a sustainable processing of the coffee cherries through an innovative wet milling station and applying the *honey process* method. This wet milling station – and others to be built in proximity to small out-growers spread around the cluster – uses far less water and ensures a safe management of wastewater, greatly reducing pressure on water resources and environmental pollution associated with the traditional wet milling process (Dadi *et al.*, 2018). While many farmers have their own wet mills, they do not always have easy access to free water, and many do not adopt best practices regarding waste-water management. Hence, the integration of the wet process through a central (and soon multiple) wet milling station translates into positive environmental impacts while also reducing cost and time for farmers.

Nicafrance and ECOM cover the renovation costs and production costs up to five years after replanting. After five years, large to medium out growers regain full control over their production and reap all the benefits from their new high yielding plantation selling coffee at high prices on a tailored specialty market. They can then pay back the remaining initial costs of renovation (plant material, labour for planting, inputs). Large to medium out-growers are certified UTZ and Rainforest Alliance (these two certification agencies having merged in 2018).

Since 2017, 24 smallholder farmers – referred to as small out-growers – have joined the cluster with on average one hectare of land renovated with new varieties – mainly the Marsellesa variety. This is a small-scale approach that allows the consortium to cover the risk associated with the experimental use of CaFCs.

Unlike large and medium size coffee farmers, who usually have various income sources and the capacity to recover from various coffee crises (diseases, price volatility, effect of the climate etc.), smallholders solely depend on the income generated by their coffee farm for their livelihood, and the various costs of joining the cluster could be a barrier to entry. A fair contract for smallholders has been developed for the pilot project, which is essential for enabling smallholders to join in the initiative. Smallholders enter into an agreement with ECOM and Nicafrance to lend the land they want to renovate at no cost during the first five years through a usufruct contract. Smallholder's entry into the initiative is facilitated by tailored credit repayment schemes with a delay in payment the first couple of years. Production costs are repaid by 50% of the coffee production during the years three to five at zero-interest for small out-growers. Renovation costs do not have to be repaid by the farmers during the first five years. In addition, ECOM offers small out-growers access to credit with favourable terms of repayment for them to cover these remaining costs.

The pre-existing relationships between CIRAD and some local large-scale producers have facilitated the current collaboration in Nicaragua. ECOM and Nicafrance have a long-standing business relationship. La Cumplida estate provides labor opportunities to local farmers in the area and Fundacion Nicafrance has established a positive link with the inhabitants around La Cumplida through a long-term project supporting education from primary school to university. Moreover, a clear interest by ECOM and Nicafrance in a sustainable supply of high-quality coffee has led them to accept the level of risks that allow the initiative to develop in the first place. Trust, mutual interest and long-term collaboration greatly

facilitated the implementation of CaFC concept and the Innovation platform.

Research questions

The impact of joining a CaFC on producers' net income plays a crucial role in incentivizing farmers and maximizing overall economic, social and environmental benefits. In order to better understand how and to what extent the specificities of the CaFC model can influence the overall income of a hypothetical smallholder, the next section will present a profitability assessment comparing the CaFC model to alternative scenarios.

Another key question relates to the reproducibility of the model in various contexts. Depending on the country, local production practices, challenges faced by coffee farmers and stakeholders, and broader social, economic and political contexts, the CaFC model may need to be adapted. Based on the Nicaragua pilot project, the BREEDCAFS project (https://www.breedcafs.eu/) has implemented two 10–15 ha clusters in Vietnam and Cameroon. Reviewing these two case studies, along with the Nicaragua prototype, will allow for the identification of key challenges and shortcomings in each context before concluding on key factors that need to be taken into account when applying the model in various contexts.

Methods

Profitability assessment

A key selling point of the CaFC model for producers is its attractive economic value in the context of plantation renovation. The impact of joining the CaFC model on producers' income is the result of multiple overlapping factors including i) quality premiums from roasters, ii) differences in varieties (–high performing variety, local line variety), implying different costs of production and yields; and iii) differences in credit repayment schemes (CaFC repayment schemes vs local credit schemes).

To assess the profitability of the CaFC model, we compare scenarios in which a producer would renovate one ha of land, through the CaFC model with the variety 'Starmaya', and alternative scenarios involving a loca pure line variety and different farm gate prices.

We focus our comparative analysis on a hypothetical agroforestry system under Fairtrade (FT) and Organic certifications, the most common combination between sustainability standards – including in Nicaragua (Fort & Ruben, 2017; Valkila, 2009). As they are also considered to be the most impactful standards (Dietz *et al.*, 2018) and to complement each other regarding economic, social and environmental sustainability issues (Parvathi *et al.*, 2017), the choice of FT-organic as a baseline to compare with the CaFC model appears the obvious one. We also add a baseline scenario with no certifications (conventional).

Data sources. To assess the profitability of a hypothetical CaFC model, we use available primary data from the Nicaragua pilot project combined with secondary sources for various scenario, including production costs data available from cooperative members in Peru.

Data was obtained from ECOM and Nicafrance regarding the costs related to the processing of coffee within the Nicaragua pilot project, and the final purchase price from Nespresso. This allowed us to calculate a realistic farm-gate price within a CaFC model that takes into account the various post-harvest processing costs for producing high-quality and homogeneous green coffee and the associated quality premium guaranteed by the roaster. Moreover, the tailored contract and repayment schemes that have been developed in collaboration with farmers through the Nicaragua pilot project will be used to model the CaFC credit repayment scheme.

As the future of the CaFC model is 100% smallholders and 100% organic, secondary data from a study in Peru considering plantation renovation with different varieties under organic production are used – see Data availability at the end of this document (Meter *et al.*, 2022a). This data was colected from three Peruvian cooperatives of more than 1000 farmers each, in the Jaen and Cajamarca region. Data used include renovation costs, costs of production and yields under organic production for two varieties: *F1 hybrid – Starmaya* and pure line *Typica*. Using production costs from another country is a limitation to our study. However, our objective is to compare the profitability of different replanting scenarios, with an emphasis on the variety and overall organisational model used. Therefore the comparisons remains valid as the cost differentials affect the different scenarios in the same way. Morevoer, typica is widely used in many producing countries (Mexico, Peru, Jamaica, etc.). For the variety description see https://varieties.worldcoffeeresearch.org/varieties/typica.

Finally, FT-organic price setting mechanisms and amounts of premiums are based on:

- Fair Trade minimum price (1.4 US$/lbs for washed Arabica coffee)
- Organic Price Premium (0.2 US$/lbs)

Farm gate prices. Based on data shared by stakeholders involved in the Nicaragua pilot project, the free on board (FOB) price for green coffee bought by Nespresso is:

$$CaFC\ FOB = Cprice + 1.03\ US\$/lbs$$

Processing and handling costs amount to 0.33 US$/lbs of green coffee, which sets the CaFC farm gate price for producers at:

$$CaFC\ FGP = Cprice + 0.7\ US\$/lbs$$

Moreover, as we are under the assumption of organic production, we add an extra organic premium to the CaFC farm gate price, set at 0.2 US$/lbs. Eventually, the price received by smallholders under the CaFC model is:

$$CaFC\ FGP = Cprice + 0.9\,US\$/lbs$$

For the FT-organic scenario, the farm gate price used is based on the current FT minimum price (1.4 US$/lbs) and organic premium (set at 0.2 US$/lbs). However, if the c-price is above the FT minimum price of 1.4, then the FT organic farm gate price is set base on the c-price and organic premium (Fort & Ruben, 2017).

When the c-price is below 1.4 US$/lbs, the FT Organic farm gate price is therefore set at:

$$FTOrganic\ FGP = 1.6\,US\$/lbs$$

When the c-price is above 1.4 US$/lbs, the FT Organic farm gate price is set at:

$$FTOrganic\ FGP = Cprice + 0.2\,US\$/lbs$$

For the conventional scenario, no premiums or minimum price are considered, with a farm gate price equal to the *Cprice*.

For all scenarios, the Cprice is set at 1.1 US$/lbs (average closing price throughout 2020).

Credit repayment schemes. The tailored contract and repayment schemes developed through the Nicaragua pilot project are used for the CaFC model credit repayment scheme. Table 1 summarizes the key modalities of the CaFC repayment scheme, along with typical local credit terms.

Planting material. Plantations in the Nicaragua project have been renovated with dwarf variety Marsellesa®, which produces good quality coffee and is resistant to coffee rust, but with average productivity (Marie *et al.*, 2020). The objective for the next smallholders' plantations and for the CaFC model in general is to renovate plantations with higher yielding varieties such as Starmaya, which produce 30% to 50% more than the Marsellesa variety (Marie *et al.*, 2020). In Vietnam and Cameroon, pilot projects are in development using the F1 hybrid variety 'Starmaya'.

To assess the profitability of the CaFC model, we will therefore consider one ha replanted with high yielding F1 hybrid variety Starmaya. For alternative scenarios, a lower-cost and lower-yielding local variety (Typica) will be considered.

Scenarios. Table 2 summarizes key parameters that vary in the three scenarios: farm gate prices, credit repayment schemes and varieties used for plantation renovation.

Profitability indicators. Assessing the impact of the CaFC model involves projecting streams of costs and benefits that vary throughout the year as coffee productivity varies worldwide

Table 1. Credit repayment schemes.

	CaFC model repayment scheme	Local credit repayment scheme
Year 1 and 2	No repayment, no costs borne by farmer	Renovation costs are paid back in 5 years, with 20% annual interest
Year 3 to 5	50% of harvest is used to pay off production costs from year 3 to 5	
Year 5 to 10	Remaining renovation costs are paid back in 5 years, with 10% interest	-

Table 2. Summary of scenarios.

Parameter	Scenario 1	Scenario 2	Scenario 3
Variety	F1 hybrid Starmaya	Typica	Typica
Price	2 US$/lbs	1.7 US$/lbs	1.1 US$/lbs (Cprice)
Credit scheme	CaFC	Local	Local
Discount rate (r)	10%	10%	10%

Scenario 1 = F1 Starmaya variety, CaFC price (2 US$/lbs), CaFC credit repayment scheme, discount rate = 10%.

Scenario 2 = Typica, FT-Organic price (1.7 US$/lbs), local credit repayment scheme, discount rate = 10%.

Scenario 3 = Typica, Cprice (1.1 US$/lbs), local credit repayment scheme, discount rate = 10%.

from one harvest to another. Moreover, the CaFC model's proposed credit repayment scheme implies adjusting costs over time. It is therefore important to assess the time differential value of money by discounting costs and revenues using the concept of net present value through *actualization*. Indicators used for profitability assessment are net present value (NPV) and benefit-cost ratio (B/C).

$$NPV = \sum_{t=0}^{t=n} \frac{(B_t - C_t)}{(1+r)^t}$$

$$B/C = \frac{\sum_{t=0}^{t=n} \frac{(B_t)}{(1+r)^t}}{\sum_{t=0}^{t=n} \frac{(C_t)}{(1+r)^t}}$$

Where B_t = benefit per ha in each year

C_t = costs per ha in each year

n = number of periods/years

r = discount rate

We set the discount rate at r = 10%.

