Rwanda's Coffee Value Chain

Insights into coffee production costs, household actual income, and supply chain efficiency

ICO Coffee Public Private Taskforce (CPPTF)
Market Transparency Technical Workstream

Prepared by:
Committee on Sustainability Assessment (COSA)

Contents

Acknowledgements

We extend our heartfelt gratitude to all those who contributed to the successful development of the Cost of Production, Actual Income, and Supply Chain Efficiency study in Rwanda. This endeavor would not have been possible without the dedication and collaboration of numerous individuals and organizations.

First and foremost, we express our sincere appreciation to Mr. Claude Bizimana, Chief Executive Officer, Mrs. Sandrine Urujeni, Chief Operations Officer, and Mr. Eric Ruganintwali, Planning Division Manager of the National Agriculture Export Board (NAEB) for their invaluable support and collaboration in facilitating the implementation of the study. Their deep insights into the Rwanda coffee landscape, guidance, logistical assistance, and analytical collaboration have played a vital role, not only in ensuring the successful execution of the project but also in emphasizing the significance of reliable data for informed decision-making, thereby setting a commendable example for other national institutions.

We are also deeply thankful to Professor Alfred Bizoza, Mrs. Odette Mutangiza, and Mr. Patrick Byishimo, and all enumerators from The Highlands Centre for Leadership and Development (HLC-L4D) for their invaluable expertise, diligent research efforts, and unwavering commitment throughout the project. Their support in understanding the Rwanda context and shaping the methodological approach of the field data collection process, guiding the sampling strategy, contributing, and respecting the methodological rigor of the work, and supporting data cleaning and analysis, have laid the foundation for a comprehensive understanding of the cost dynamics and income generation within Rwanda's agricultural sector.

Furthermore, we extend our gratitude to all the 1,231 coffee farmers who opened the doors of their homes and who generously shared their personal information, time, knowledge, and experiences. Without their invaluable contributions, this study could not have been possible. Additionally, we extend our appreciation to all agricultural supply chain stakeholders who actively participated in the interviews and the study validation workshop. Their involvement allowed us to delve deeper into understanding the costs associated with their work and the barriers they encounter. Additionally, their support was invaluable in assessing the adequacy of the recommendations derived from the study.

This study wouldn’t be possible without the support of the Coffee Exporters and Processors Association of Rwanda (CEPAR) whose invaluable assistance was pivotal in facilitating our work. Additionally, we are grateful to Ambassador Solomon Rutega, Secretary General, and Dr. Celestine Gatarayiha, Director of Research and Development at the Inter African Coffee Organization (IACO), for their steadfast support in validating and disseminating the study objective. Special thanks are also due to the members of the Technical Workstream II International Technical Advisory Panel (ITAP), whose expertise helped shape the study's indicators and methodologies.

We thank Mrs. Vanusia Nogueira, Executive Director of the International Coffee Organization (ICO), for her invaluable contribution in endorsing and entrusting The Committee on Sustainability Assessment (COSA) with the facilitation of the ICO’s Coffee Public Private Task Force (CPPTF) Technical Workstream on Market Transparency (TWS2). Her continuous support and encouragement have been instrumental in defining valuable strategies aimed at fostering the sustainability of the coffee sector. We acknowledge the contributions of the (ICO)'s sherpas, whose participation in the workstream meetings provided valuable insights and guidance.

We acknowledge the following individuals from the COSA team for their contributions to this report:

Research Lead/Author:

- Carlos De Los Ríos:

Contributors:

- Sjoerd Panhuysen
- Prof. Alfred Bizoza
- Sylvia Calfat
- Liam Brody

Lastly, we would like to acknowledge the funding support provided by the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), under the leadership of Mrs. Ulrike Niesmanna and Mrs. Laura Bender, which enabled the realization of this important initiative. GIZ’s investment in research and development underscores their commitment to advancing the prosperity and sustainability of the agricultural sector.

We express our deepest appreciation to everyone involved for their dedication, collaboration, and commitment to advancing this study. Together, we have laid the groundwork for informed decision-making and policy formulation aimed at enhancing the livelihoods of farmers and promoting sustainable agricultural practices in Rwanda.

Executive Summary

The International Coffee Organization (ICO) collaborates with nations to strengthen the global coffee sector and promote its sustainable growth within a market-driven framework. In 2019, it launched the Coffee Public-Private Taskforce (CPPTF) to foster consensus between public and private stakeholders on priority issues and actions. This initiative aims to ensure the sustainability and fairness of the global coffee sector at both local and global levels. Through the CPPTF's Technical Work Stream on Market Transparency (TWS II), The Committee on Sustainability Assessment (COSA) facilitated the development of methodologies and tools specifically tailored for data collection on vital topics, such as coffee production costs, actual income of coffee farmers, and efficiency within the coffee supply chain.

With the support of The Deutsche Gesellschaft für International Zusammenarbeit (GIZ), COSA, in partnership with The National Agriculture Export Board (NAEB) and its designated research institution, The Highlands Centre for Leadership and Development (HLC-L4D), embarked to pilot the work of the ICO TWS II in Rwanda. Since February 2023, the organizations have collaborated to refine and adapt methodologies and tools to the local Rwandan context, executing fieldwork to collect robust and reliable data on the cost of coffee production and supply chain efficiency. This data will guide targeted policy and investment initiatives in Rwanda. The findings outlined in this report are the result of this collaborative effort.

As per the findings of the National Coffee Census (2015), coffee is produced by 352,830 farmers in Rwanda, spanning over 35,000 hectares. To accurately represent Rwanda's coffee sector, this study employed a proportional random sampling methodology, resulting in a sample size of 1,344 households distributed across provinces, with a margin of error of 4.2% at a 95% confidence level and a 10% contingency for non-responses. However, fieldwork in Rwanda faced challenges due to scattered farms, difficult access, and issues with the farmers' list, including farmers who had stopped coffee production, relocated, sold their farms, or were deceased. As a result, the final data was collected from 1,231 households, yielding a margin of error of 4.6%. The sample distribution process involved three stages: selecting representative districts within each province based on the number of farmers, choosing a proportional representation of privately-owned and cooperatively owned Coffee Washing Stations (CWS) within those districts, and randomly selecting