All scenarios were modelled based on available data, with parameters set for each scenario and profitability indicators computed using RStudio – R version 4.1.0 (RRID:SCR_000432). The source code is available publicly (Meter *et al.*, 2022b).

Sensitivity analysis. A sensitivity analysis was applied by measuring NPV under variations of the following parameters:

- Price
- Interest rate of credit
- Discount rate *r*

CaFC model's reproducibility in other contexts

While the basic principles of the CaFC model were successfully implemented through the pilot project in Nicaragua, questions remain regarding its scaling up potential and applicability in other regions with different institutional and technological contexts (Manning & Von Hagen, 2010). Divergent results across studies assessing the impacts of sustainability governance schemes – mainly VSS – could often be partly attributed to differences in social, economic, political or cultural contexts that affect their performance (Oya *et al.*, 2017). Such differences can translate into potential obstacles – but also opportunities – to the development of a similar CaFC model in other contexts. Moreover, different practices and access to technology, and their impacts on the environment, on producer's income and other stakeholders, affect the model's potential for impact. For instance, the value of the CaFC model can vary across areas according to differences in swing potential – the difference between the best and worst ways of producing a commodity (Mithöfer *et al.*, 2017).

Along with the pilot project in Nicaragua, we use the case studies of Cameroon and Vietnam to discuss the reproducibility of the model in different contexts and its scaling up potential, and identify key elements to consider when implementing the CaFC model in other contexts.

The three case studies were discussed between the leaders of each project and documented. The Nicaragua case study is described on page 6 of this article. An overview of the Cameroon and Vietnam cases are presented in the following sections.

Important elements of these cases were organized in a table. This exercise led to the identification of key factors enabling the implementation of a CaFC model, organized in categories and presented in the Results section.

Overview of case study 2: Cameroon. In Cameroon, the CaFC model is being exclusively established with Starmaya. The size of the cluster will initially be based on a far smaller size due to reduced planting material availability with about 20 hectares for potential production between 30 and 40 tons/year. Current domestic production of Arabica coffee does not exceed 3,000 tons/year in Cameroon and the Arabica value-chain is considered as "desperate" after years of decay.

The model offers an integrated approach (production, fair market, socio-economic aspects) defined by common specifications, mutual respect of procedures and the guarantee of 100% traceability. In Cameroon, there are no large producers, but some mid-sized producers (between 10 and 100 hectares) and a vast majority of smallholders often grouped in cooperatives in connection with mid-sized producers and roasters. Coffee would be paid at the same price to all actors, at a level above the world price justifying the change of varieties and production practices in the present context where smallholders are currently discouraged by the low productivity of their variety and low prices.

Currently the highest quality coffee beans are sold 40 % above world price to two local roasters selling their product in France and locally. Agroforestry systems are still to be defined by the members of the cluster, respecting good quality coffee production constraints. Coffee farmers have switched to other crops, and in particular to annual crops and fruit trees, at the expense of coffee production. Coffee is only "tolerated" as long as it does not compete too much with crops that provide most farmers' incomes. Camus (2021) has pointed out two different trajectories depending on farmer age. The younger generation is transitioning towards cash crops and fruit tree systems – in particular avocado and safoutier (*Dacryodes edulis*) – while the older generation prefers trees that bring less income but require minimal management. In Cameroon, a strong local demand on safoutier and avocado show that these fruit trees are not adapted to coffee agroforestry systems as they provide too much shading (Manga *et al.*, 2013). The 'Shade Tree Advise' tool has been updated for this region of West Cameroon. This tool will help guide farmers' choice of shade trees within the agroforestry cluster.

The Bamiléké area is facing a very strong economic pressure towards enhanced productivity. In 2020, the first actors of the future cluster and Innovation and Dialogue platform were

identified after two preliminary identification missions (Penot *et al.*, 2018; Penot *et al.*, 2019). Local roasters would be associated to the cluster for a niche market ("Cafés André" and "Brûleries modernes", located in Douala) for this innovative action. Local mid-sized plantations are the "Koutaba monastery" plantation, the "Frères du Noun" plantation, the Bangoua chief and the Foumbot IRAD station with plantations undertaken in 2020. The cluster, initiated in May–July 2020 with the first plantation renovations, was first mainly comprised of small farmers located in the Bangoua, Batoufam, Djutissa, Fongo and Njiyoum communities, along with the aforementioned mid-sized plantations. For further planting in 2021 (around 10,000 trees), new cluster members will be recruited by IRAD from the Foumban, Bafang, Njuttisa, Dschang localities. The cluster remains quite limited but holds great value in terms of demonstration of what could be expected from a new Arabica cluster for farmers very much inclined to abandon coffee in the current production conditions. The new hybrid would provide a real boost in productivity and quality – particularly in agroforestry conditions to which it is adapted – compared to the local traditional variety. Successful implementation of the CaFC model in Cameroon could bring new hope to producers and an alternative to the projected demise of national Arabica production within the next 10 years.

In Cameroon, there is a clear common interest from different stakeholders for the production of high-quality coffee especially in the context of a country that is recognized worldwide as a quality origin. Still, attracting international traders is proving difficult and one question remains: Is there a clear incentive for private actors, especially multinationals, in investing in high quality coffee in Cameroon? While CIRAD partners are already present on the ground, a network with other potential partners has to be built, and with it the trust needed for all stakeholders to join in the initiative.

Overview of case study 3: Vietnam. The Vietnamese situation is fundamentally different from the cases of Nicaragua and Cameroon. In Vietnam, almost all the coffee produced is Robusta (Vietnam being the largest Robusta producer in the world). Specialty coffee is an emerging and marginal market. Still, there is some interest in developing the production of quality Arabica, especially in isolated regions of the north that already produce Arabica and on which the BREEDCAFS project is focusing (Northwest regions of Son La and Dien Bien). The social value-chain context appears to be that of mostly isolated smallholders in a form of social and economic atomization as there are very few coffee cooperatives or any forms of farmers' structuration concerning coffee selling. However, many farms are connected with factories/buyers through informal networks. The current developing mode of farmers' structuration is based on the process of certification – mainly 4C and UTZ – engaged and highly promoted by mid-size buyer/roaster companies (Mien Tien and Cat Que) and some small size buyers entering the market. Agroforestry systems are based on local fruit trees with coffee, mainly plum, peach and avocado trees in the vicinity of the road and access to market and timber trees in more remote areas (Nguyen *et al.*, 2020).

A small 30 ha coffee cluster is in the process of being created with the Starmaya comprising the current core of 12 farmers with demo plots and 50 to 60 associated neighbouring farmers that have yet to confirm their interest in planting the new varieties. New nurseries have enabled the production of one hundred thousand plants in 2020, allowing the extension of the existing cluster based on demoplots with an additional 30 hectares. This cluster is also likely to grow according to the desire of farmers and roasters. In Vietnam, small size fruit trees such as plum seem to be locally adapted for agroforestry. Further discussions with local smallholders are necessary to develop technical recommendations for associating the right fruit and timber tree species to local context. In this regard, the farmers' surveys and recent development of the 'Shade Tree Advise' tool in all the three targeted regions in Vietnam, Cameroon and Nicaragua is of great help.

Discussions between local actors are in progress. The current trend towards certification, either UTZ or 4C, should help structure farmers' organizations and promote the adoption of new hybrid coffee varieties managed in agroforestry systems and management, particularly processing, to improve quality resulting in higher farm gate prices. Finally, different local companies have clearly expressed their interest to be the final roaster/buyer (as is Nespresso in Nicaragua). These stakeholders constitute so far the main actors of the future cluster and associated Innovation and Dialogue platform.

The development of a CaFC in Vietnam could be highly beneficial not only for local smallholders but also in terms of environmental impact given the sustainability crisis faced by the Vietnamese coffee sector. This is due to the excess use of agro-chemicals and the absence of anti-erosion management on very sloppy lands. Hence, the lack of sustainable Arabica coffee produced in Vietnam and the value of the CaFC model in addressing this could become an opportunity if properly communicated. The question remains whether local roasters in Vietnam can lead such a marketing campaign or would need to collaborate with international roasters who may be better equipped to "launch a new origin".

In Vietnam, a strong network of stakeholders able and ready to develop an organic CaFC has yet to be developed, which will have to take into account the specific institutional and political context. For instance, international companies cannot buy coffee directly from farmers and local actors have to be integrated into the buying scheme. The absence of both large producers and smallholder organizations, the political and regulatory context hindering collaboration with international stakeholders and the full control of the Arabica value-chain by a few local actors call for a different strategy to develop the right incentives and adapted contracts between participants. In northern Vietnam, two companies may have the resources to develop a cluster model: Cat Que and Mien Tien and some others are quite interested. While mutual interest

might be the common feature to implement CaFC, trust remains to be built between local actors who are waiting for the first coffee hybrid productions from 2021 to assess its quality and productivity.

Given the many contextual differences between Nicaragua and Vietnam, the ongoing development of the BREEDCAFS project in northern Vietnam will also be a great opportunity to better assess the applicability of the model across various regions and socio-economical contexts.

Results

Profitability assessment

Measuring key profitability indicators. Figure 1 displays expected income (annual present value per hectare) and accumulated balance (cumulated annual present value) in the different scenarios.

The variations in results between these different scenarios are explained by three overlapping effects: i) Differences in credit repayment schemes (CaFC repayment schemes vs local credit), ii) Differences in varieties (F1 hybrid – Starmaya, Typica), implying different costs of production and yields; and iii) Differences in farm gate prices.

Results show that coffee production under scenarios 1 and 2 are profitable – positive NPVs – while scenario 3 leads to negative NPV (see Table 3). The first scenario corresponding to the CaFC model with Starmaya comes out as a clear winner with a NPV of 11.694 US$ at year 12 and a B/C ratio of 2.60. Scenario 1 also stands out by its results in the first two years, with a cumulated net present value at year 2 of 0 US$, versus -2332 US$ for scenarios 2 and 3. This is a consequence of the CaFC credit repayment scheme alowing producers to pay back renovation costs after 5 years.

Sensitivity analysis. Table 4 summarizes results of the sensitivity analysis for the three scenarios. Results show that scenario 1 remains more profitable in any case considered.

Price sensitivity

Results of variation in prices show that the FT-Organic scenario outperforms the CaFC model when the Cprice is under 0.5 US$/lbs, a price that has never been reached and is unlikely to be in the near future – see Figure 2.

Interest rate sensitivity

In our scenarios, we used an interest rate of 20% for local loans. This appears to be a realistic value in Nicaragua. However, this can vary significantly across countries and regions. It is interesting to note that even with an interest rate lower than that of the CaFC model (<10%), the first scenario still outperforms the two others. Moreover, even at an interest rate of 20%, the NPV for scenario 1 remains over 10,000 US$ per Ha.

Discount rate sensitivity

Choosing the right discount rate when calculating NPV is difficult. While we chose to set a discount rate of 10%, this value could change in other contexts where the time-value of money is different. Results from sensitivity analysis show that the relative gap in NPV values between scenario 1 and scenarios 2 and 3 widens as the discount rate increases.

Reproducibility of the model: lessons learned from the ongoing BREEDCAFS project

The analysis of the three case studies – Nicaragua, Cameroon and Vietnam – led to the identification of several key enabling factors in the implementation of a CaFC model. These factors may have one or multiple dimensions (political, social, economic or technical), and could influence the replicability of the model in multiple ways:

- Enablement – *complicates or facilitates the implementation of the CaFC model*
- Adaptation – *requires an adaptation of the model for it to be applicable*
- Potential for impact – *implies changes in potential for impact of the model, possible tradeoffs*

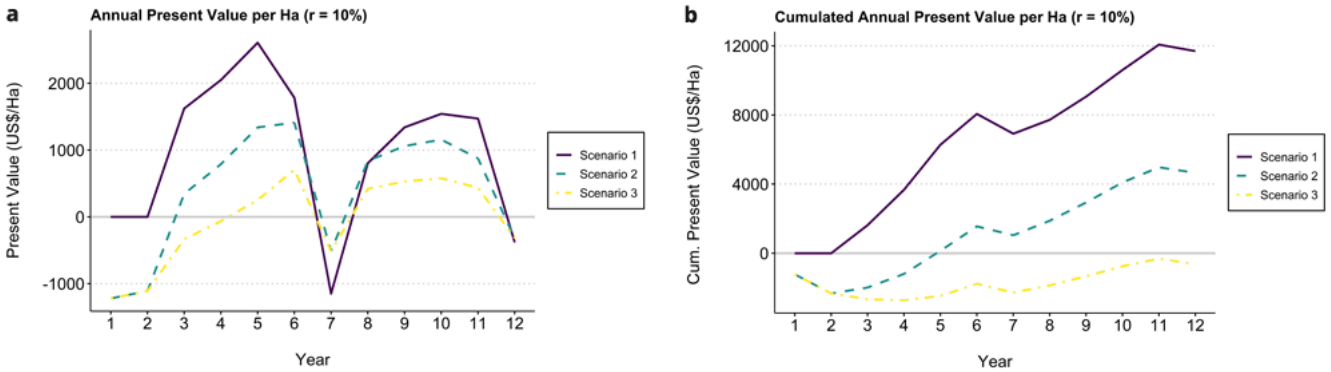

Figure 1. Annual present value (**a**) and cumulated annual present value (**b**) per hectare for each scenario from year one to 12. Scenario 1 = F1 Starmaya variety, CaFC price (2 US$/lbs), CaFC credit repayment schemes, discount rate = 10%. Scenario 2 = Typica, FT-Organic (1.6 US$/lbs), local credit repayment schemes, discount rate = 10%. Scenario 3 = Typica, Cprice (1.1 US$/lbs), local credit repayment schemes, discount rate = 10%.

Table 3. Results of net present value (NPV) per hectare benefit/ cost (B/C) ratio at year 12. *B/C:

	NPV (US$)	B/C ratio
Scenario 1	11694	2.60
Scenario 2	4654	1.38
Scenario 3	-635	0.95

Table 4. Results of net present value (NPV) per hectare at year 12.

	Scenario 1	Scenario 2	Scenario 3
Cprice variation			
0.8 US$/lbs	9796	4654	-2750
1.1 US$/lbs	11694*	4654*	-635*
1.5 US$/lbs	15490	5711	3596
Interest rate variation			
10%	11694*	5927	638
20%	10880	4654*	-635*
30%	10066	3381	-1908
Discount rate variation			
5%	15843	7270	94
10%	11694*	4654*	-635*
20%	6909	1807	-1301

* base value for this scenario

Table 5 lists the identified key enabling factors for the implementation of the CaFC model in a given area. While not meant to be exhaustive, this list of factors underlines some important challenges and opportunities in the reproducibility of the CaFC model, especially regarding:

- National context and policies
- Farmers and collaboration
- CaFC organisational model and stakeholder collaboration
- Agroforestry systems, diversification, and agronomic practices
- Coffee quality, origin and differentiation strategies
- Breeding strategy and dissemination pathways

Discussion

Environmental and economic value of the CaFC model

The CaFC model has great potential for positive environmental and economic impact. Its strategy based on a homogeneous production of high-quality coffee offers strong incentives for the stakeholders involved in its resulting micro value-chain. Especially for smallholder farmers, quality premiums coupled with capacity building and access to i) high performing, adapted and resilient varieties; ii) renovation of plantations; and iii) adapted credit with favourable repayment schemes make CaFC very attractive. This is reflected by the growing interest of farmers in proximity to the pilot project in Nicaragua that have shared their enthusiasm in joining the next phases of integration and plantation renovations.

Yet, in its current state, the already encouraging pilot project in Nicaragua falls short from an ideal CaFC on some key issues. The aim of CaFC is towards 100% smallholders, 100% organic production and 100% Arabica high performing varieties used for plantation renovation and management. Results of the profitability assessment of such a hypothetic

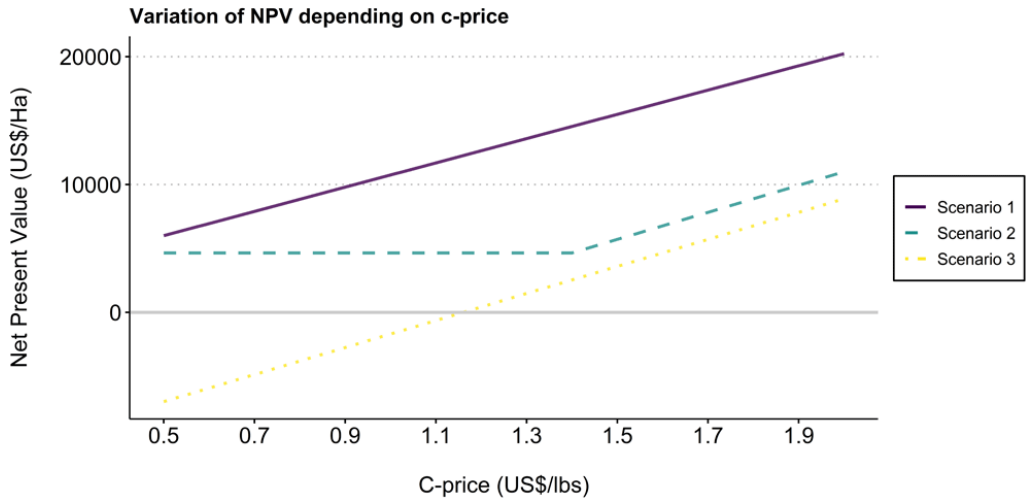

Figure 2. Impact of cprice variation on net present value for each scenario. Scenario 1 = F1 Starmaya variety, CaFC price, CaFC credit repayment schemes, discount rate = 10%. Scenario 2 = Typica, FT-Organic price, local credit repayment schemes, discount rate = 10%. Scenario 3 = Typica, bulk price, local credit repayment schemes, discount rate = 10%.

Table 5. Key factors enabling the implementation of the coffee agroforestry business-driven clusters (CaFC) model in a given target area.

Enabling Factor		Conclusion based on observations in case studies
National context and policies		
Stability of situation	Is the political and economic situation stable enough to invest in the medium term (5–10 years)?	National political and economic situation may enable or hinder the various interventions needed for implementing CaFC, before and during the implementation.
Environmental policies	What are the environmental policies in place in the country?	Positive regulatory and policy environment (e.g. Carbon Credit) can facilitate implementation and increase the value of the model.
Farmers and collaboration		
Farmer typology	What is the typology of farmers in the target area? What does it imply for the implementation of a CaFC?	CaFC may need to be adapted based on typology of farmers in target area. Potential for positive impact is maximised when CaFC applicable to smallholders.
Farmer typology	What is the initial economic situation of farmers in the target area? What does it imply for the implementation of a CaFC?	CaFC may need to be adapted based on economic situation of farmers in target area. Potential for positive impact is maximised when CaFC can significantly improve income.
Farmers and collective action	Are farmers in the target area inclined to collaborate? Are cooperatives commonplace?	Reluctance to collective action and low trust between producers in the area will complicate the implementation of the CaFC and might require compensation through other trust-building mechanisms.
Relationships between producers	Are there relationship issues or economic inequalities in the target area that could lead to tensions between neighbouring producers?	A negative social context between producers at the local level will complicate the implementation of the CaFC and might require compensation through other trust-building mechanisms.
CaFC organizational model and stakeholder collaboration		
Collective action and relationships between stakeholders	Are the different actors/stakeholders needed for the development identified? Are they inclined to collaborate?	Initial set of actors needed to implement CaFC Engagement of actors and will to collaborate is important, especially Roaster. Collective action will have impact on results of CaFC throughout.
Contract acceptability	Is the CaFC contract acceptable, would it need adaptation?	Depending on political, regulatory and social context, CaFC contract may or may not be acceptable, or may need adaptation.
Direct contracting	Is it possible to contract directly with the producer?	Possibility of direct contracting with producers may imply adaptation of contract and relationships with stakeholders.
Access to credit	Is agricultural credit available to small producers for replanting?	Depending on credit access, CaFC, its contract and credit terms may need adaptation, and depending on terms available in target area, impact of CaFC may vary.
Agroforestry systems, diversification, and agronomic practices		
Prevalence of agroforestry systems	Are agroforestry system common farming systems in the target area?	Depending on prevalence of Agroforestry systems in the target area, implementation of CaFC may be easier / need varying levels of technical training. However, if agroforestry systems are not the predominant system in the target area, potential for positive environmental impacts increases.
Timber trees availability and impact	Are there local timber trees suitable for agroforestry? May any complication arise from their use?	Availability of local timber trees suitable for agro-forestry will impact design of Agroforestry system, can result in different costs/revenues and environmental impact.
Fruit trees availability and impact	Are there fruit trees suitable for agroforestry in the area? May any complication arise from their use?	Availability of fruit trees suitable for agro-forestry will impact design of Agroforestry system, can result in different costs/revenues and environmental impact.
Pesticide contamination	Is coffee cultivation accompanied by pesticides contamination?	Depending on current situation in target area regarding pesticide contamination, environmental impact of CaFC will vary.

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Enabling Factor		Conclusion based on observations in case studies
Parasitic threats	Are there specific parasitic threats?	Specific parasitic threats in target area may be incompatible with CaFC, require adaptation of the model, and could influence on long term impacts (e.g. economic through yields, environmental if use of chemicals).
Productivity	What are the productivity levels?	Productivity levels are indicative of the leeway for increase in productivity and hence potential for positive impact.
Extension services	Do small farmers receive sufficient agronomic support (field visits)?	Quality of extension service would lead to varying levels of technical assistance needed and possible adaptation of the model. Lower quality of existing extension services would translate into potentially high positive impact via the provision of state-of-the-art technical assistance provided to farmers through CaFC.
Certifications	What are the main certification schemes in the target area?	Certifications schemes in target area are conducive to adoption of goodproduction practices that can facilitate implementation of CaFC.
Coffee quality, origin and differentiation strategies		
Certifications	What are the main certification schemes in the target area and their role in differentiation strategy?	Interest in certification schemes as differentiation strategy can be in sync with CaFC.
Interest in quality improvement	Is there interest in improving quality among stakeholders?	A clear interest of stakeholders in improving quality of coffee is key for their engagement in the required collaboration for the CaFC model's implementation.
Interest in origin differentiation	Is there interest in promoting the coffee origin of the country of the target area among stakeholders?	An interest in promoting origin differentiation of the target area can further increase mutual interest in quality improvement and the value of the CaFC model.
Established economic incentives for quality	Are there economic clear incentives for farmers and stakeholders to improve the quality of their coffee?	Established economic incentives for quality improvement in the target area, such as price differentiation based on quality, can further increase the value of the CaFC model.
Quality level	Is the quality level of coffee in the target area satisfactory? Is there room for improvement?	Depending on the general quality level of coffee already produced in the target, the CaFC model could be more or less attractive and imply different levels of impact, with higher impact in areas where general quality is low.
Breeding strategy and dissemination path		
Robusta / Arabica	What varieties are mainly produced in the target area, Robusta / Arabica?	Production of Robusta vs. Arabica and varieties of Arabica found in the target area will impact the design of the CaFC model and its potential for impact.
New varieties	Are stakeholders aware of the value of the new varieties proposed? Is there interest in these new varieties?	Awareness of the quality and value of new varieties proposed through the CaFC would ease implementation. Lack of awareness would imply need to organise demonstration plots etc.
Propagation capacity	What is the propagation capacity in the target area? Can the new variety be made easily available?	Propagation capacity impacts scale of implementation. Implies costs for developing propagation capacities (nurseries, training) etc.
Plantation renovation	Is there a need expressed by producers in target area for plantation renovation with high performing planting material?	The need from producers for plantation renovation is a pilar of the CaFC model, CaFC model loses its value if implemented in an area where most farms have recently been renovated.
Plantation renovation	Are costs of renovation high? Is a solution needed to reduce costs?	Cost of farm renovation in the target area will determine the value of the CaFC model to producers, with higher impacts in areas where renovation costs are high and credit not available to cover them.
Plantation renovation	Knowledge on replanting accessible to farmers? Is there a need for technical assistance?	Accessibility to farmers of knowledge on farm renovation in the target area will determine the value of the CaFC model to producers, with higher impacts in areas where technical assistance needed by farmers.

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CaFC model clearly demonstrates its economic value, as the CaFC scenario consistently outperformed the FT-Organic and conventional scenarios. While the results of this exercise are encouraging, further work is needed for a thorough assessment of the economic impact for producers as well as other stakeholders. In this regard, the ongoing extension of the Nicaragua cluster by an extra 350 hectares in an exclusive collaboration with smallholders, under organic certification and using high performing, is a tremendous opportunity to further assess the benefits of the ideal organic CaFC highlighted in this study.

The environmental value of the model is mostly derived from its application of agroforestry practices, the expected role of which are multiple:

- Reduction of temperature at the coffee tree level – up to 6°– and create a very buffered growing micro-environment in a context of climatic change (Vaast *et al*., 2005).
- Adapt coffee hybrid production potential to a relatively high productivity (comparable to full sun for other local varieties) and a long lifespan or more than 30 years providing therefore short-term and long-term high productivity.
- Income diversification during coffee production via associated fruit trees or at the end of the lifespan if use of timber trees.
- Carbon sequestration by shade trees with a high traceability.

Reproducibility of the model

The success of the pilot project in Nicaragua is quite context specific. Many factors have come into play to make this project successful. While the CaFC model has great potential for wider application, its reproducibility with comparable success in other contexts may be determined by numerous factors. The comparison of the Nicaragua pilot project and the ongoing application of the model in Vietnam and Cameroon allowed for the identification of key factors enabling the model's implementation. They include national context and policies; farmer typologies and their socio-economic context; stakeholders, mutual interests in the production of high-quality coffee and potential for collaboration; the status of agroforestry production, local agronomic and technological challenges and specific needs; and breeding strategies, dissemination pathways and challenges in plantation renovation. These factors determine the possibility of replicating the model, enabling or hindering its implementation, but also imply a need for adaptation of the model.

Differences in environmental conditions, climate, local practices etc. requires adapting some elements of the model. For instance, the shade level provided by associate trees has to be adapted to local conditions (generally between 30% and 40%) and take into account local preferences in timber and/or fruit trees. The system is already well defined and well documented in Nicaragua with timber trees, and needs to be adapted with fruit trees. Further discussions with local smallholders are necessary to develop technical recommendations for associating the right fruit and timber tree species to local context. In this regard, the recent development of the 'Shade Tree Advise' tool in all the three targeted countries is of great help.

Different contexts also imply various levels of potential for impacts. In Vietnam, the development of a CaFC cluster could be highly beneficial, not only for local smallholders, but also in terms of environmental impact given the sustainability crisis faced by the Vietnamese coffee sector. In Cameroon, the Arabica coffee value-chain is disappearing if no alternative is provided. CaFC clusters based on new varieties with both increases in price and production could raise a new interest to local smallholders in the Bamiléké area. In this context, the CaFC model stands out as a unique opportunity for local roasters to save Arabica production and the current market, extending its social and economic impact throughout the local value-chain.

An important lesson learned from the cases of Nicaragua, Cameroon and Vietnam is the importance of trust and mutual interest. The success of the on-going cluster in Nicaragua is the result of the collaboration between multiple stakeholders and individuals with mutual interests and relies heavily on trust on at least two levels:

- Trust in the quality of the product and the capacity of various stakeholders to uphold their promises on said quality – e.g. the performance of the new varieties for plantation renovation, the commitment of the farmers to adopt the required agricultural and management practices, the consistency in quality of green coffee resulting from the risky honey-processing.
- Trust in the commitment of all stakeholders in the initiative, particularly smallholder farmers who are trusted to hold their end of the agreement regarding land rights and paying back the loan through initial harvests. Producers in turn trust other stakeholders to hold their promises regarding the performance of the new varieties and benefits arising from their adoption as well as their commitment to buy their production at the agreed price.

A clear common interest from different stakeholders to produce high-quality coffee was key in enabling the projects in all three countries, and a pre-requisite for buyers to accept the level of risks that allow the initiative to develop in the first place. Pre-existing relationships with local stakeholders was a great advantage participating in the success of the model in Nicaragua. The case of Nicaragua has also proven the power of demonstration as an important trust-building mechanism, as demo-plots in La Cumplida were critical in convincing smallholder farmers to join the project. Positive results from demo-plots in Cameroon and Vietnam are eagerly awaited by stakeholders to confirm their expectations regarding the productivity of the new varieties to be introduced in the local implementation of the CaFC model.

If the Nicaraguan case proves that mutual interest and trust can bring together large and small producers, a final roaster and a trader (ECOM), it is still questionable whether the CaFC could be applied with different stakeholders, such as with a cooperative of a group of smallholders as a key intermediary organisation. The cluster is very innovative especially regarding the post-harvest processes that allow for the homogeneous production of high-quality coffee. For now, it seems that expertise of some actors (e.g. ECOM) are essential to the success of the initiative and initially to trigger the development of the initiative. However, with insights gained from Nicaragua and ongoing implementation of the CaFC model, perhaps knowledge and technology could be transferred to cooperatives for instance. The answer is probably yes in Nicaragua. In Vietnam, other farmers' structuration patterns such as certification groups could be used for the same purpose. In Cameroon, the question has yet to be answered.

Eventually, these findings point to the importance of formalizing a Dialog and Innovation platform to ensure transparent communication between stakeholders. For the development of such Dialog and Innovation platforms, a methodological proposal has been designed to systematize the BREEDCAFS project in Nicaragua, which is based on the following items: i) provide the history of the project; ii) develop a global reflection and a critical analysis of the successful/not so successful various results of the project, iii) communicate on the experience and iv) collect and use the lessons learned derived from this project to scale up to CaFC including small producers, identifying strategies to adapt this model to the context of small producers based on market demands. The Nicaragua cluster is fully organized and already functional. The objective is to link the current Nicaragua cluster with existing local platforms, associations and other actors in the Arabica sector. Such a Innovation and Dialogue platform has been established as well in both Cameroon and Vietnam for four years where discussions and actions have been engaged with local and international stakeholders.

Conclusions

The coffee agroforestry business-driven cluster (CaFC) model was developed with the aim of turning the predicament of coffee plantation renovation into a business opportunity by integrating various actors around the plantation and production of coffee with very high organoleptic quality and high added economic value.

The model is based on 1) The creation of a specific micro value-chain, involving a limited set of stakeholders working together to maximize the quality and added value of the coffee produced; 2) The use of high performing and resilient coffee varieties that guarantee high yields under agroforestry production systems and high organoleptic quality; and 3) Agroforestry management that stabilizes production, improves and homogenizes coffee quality and provides valuable ecosystem services.

The CaFC model relies on collaboration, recognition of mutual interests, and trust between the stakeholders involved. In particular, the roaster plays a crucial role by committing itself to buying the product at a high price – between 1.3 and 2 times the standard world price – guaranteeing all actors downstream the share of a significant quality price premium, including participating producers.

The ambition is to establish a sustainable and economically efficient system that could contribute to several global objectives of sustainable development: reduction of social inequalities, fight against global warming, protection of biodiversity, sustainability of agricultural activities.

This paper presented the operational principles of the CaFC model and its potential for positive environmental, social and economic impact. The prototype in Nicaragua helped illustrate the application of the model in a real setting. Especially, results of the model's profitability assessment clearly shows the economic value of the model for coffee producers that would join a cluster when replanting of coffee trees is needed.

The concept was initially developed in Nicaragua for coffee but could also be developed in other countries or even with other commodities such as cocoa. An analysis of case studies in Nicaragua as well as ongoing implementation in Vietnam and Cameroon allowed for the identification of key enabling factors to consider when implementing the CaFC. A key lesson from the three current cases is the importance of mutual interests and trust between stakeholders: the CaFC model relies heavily on the collaboration between various actors with different motives and objectives, highlighting the importance of using an Innovation and Dialogue platform to ensure communication throughout the process, and trust-building.

While the results of this exercise are encouraging, further work is needed for a thorough assessment of the economic, social and environmental impact of the model as well as its overall value for producers and other stakeholders, along with its replicability in other contexts.

Data availability

Underlying data

CIRAD Dataverse: Underlying data for 'Local value-chains dedicated to sustainable production (coffee agroforestry business-driven clusters or CaFC): a new organizational model to foster social and environmental innovations through farm renovation', 'Profitability assessment of the coffee agroforestry business-driven clusters (CaFC)'. https://doi.org/10.18167/DVN1/8RKHFX (Meter *et al*., 2022a)

The profitability assessment is based on the following underlying data:

- Data file 1. – BREEDCAFS CaFC: Renovation costs with Starmaya variety-Peru data.tab
- Data file 2. – BREEDCAFS CaFC: Renovation costs with Typica variety-Peru data.tab
- Data file 3. – BREEDCAFS CaFC: Costs and Yields with Starmaya variety-Peru data.tab

- Data file 4. – BREEDCAFS CaFC: Costs and Yields with Typica variety-Peru data.tab

- Data file 5. – BREEDCAFS CaFC: Processing costs and buyer price-Nicaragua data.tab

Software availability

The R script used for the profitability assessment is available from:

https://github.com/aemeter/CaFC_profitability_assessment.git

Archived source code at time of publication: https://doi.org/10.5281/zenodo.6353652 (Meter *et al*., 2022b)

Author contributions

AM is the main contributor to the paper and analysed the data for the profitability assessment. BB and EPonçon established the framework for the study. EP, PV and HE provided the information on the Nicaragua, Vietnam and Cameroon cases respectively for the case study analysis. All authors contributed to the article and approved the submitted version.

Acknowledgements

We thank ECOM Agroindustrial corporation (https://www.ecomtrading.com/), Fundacion NicaFrance (https://fundacion-nicafrance.org) and Moringa (www.moringapartnership.com) for technical support in the field and provision of project documents and data.

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Open Peer Review

Current Peer Review Status: ✔ ✔

Version 2

Reviewer Report 31 March 2023

https://doi.org/10.21956/openreseurope.16963.r30871

✔ **Leonel Lara-Estrada**
Natural Resources Institute, University of Greenwich, Chatham, UK

The revised version and authors' comments partially address the comments given in the review, but it is enough considering the manuscript topic and circumstances. Thanks.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Coffee production, agroforestry, and trade-off analysis in Central America.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Reviewer Report 28 February 2023

https://doi.org/10.21956/openreseurope.16963.r30872

✔ **Christophe Montagnon**
RD2 Vision, Valflaunes, France

The revised version is improved and all comments have been taken into account. Hence, I suggest to Approve for indexing.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Coffee agronomy and genetics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 1

Reviewer Report 01 November 2022

https://doi.org/10.21956/openreseurope.15732.r30060

?

Leonel Lara-Estrada
Natural Resources Institute, University of Greenwich, Chatham, UK

General comments

The paper introduces a business model (CaFC) to finance the implementation of agroforestry systems using high-performance coffee varieties (high yields & quality and resistance to diseases). The model is a systematization of a past joint experience between public and private entities in Nicaragua. The concept is interesting because it opens the possibility of improving the sustainability of coffee agroforestry systems through a stable and financially attractive scheme for farmers to renovate coffee plantations and sell the coffee produced at a higher price over many years. However, the model's success relies on a particular set of conditions and actors that are at the same time advantages but also constraints for the model replicability and scalability.

The model relies on using high-performance coffee varieties under agroforestry systems (Principles of the clusters), calling for the multiple benefits of agroforestry, like income diversification, but this is not included in the model evaluation (profitability assessment).

Specific comments

Introduction

"The changes in production practices needed to achieve these goals often require replanting coffee farms with adapted and efficient varieties." What do you mean by replanting coffee farms? Do you mean renovating? If so, this paragraph mentions this is an option "often" chosen by farmers, but in the next paragraph, it mentions that farmers have difficulties to renovate and tend to postpone renovations because of the high investment. Please elaborate.

"The major risk in using line varieties is that of uniformity." Please, explain shortly why it is a risk; not all readers may know why.

"Innovation and Dialogue platform." It described what topics are discussed and agreed under the

platform, but it is unclear what the decision-making "power" of each stakeholder involved is. Do all have the same voice? Please clarify in the text the governance of this platform.

"This reduces risks and allows for the various investments required to develop a system that produces a consistent supply of high-quality coffee." A pillar of the model is high coffee quality; studies on the impacts of climate change expect a reduction in the land/climatic suitability for current coffee areas; this was not considered in the profitability assessment; so, I would recommend discussing the possible impacts of climate change on CaFC (yields and quality).

"...a 'degenerative effect' of the variety after a few generations. With an allogamy rate of 4% to 10%, the percentage of off-types is estimated to be between 12 and 20% after three generations." Provide a citation/reference.

"The F1 hybrid generation obtained between two different gene pools – e.g. American cultivated varieties and Ethiopian wild accessions – yield 30 to 40% more than the best parent (Bertrand et al., 2019)." This reference is for an abstract in a conference, for this statement, a peer reviewed article would be better.

"Coffee agroforestry systems that have limited disturbance to the soil present a..." According to Guillemot *et al.* (2018), the change from one coffee agroforestry system to another, changes in tree and coffee plants (varieties), provoke a reduction in the carbon content and, therefore, climate change mitigation potential. CaFC model is about renovating coffee plantations, so the model will cause disturbance above and below the ground during there remotion of old coffee plants and trees and then establish the new coffee plants and shade trees. Discuss the impact of these implications.

The paper introduces study cases from Nicaragua (1300 ha planted in 2016), Cameroon (20 ha in 2020) and Vietnam (clusters in the process of being created). However, only Nicaragua is a fully implemented case, and the other countries are still in the very early stages (or about to begin) to provide sufficient information on the model performance in those countries.

"The pilot cluster was formed in 2016 in Nicaragua, where 1,300 ha of coffee trees are currently cultivated..." Does the 1300 ha were established in 2016, or were they established in previous years? Clarify in the text.

Methods

The profitability assessment evaluates three scenarios where the option using CaFC result the best; from this assessment and scenarios, some questions arise:

1. *Data sources. "To assess the profitability of a hypothetical CaFC model, we use available primary data from the Nicaragua pilot project combined with secondary sources for various scenarios."* Data on postharvest processing costs, coffee price, and financial scheme are from Nicaragua and data on renovating organic coffee plantations from Peru.

   a. Combining data from different countries for this type of analysis might not be the best for consistency: using the costs of one country and coffee prices from another. Discuss why this combination of data, and mention the possible impacts on the profitability assessment.

b. List the variables used (units and values) from each country.

c. Are the certification costs included in the analysis (>2year)? They do not appear in the renovation cost files.

d. Does the data from Peru come from an experiment or plots in different commercial coffee plantations?

e. The production data (yields) available in the files show that the production values from year 3 to year 6 are the same for the period from year 8 to year 11 (except year 10). Please comment on this. Did the reported data come from actual yields from coffee plantations for the 12 years? If so, the production data are an average of different plantations or came from a single plantation?

f. Using the same production data provided in the files, I calculated the rate of change (%) from one year to the next for Starmaya and Typica for the 12 years; and it can observe that both varieties have the same rate of change for most years, which is very interesting. I would expect different rates of change. Similar situation for production costs. If I am missing something, please, explain and describe it in the text.

g. Data from Peru. There is no mention of the biophysical conditions where the coffee plantations were established (altitude, temperature, precipitation, region, etc.); knowing this information would create a clearer picture of the coffee systems under comparison. This information could be added to the text or in Table 2. Summary of scenarios.

h. All the files in the Data file 1-5 should mention the country of origin in the metadata and the corresponding actual years (e.g. 1996, 1997, etc..) as a column inside each file.

i. The data on production costs indicate that Starmaya and Local Variety (Typica) has different production costs (≥ 3 years). Starmaya has higher production costs. Why the differences? If comparing both systems, I would assume similar management.

2. It compared the coffee hybrid Starmaya vs the local variety Typica. Why was Typica selected? Its performance is not the best among the traditional varieties or the most used by farmers in the region, such as Caturra. Caturra is widely used in conventional and organic coffee plantations in Nicaragua, where there are 1300 ha under CaFC.

3. Add a short description of Typica in terms of yields, quality, and disease resistance performance; so the reader knows against what is compared to the hybrid Starmaya.

4. *"...with the F1 hybrid variety 'Starmaya', and alternative scenarios involving local varieties..."* It is only one local variety.

5. Be specific and use the Typica instead of "Local Variety" in the corresponding figures and tables. There are many local (traditional) varieties with different performances.

6. On the three scenarios that were evaluated, I am not sure they are the best choice because of the narrow comparison, and my impression is that there is not much information to

justify the selection. For example, coffee quality is a pillar in CaFC; however, the scenario description does not mention the coffee quality for each scenario; or if the plantations of the three scenarios are supposed to be established at the same location. It is clear that Scenario 1 has high coffee quality and gets the CaFC coffee price premiums (Nesspreso + Organic), but it is unclear what the quality is for Scenarios 2 (FT-Organic) and 3 (conventional). If Scenario 2 and 3 have good coffee quality, they could also participate in Nespresso and get the premiums; otherwise, if the quality of Scenario 2 and 3 is low because they are located under suboptimal conditions, I do not see a point of comparison. This needs to be clarified in the text to avoid a possible misunderstanding of bias in favor of Scenario 1.

7. *Planting material. "Plantations in the Nicaragua project have been renovated with dwarf variety Marsellesa®...(Marie et al., 2020)."* This section is part of the description of the methodology used to do the Profitability assessment, Marsellesa is not part of the scenarios, and the comparison between Marsellesa and Starmaya (already mentioned before in the text) is not ideal because both are relatively new varieties, and Marsellesa is not a local (traditional) variety. This paragraph would be omitted from the text.

Results

"Results from sensitivity analysis show that the relative gap in NPV values between scenario 1 and scenarios 3 and 4 widens as the discount rate increases." There are only 1, 2, and 3 scenarios.

Why was the profitability assessment only for 12 years? Why not 30 years, as it is mentioned in the text? Coffee plantations using traditional (local) varieties have a longer lifespan than the one evaluated here; a new renovation is required after 12 years? What is the expected productive lifespan of Starmaya? Even if farmers received favorable conditions to renovate their plantations and received good prices, they expected the plantations to be productive for more than 12 years, and the profitability analysis should consider it.

"...and a long lifespan or more than 30 years providing therefore short-term and long-term high productivity." What does it mean for short-term and long-term high productivity?

"...the hybrids developed by CIRAD..." for precision, provide the name of the hybrids that this text is referring. Some hybrids were developed in the region by the collaborative effort of many institutions, including CIRAD.

"*Pre-existing relationships with local stakeholders was detrimental in the success of the model in Nicaragua."* Detrimental?

"...stakeholders. In this activity, a methodological proposal has been designed." It is not clear what activity you are referring.

Conclusions

"2) The use of high-performance coffee varieties that guarantee high yields under agroforestry production systems..." on the description of the scenarios include the description of the agroforestry systems (shade tree species, shade level, prunings, etc).

"3) Agroforestry management that stabilizes production, improves and homogenizes coffee quality..." Stabilization of the production because agroforestry is not supported in the paper, there is no comparison with full-sun systems to see the such positive effects; and the results on NPV in Figure 1a and the this figure I did using the production data (Data availability section) show that scenario 1 (Starmaya) has similar trend than Typica and a similar rate of change in production from one year to the next (see the image in comments for Methods).

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and does the work have academic merit?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Partly

If applicable, is the statistical analysis and its interpretation appropriate?
Partly

Are all the source data underlying the results available to ensure full reproducibility?
No source data required

Are the conclusions drawn adequately supported by the results?
Partly

Competing Interests: Excluding the first author, I know three of the co-authors, but I have had non or very little interaction with them in the last decade, so knowing them does not affect my impartiality for this review.

Reviewer Expertise: Coffee production, agroforestry, and trade-off analysis in Central America.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 10 Feb 2023

Andrew Meter

General comments

The paper introduces a business model (CaFC) to finance the implementation of agroforestry systems using high-performance coffee varieties (high yields & quality and resistance to diseases). The model is a systematization of a past joint experience between public and private entities in Nicaragua. The concept is interesting because it opens the possibility of improving the sustainability of coffee agroforestry systems through a stable and financially attractive scheme for farmers to renovate coffee plantations and sell the coffee produced at a higher price over many years. However, the model's success relies on

a particular set of conditions and actors that are at the same time advantages but also constraints for the model replicability and scalability.
R: We thank the reviewer for his interest in the article and the concept. We agree that the replicability of the model and its scaling is not proven and merits further investigation. We point this out in the perspectives and the last line of the conclusion. Further insight into the replicability of the model will be available soon as a new cluster is currently being set up in Vietnam.

The model relies on using high-performance coffee varieties under agroforestry systems (Principles of the clusters), calling for the multiple benefits of agroforestry, like income diversification, but this is not included in the model evaluation (profitability assessment).
R: We agree : In the agroforestry cluster presented here, diversification is done with timber trees. These trees take years to grow and their economic exploitation will have to wait another twenty years.On the other hand, the hidden benefits of agroforestry (preservation of biodiversity, carbon sequestration ..) or the hidden costs of intensification in sunny areas (notably through increased use of pesticides) have not been taken into account because these hidden benefits/costs are very difficult to evaluate in the country context.

Specific comments

Introduction
"The changes in production practices needed to achieve these goals often require replanting coffee farms with adapted and efficient varieties." What do you mean by replanting coffee farms? Do you mean renovating? If so, this paragraph mentions this is an option "often" chosen by farmers, but in the next paragraph, it mentions that farmers have difficulties to renovate and tend to postpone renovations because of the high investment. Please elaborate. R: We agree to reword the sentence as follows : The changes in production practices ideally needed to achieve these goals require renovating coffee farms with adapted and efficient varieties in order to increase the productivity signicantly.

"The major risk in using line varieties is that of uniformity." Please, explain shortly why it is a risk; not all readers may know why.
R : We agree and add : « The major risk in using line varieties is that of uniformity as they present poor adaptability due to their narrow genetic base and are more prone to the attack of new diseases (Bertrand et al., 2021).»

"Innovation and Dialogue platform." It described what topics are discussed and agreed under the platform, but it is unclear what the decision-making "power" of each stakeholder involved is. Do all have the same voice? Please clarify in the text the governance of this platform.
R : "the dialogue platform also aims to negotiate the purchase price of coffee. Of course the balance between the stakeholders is delicate and requires a sincere and transparent dialogue."

"This reduces risks and allows for the various investments required to develop a system that produces a consistent supply of high-quality coffee." A pillar of the model is high coffee quality; studies on the impacts of climate change expect a reduction in the land/climatic suitability

for current coffee areas; this was not considered in the profitability assessment; so, I would recommend discussing the possible impacts of climate change on CaFC (yields and quality).
R : Indeed, climate change could have negative impacts on the quality of the coffee produced. However, there is no known data on the impact of climate on coffee quality. We therefore prefer not to discuss this impact, which is speculative for the moment.

"...a 'degenerative effect' of the variety after a few generations. With an allogamy rate of 4% to 10%, the percentage of off-types is estimated to be between 12 and 20% after three generations." Provide a citation/reference. R : Gallais A. Théorie de la sléection en amélioration des plantes. Coll. Sci. Agron. Masson,Paris. 1989. ISSN : 0336-5247 *"The F1 hybrid generation obtained between two different gene pools – e.g. American cultivated varieties and Ethiopian wild accessions – yield 30 to 40% more than the best parent (Bertrand et al., 2019)."* This reference is for an abstract in a conference, for this statement, a peer reviewed article would be better.
R : This comment doesn't apply following changes made to the text based on first reviewer (this part was erased).

"Coffee agroforestry systems that have limited disturbance to the soil present a..." According to Guillemot *et al.* (2018), the change from one coffee agroforestry system to another, changes in tree and coffee plants (varieties), provoke a reduction in the carbon content and, therefore, climate change mitigation potential. CaFC model is about renovating coffee plantations, so the model will cause disturbance above and below the ground during there remotion of old coffee plants and trees and then establish the new coffee plants and shade trees. Discuss the impact of these implications.
R : This remark is interesting, but it leads us into too specific considerations in an already very long article. The paper introduces study cases from Nicaragua (1300 ha planted in 2016), Cameroon (20 ha in 2020) and Vietnam (clusters in the process of being created). However, only Nicaragua is a fully implemented case, and the other countries are still in the very early stages (or about to begin) to provide sufficient information on the model performance in those countries.

"The pilot cluster was formed in 2016 in Nicaragua, where 1,300 ha of coffee trees are currently cultivated..." Does the 1300 ha were established in 2016, or were they established in previous years? Clarify in the text.
R : « The pilot was established intwo years from 2016 to 2017 in Nicaragua.. »

Methods
The profitability assessment evaluates three scenarios where the option using CaFC result the best; from this assessment and scenarios, some questions arise: *Data sources. "To assess the profitability of a hypothetical CaFC model, we use available primary data from the Nicaragua pilot project combined with secondary sources for various scenarios."* Data on postharvest processing costs, coffee price, and financial scheme are from Nicaragua and data on renovating organic coffee plantations from Peru.

a. Combining data from different countries for this type of analysis might not be the best for consistency: using the costs of one country and coffee prices from another. Discuss why this combination of data, and mention the possible impacts on the profitability assessment.
R : We agree, however the comparisons between options remains valid. We modified the

text accordingly : « To assess the profitability of a hypothetical CaFC model, we use available primary data from the Nicaragua pilot project combined with secondary sources for various scenarios, including production costs data available from cooperative members in Peru. Using production costs from another country is a limitation to our study. However, our objective is to compare the profitability of different replanting scenarios, with an emphasis on the variety and overall organisational model used. Therefore the comparisons remains valid as the cost differentials affect the different scenarios in the same way. »

b. List the variables used (units and values) from each country.
R : The list of variables and units used are available in the data files 1 to 5. We have added the country of origin of the data in the title to clarify.

c. Are the certification costs included in the analysis (>2year)? They do not appear in the renovation cost files.
R : No the costs of certification are not included, as they would be the same for all three options.

d. Does the data from Peru come from an experiment or plots in different commercial coffee plantations?
R : The data on production costs from Peru were collected from three cooperatives of more than 1000 farmers each. This information was added in the text.

e. The production data (yields) available in the files show that the production values from year 3 to year 6 are the same for the period from year 8 to year 11 (except year 10). Please comment on this. Did the reported data come from actual yields from coffee plantations for the 12 years? If so, the production data are an average of different plantations or came from a single plantation?
R : The production of coffee trees is cyclical and the years 6 and 10 are years of pruning therefore without production. The production data are an average of different plantations.

f. Using the same production data provided in the files, I calculated the rate of change (%) from one year to the next for Starmaya and Typica for the 12 years; and it can observe that both varieties have the same rate of change for most years, which is very interesting. I would expect different rates of change. Similar situation for production costs. If I am missing something, please, explain and describe it in the text.
R : These are data observed for the Typica and Starmaya varieties, on several sites in different cooperatives in northern Peru. For Starmaya in addition to greater productivity, a) annual variations are less important, b) production breaks are less important, c) the number of harvests per cycle is higher. However, we favored a 'conservative' comparison based on the Typica cycle.

g. Data from Peru. There is no mention of the biophysical conditions where the coffee plantations were established (altitude, temperature, precipitation, region, etc.); knowing this information would create a clearer picture of the coffee systems under comparison. This information could be added to the text or in Table 2. Summary of scenarios.
R : All the data come from the region Norte de Peru'. Region de Jaen and Cajamarca. This information was added in the text.

h. All the files in the Data file 1-5 should mention the country of origin in the metadata and the corresponding actual years (e.g. 1996, 1997, etc..) as a column inside each file.
R : The country of origin of the data was added in the title of the files. We do not have the actual years in the original data. i. The data on production costs indicate that Starmaya and Local Variety (Typica) has different production costs (≥ 3 years). Starmaya has higher production costs. Why the differences? If comparing both systems, I would assume similar management.

R : Since the two varieties have very different production potentials, the input and labor costs are very different.

It compared the coffee hybrid Starmaya vs the local variety Typica. Why was Typica selected? Its performance is not the best among the traditional varieties or the most used by farmers in the region, such as Caturra. Caturra is widely used in conventional and organic coffee plantations in Nicaragua, where there are 1300 ha under CaFC.
R : That's a good point by the reviewer. Typica is used here as a type of coffee not very improved which is also a historical reference still often used in many producing countries (Mexico, Peru, Jamaica for the Blue mountain, etc...). Added this in the text.

Add a short description of Typica in terms of yields, quality, and disease resistance performance; so the reader knows against what is compared to the hybrid Starmaya.

R : Added this information in the text.

"...with the F1 hybrid variety 'Starmaya', and alternative scenarios involving local varieties..." It is only one local variety. R : We change the sentence « with the F1 hybrid variety 'Starmaya', and alternative scenarios involving a local pure line variety..."

Be specific and use the Typica instead of "Local Variety" in the corresponding figures and tables. There are many local (traditional) varieties with different performances.
R : We agree and replaced « Local variety » with « Typica » in our analysis of scenarios

On the three scenarios that were evaluated, I am not sure they are the best choice because of the narrow comparison, and my impression is that there is not much information to justify the selection. For example, coffee quality is a pillar in CaFC; however, the scenario description does not mention the coffee quality for each scenario; or if the plantations of the three scenarios are supposed to be established at the same location. It is clear that Scenario 1 has high coffee quality and gets the CaFC coffee price premiums (Nesspreso + Organic), but it is unclear what the quality is for Scenarios 2 (FT-Organic) and 3 (conventional). If Scenario 2 and 3 have good coffee quality, they could also participate in Nespresso and get the premiums; otherwise, if the quality of Scenario 2 and 3 is low because they are located under suboptimal conditions, I do not see a point of comparison. This needs to be clarified in the text to avoid a possible misunderstanding of bias in favor of Scenario 1.
R : The higher quality of the coffee produced under the CaFC model is the result of the collaboration between stakeholders and various investments put into the variety used in

farm renovation, processing equipment and protocols that result in a coffee with a specific flavour profile. The quality premium offered by Nespresso is therefore only available to participating producers. Producing higher quality coffee does not necessarily translate into higher prices without access to higher value markets that will pay for it. Hence, an original assumption in our scenarios 2 and 3 is that producers outside of the CaFC model do not have access to quality premiums and sell their coffee at the international coffee price (c-price). Scenario 2 also includes Fair trade and Organic benefits (FT minimum price and Organic premium). While the quality premium offered by Nespresso is relatively high, the final price within the CaFC scenario is still based on the c-price and subject to its volatility. This is why comparing it to a Fair-trade organic scenario is interesting, as it includes the benefit of the Fait trade minimum price if the c-price goes below a certain threshold – see results of sensitivity analysis.

Planting material. "Plantations in the Nicaragua project have been renovated with dwarf variety Marsellesa®...(Marie et al., 2020)." This section is part of the description of the methodology used to do the Profitability assessment, Marsellesa is not part of the scenarios, and the comparison between Marsellesa and Starmaya (already mentioned before in the text) is not ideal because both are relatively new varieties, and Marsellesa is not a local (traditional) variety. This paragraph would be omitted from the text.
R : In deed Marsellesa is not part of the scenarios. This is mentioned to clarify that the pilot cluster in Nicaragua was initiated using Marsellesa, but is now ongoing using Starmaya variety – as is the case for projects in Vietnam and Cameroon. The use of high performing varieties such as Starmaya is also the objective for future implementations of the CaFC model. Therefore, the Starmaya variety and associated costs/yields is used in the CaFC scenario, and compared to Typica in scenarios 2 and3.

Results *"Results from sensitivity analysis show that the relative gap in NPV values between scenario 1 and scenarios 3 and 4 widens as the discount rate increases*." There are only 1, 2, and 3 scenarios.
R : Corrected to «... and scenarios 2 and 3 widens...».

Why was the profitability assessment only for 12 years? Why not 30 years, as it is mentioned in the text? Coffee plantations using traditional (local) varieties have a longer lifespan than the one evaluated here; a new renovation is required after 12 years? What is the expected productive lifespan of Starmaya? Even if farmers received favorable conditions to renovate their plantations and received good prices, they expected the plantations to be productive for more than 12 years, and the profitability analysis should consider it.

"...and a long lifespan or more than 30 years providing therefore short-term and long-term high productivity." What does it mean for short-term and long-term high productivity?
R : We agree that a coffee plantation should be established for more than 12 years. We expect a useful life of more than 15 years at a minimum and even traditionally up to 25-30 years. However, recent coffee rust crises have destroyed many of the traditional plantations of Typica, Bourbon, Caturra or Catuai in Central America. They are replaced today by plantations of Sarchimors (Obata, Paraiso, T5175, Marsellesa, etc.); the lifespan of these plantations is not yet sufficient to estimate their useful life. As for the F1 hybrids, the plantations that were made in Costa Rica from 2003 and in Nicaragua from 2005, show that

their useful life is much longer than those of pure lines. In fact what we demonstrate here over 12 years should be even more true after 20 years. However, we considered that 12 years was a sufficient period of time to draw solid conclusions from our study.

"...the hybrids developed by CIRAD..." for precision, provide the name of the hybrids that this text is referring. Some hybrids were developed in the region by the collaborative effort of many institutions, including CIRAD
R : We removed the mention of 'hybrids developed by CIRAD' as replaced by “the performance of the new varieties for plantation renovation”.

"Pre-existing relationships with local stakeholders was detrimental in the success of the model in Nicaragua." Detrimental?
R : In deed not the right choice of word, Modified text as follows « Pre-existing relationships with local stakeholders was a great advantage participating in the success of the model in Nicaragua.” *"...stakeholders. In this activity, a methodological proposal has been designed*." It is not clear what activity you are referring. R30/ Clarified that “this activity” is referring to the development of Dialog and Innovation platforms.

Conclusions
"2) The use of high-performance coffee varieties that guarantee high yields under agroforestry production systems..." on the description of the scenarios include the description of the agroforestry systems (shade tree species, shade level, prunings, etc).

"3) Agroforestry management that stabilizes production, improves and homogenizes coffee quality..." Stabilization of the production because agroforestry is not supported in the paper, there is no comparison with full-sun systems to see the such positive effects; and the results on NPV in Figure 1a and the this figure I did using the production data (Data availability section) show that scenario 1 (Starmaya) has similar trend than Typica and a similar rate of change in production from one year to the next (see the image in comments for Methods).

R : Added this in the introduction ; “The shade is composed of native species that have proven themselves in agroforestry systems, associated with coffee (Cordia alliodora ‘Laurel’, Swietenia humilis ‘Caoba’, Juglans olanchana ‘Noga’l, Platymiscium pleiostachyum ‘Coyote’), with densities between 250 and 400 trees per hectare at the time of replanting. During the first 5 years of development, thinning leads to real densities of 200 to 350 trees/hectare The percentage of shade at noon on a sunny day varies between 25 and 40% depending on the plots (exposure and age of trees). “

Competing Interests: No competing interests were disclosed.

Reviewer Report 25 May 2022

https://doi.org/10.21956/openreseurope.15732.r29316

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Christophe Montagnon
RD2 Vision, Valflaunes, France

This article presents an innovative business driven local value chain based on a trustful partnership involving different stakeholders: farmers, research, financial entity, trader, roaster. The paper is well written, brings novelty and is based on good framework of analysis and data. The discussion and conclusions are well supported.

General comments:
Title is too long. It needs to be shortened. I would suggest the word "innovative" be in the title.

Literature: Literature review is good in general. However, it would be good to add some recent publications of Dietz and/or Grabbs, such as "Dietz, T., & Grabs, J. (2022). Additionality and implementation gaps in voluntary sustainability standards. *New political economy*, *27*(2), 203-224"[1]. Indeed, it would naturally support the CaFC.

Varieties (1): CaFC are supposed to be using improved or "high performance coffee varieties", as stated in the conclusion. The paper states that F1 hybrids are the appropriate varieties. While this sounds correct, it is not necessary to equate CaFC to F1 hybrids but rather to "high performance varieties", what ever they are from a breeder's perspective. It is fair to explain in the beginning of the paper why the choice is to use F1 hybrids as the best available performing varieties, but then in the text and discussion / conclusion you might be more generic on using the best performing available varieties.

Varieties (2): A side effect on referring to F1 hybrids is that the word "hybrid" is used all along the paper, sometimes not consistently (F1 or F1 hybrid or hybrid or even Starmaya hybrid). Apart from inconsistency, the word "Hybrid" might be misinterpreted. What is important is that the variety is resilient, adapted to shade and accessible. The last part is specific to "F1 hybrid". However, the important part is to build a good local seed or cuttings sector. I suggest you search for "hybrid" in your text and make it consistent. My recommendation is to use high performance varieties after you first explain that the highest performance variety in your case if a variety that happens to be a F1 hybrid. You can choose otherwise, but be consistent.

Research and farming practices in CAFS: You should insist more that in fact there is not much of literature that gives clear recommendation and Ag practices for CAFS system and even less related to profitability. it does not change your paper and initiative, but you should insist on the need of simple, realistic applied research.

"Do nothing" scenario: I was wondering why you did not add a "Do nothing" scenario, that is don't renovate and continue. At least, you should explain your choice.

Table 5 - Table 5 should be improved or even rethought. It is very difficult to read and not much informative. You list issues and basically tell that this issue is to be taken into account depending

on the context. It would be more important to the reader to give your top issues (like the top 5) and give more explanations on how they can be key factors of success or failure.

Details:
"High quality": You should give your definition of "High quality coffee" and "High quality" planting material.

"The changes in production practices needed to achieve these goals often require replanting coffee farms with adapted and efficient varieties". Give a reference and explain what is an efficient variety (see general comments on variety).

"2) The use of high-performance coffee varieties that guarantee high yields under agroforestry production systems, resistance to local diseases and high organoleptic quality." Resistance to local diseases is not necessarily true for F1 hybrids but their vigor allows to cope with susceptibility (see Cirad references, Toniutti *et al*.[2]). Maybe you might use the word "resilient" varieties?

"*In order to avoid a drastic decline in productivity, a coffee plantation must be replanted after 15 to 30 years of production – depending on the variety*". Please be cautious in that statement or support it with literature review. I have not seen robust support to that statement. However, it is very likely that sustainable practices in CaFC would allow to increase the lifespan of a coffee plot.

"The cost of replanting itself lies in the order of 3500 to 7000 USD/ha for the first two years according to a 2020 survey implemented by CIRAD in Nicaragua." Are you considering the first two years here because of the time for the first harvest? Which is highly depending on variety. Please be precise.

"Adopting high quality varieties adapted to agroforestry systems". All this section ending just before "***Offering a fair price",*** should be improved. You seem to oppose fixed lines and F1 hybrids (which is a debate in many dimensions). Why not just tell you need the best available variety and that in your case, given the status of art, the best available variety happen to be modern varieties selected under a F1 hybrid breeding programme? Then of course, you will mention the caveat of F1 hybrids related to their genetic make up. But recent progress / Starmaya and superiority of these varieties is worth it.

"Today, 90% of the world's Arabica plantations (more than seven million hectares) are planted with line varieties derived from a narrow genetic basis" You might cite my paper: Montagnon, C., Mahyoub, A., Solano, W., & Sheibani, F. (2021). Unveiling a unique genetic diversity of cultivated Coffea arabica L. in its main domestication center: Yemen. Genetic Resources and Crop Evolution, 68(6), 2411-2422[3].

"In the majority of Arabica producing countries, there are no controlled or certified seed production bodies, putting farmers at risk that the seeds for new trees are not of consistent quality, genetic purity and variety standards" You might cite my paper: Pruvot-Woehl, S., Krishnan, S., Solano, W., Schilling, T., Toniutti, L., Bertrand, B., & Montagnon, C. (2020). Authentication of Coffea arabica varieties through DNA fingerprinting and its significance for the coffee sector. *Journal of AOAC International*, *103*(2), 325-334[4].

"In Arabica, only the best individual of the best F1 hybrid progenies (...)" : individual(S)

"A Starmaya plant coming out of the nursery and ready to be planted costs about 1.2 times the cost of a plant produced by the producer with pure line seeds". I think you mean that it is cheap compared to clonal plants. This should be precise.

"Voluntary sustainability standards (VSS) such as Fair Trade, which are becoming a sine qua non for access to specialty coffee markets, (...)": "Sine qua non" is a little bit strong. "are often associated with" sounds more correct.

"the shift from diversified shade coffee to simplified shade or unshaded coffee (Goodall et al. 2015; Jha et al. 2014)".: I think there are more recent publications such as Harvey, C. A., Pritts, A. A., Zwetsloot, M. J., Jansen, K., Pulleman, M. M., Armbrecht, I., ... & Valencia, V. (2021). Transformation of coffee-growing landscapes across Latin America. A review. *Agronomy for sustainable development*, *41*(5), 1-19[5].

"La Cumplida also provides other farms with planting material and access to an innovative processing facility." The point here is "High quality" planting material.

"(...) smallholders are currently discouraged by the low productivity of their variety (the Java variety) and low prices." Be cautious on the Java variety which is not a poor variety in other context. Farming practices and neglecting the coffee plots is the main issue here.

Figure 1a. You might explicit in the text the reason why the NPV is zero for scenario 1 in the first two years. It is one of the main characteristic of this scenario.
+ in the capture you mention "F1 local variety" for scenario 2.

Table 4. Is the title correct?

(Discussion)
"Especially for smallholder farmers, high quality premiums coupled with capacity building and access to i) highly productive varieties; ii) renovation of plantations; and iii) adapted credit with favourable (...)." Be consistent with your qualification of varieties 'Highly productive"? Or "highly performing"? Or "Shade adapted"? Or other (resilient)? I think "Highly productive" is not giving justice to the message of the paper.

"Differences in environmental conditions, climate, local practices etc. requires adapting some elements of the model. For instance, the shade level provided by associate trees has to be adapted to local conditions (generally between 30% and 40%) and take into account local preferences in timber and/or fruit trees. " See my general comment of Ag practices which are not well documented and for which applied research is needed.

"Pre-existing relationships with local stakeholders was detrimental in the success of the model in Nicaragua." Detrimental?

"a final roaster and a key intermediary organisation (ECOM)," In fact, Ecom is the trader. Indeed, trader is at the interface between farmers and roasters.

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1. Dietz T, Grabs J: Additionality and Implementation Gaps in Voluntary Sustainability Standards.

New Political Economy. 2022; **27** (2): 203-224 Publisher Full Text
2. Toniutti L, Breitler JC, Etienne H, Campa C, et al.: Influence of Environmental Conditions and Genetic Background of Arabica Coffee (C. arabica L) on Leaf Rust (Hemileia vastatrix) Pathogenesis.*Front Plant Sci*. 2017; **8**: 2025 PubMed Abstract | Publisher Full Text
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4. Pruvot-Woehl S, Krishnan S, Solano W, Schilling T, et al.: Authentication of Coffea arabica Varieties through DNA Fingerprinting and its Significance for the Coffee Sector.*J AOAC Int*. 2020; **103** (2): 325-334 PubMed Abstract | Publisher Full Text
5. Harvey CA, Pritts AA, Zwetsloot MJ, Jansen K, et al.: Transformation of coffee-growing landscapes across Latin America. A review.*Agron Sustain Dev*. 2021; **41** (5): 62 PubMed Abstract | Publisher Full Text

Is the work clearly and accurately presented and does it cite the current literature?
Partly

Is the study design appropriate and does the work have academic merit?
Yes

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Yes

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Coffee agronomy and genetics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 10 Feb 2023

Andrew Meter

General comments:
Title is too long. It needs to be shortened. I would suggest the word "innovative" be in the title.

R : We agree and change the title as follow :
« Coffee agroforestry business-driven clusters »: an innovative social and environmental model organization for coffee farm renovation

Literature: Literature review is good in general. However, it would be good to add some recent publications of Dietz and/or Grabbs, such as "Dietz, T., & Grabs, J. (2022). Additionality and implementation gaps in voluntary sustainability standards. *New political economy*, *27*(2), 203-224"[1]. Indeed, it would naturally support the CaFC.
R : We agree and thank the reviewer for this reference that we add.

Varieties (1): CaFC are supposed to be using improved or "high performance coffee varieties", as stated in the conclusion. The paper states that F1 hybrids are the appropriate varieties. While this sounds correct, it is not necessary to equate CaFC to F1 hybrids but rather to "high performance varieties", what ever they are from a breeder's perspective. It is fair to explain in the beginning of the paper why the choice is to use F1 hybrids as the best available performing varieties, but then in the text and discussion / conclusion you might be more generic on using the best performing available varieties.
R : We agree and have modified the text accordingly

Varieties (2): A side effect on referring to F1 hybrids is that the word "hybrid" is used all along the paper, sometimes not consistently (F1 or F1 hybrid or hybrid or even Starmaya hybrid). Apart from inconsistency, the word "Hybrid" might be misinterpreted. What is important is that the variety is resilient, adapted to shade and accessible. The last part is specific to "F1 hybrid". However, the important part is to build a good local seed or cuttings sector. I suggest you search for "hybrid" in your text and make it consistent. My recommendation is to use high performance varieties after you first explain that the highest performance variety in your case if a variety that happens to be a F1 hybrid. You can choose otherwise, but be consistent.
R : We agree and have modified the text accordingly

Research and farming practices in CAFS: You should insist more that in fact there is not much of literature that gives clear recommendation and Ag practices for CAFS system and even less related to profitability. it does not change your paper and initiative, but you should insist on the need of simple, realistic applied research.
R : We agree and have modified the text accordingly

"Do nothing" scenario: I was wondering why you did not add a "Do nothing" scenario, that is don't renovate and continue. At least, you should explain your choice.
R : As most farms are de facto insolvent, we believed that the "do nothing" was explicit. We did not consider the 'Do nothing' scenario' because without replanting the farm is considered unprofitable by the stakeholder. We added an explanation in the text

Table 5 - Table 5 should be improved or even rethought. It is very difficult to read and not much informative. You list issues and basically tell that this issue is to be taken into account depending on the context. It would be more important to the reader to give your top issues (like the top 5) and give more explanations on how they can be key factors of success or failure.

R : This table represents a grid for evaluating the feasibility of a cluster. We don't think that sorting according to priorities would bring more readability.

Details:
"High quality": You should give your definition of "High quality coffee" and "High quality" planting material.

"The changes in production practices needed to achieve these goals often require replanting coffee farms with adapted and efficient varieties". Give a reference and explain what is an efficient variety (see general comments on variety).
R : we modified the text according to the suggestion of the reviewer. We changed 'high quality ' by 'Specialty coffee' and « High quality planting material' by high performance varieties

"2) The use of high-performance coffee varieties that guarantee high yields under agroforestry production systems, resistance to local diseases and high organoleptic quality." Resistance to local diseases is not necessarily true for F1 hybrids but their vigor allows to cope with susceptibility (see Cirad references, Toniutti *et al*.[2]). Maybe you might use the word "resilient" varieties
R : we modified the text according to the suggestion of the reviewer
"*In order to avoid a drastic decline in productivity, a coffee plantation must be replanted after 15 to 30 years of production – depending on the variety*". Please be cautious in that statement or support it with literature review. I have not seen robust support to that statement. However, it is very likely that sustainable practices in CaFC would allow to increase the lifespan of a coffee plot. R : we modified the text according to the suggestion of the reviewer

"The cost of replanting itself lies in the order of 3500 to 7000 USD/ha for the first two years according to a 2020 survey implemented by CIRAD in Nicaragua." Are you considering the first two years here because of the time for the first harvest? Which is highly depending on variety. Please be precise.
R : This range is based on calculations made taking into account low yielding varieties like Typica or high yielding varieties like the H1 hybrid 'centroamerica'

"Adopting high quality varieties adapted to agroforestry systems". All this section ending just before "***Offering a fair price",*** should be improved. You seem to oppose fixed lines and F1 hybrids (which is a debate in many dimensions). Why not just tell you need the best available variety and that in your case, given the status of art, the best available variety happen to be modern varieties selected under a F1 hybrid breeding programme? Then of course, you will mention the caveat of F1 hybrids related to their genetic make up. But recent progress / Starmaya and superiority of these varieties is worth it.
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Crop Evolution, 68(6), 2411-2422[3].
R : we modified the text according to the suggestion of the reviewer and modifed the bibliography

"In the majority of Arabica producing countries, there are no controlled or certified seed production bodies, putting farmers at risk that the seeds for new trees are not of consistent quality, genetic purity and variety standards" You might cite my paper: Pruvot-Woehl, S., Krishnan, S., Solano, W., Schilling, T., Toniutti, L., Bertrand, B., & Montagnon, C. (2020). Authentication of Coffea arabica varieties through DNA fingerprinting and its significance for the coffee sector. *Journal of AOAC International*, *103*(2), 325-334[4].
R : we modified the text according to the suggestion of the reviewer and modifed the bibliography

"In Arabica, only the best individual of the best F1 hybrid progenies (...)" : individual(S)

"A Starmaya plant coming out of the nursery and ready to be planted costs about 1.2 times the cost of a plant produced by the producer with pure line seeds". I think you mean that it is cheap compared to clonal plants. This should be precise.
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"Voluntary sustainability standards (VSS) such as Fair Trade, which are becoming a sine qua non for access to specialty coffee markets, (...)": "Sine qua non" is a little bit strong. "are often associated with" sounds more correct.
R : we modified the text according to the suggestion of the reviewer

"the shift from diversified shade coffee to simplified shade or unshaded coffee (Goodall et al. 2015; Jha et al. 2014)".: I think there are more recent publications such as Harvey, C. A., Pritts, A. A., Zwetsloot, M. J., Jansen, K., Pulleman, M. M., Armbrecht, I., ... & Valencia, V. (2021). Transformation of coffee-growing landscapes across Latin America. A review. *Agronomy for sustainable development*, *41*(5), 1-19[5]. R : we modified the text according to the suggestion of the reviewer and modified the bibliography
"La Cumplida also provides other farms with planting material and access to an innovative processing facility." The point here is "High quality" planting material.
R : we modified the text according to the suggestion of the reviewer

"(...) smallholders are currently discouraged by the low productivity of their variety (the Java variety) and low prices." Be cautious on the Java variety which is not a poor variety in other context. Farming practices and neglecting the coffee plots is the main issue here.
R : we modified the text according to the suggestion of the reviewer

Figure 1a. You might explicit in the text the reason why the NPV is zero for scenario 1 in the first two years. It is one of the main characteristic of this scenario.
+ in the capture you mention "F1 local variety" for scenario 2.
R : we modified the text according to the suggestion of the reviewer

Table 4. Is the title correct?
R : Yes

(Discussion)
"Especially for smallholder farmers, high quality premiums coupled with capacity building and access to i) highly productive varieties; ii) renovation of plantations; and iii) adapted credit with favourable (...)." Be consistent with your qualification of varieties 'Highly productive"? Or "highly performing"? Or "Shade adapted"? Or other (resilient)? I think "Highly productive" is not giving justice to the message of the paper.
R : we modified the text according to the suggestion of the reviewer

"Differences in environmental conditions, climate, local practices etc. requires adapting some elements of the model. For instance, the shade level provided by associate trees has to be adapted to local conditions (generally between 30% and 40%) and take into account local preferences in timber and/or fruit trees. " See my general comment of Ag practices which are not well documented and for which applied research is needed.
R : we modified the text according to the suggestion of the reviewer

"Pre-existing relationships with local stakeholders was detrimental in the success of the model in Nicaragua." Detrimental?
R : we modified the text according to the suggestion of the reviewer

"a final roaster and a key intermediary organisation (ECOM)," In fact, Ecom is the trader. Indeed, trader is at the interface between farmers and roasters.
R : we modified the text according to the suggestion of the reviewer

Competing Interests: No competing interests were disclosed.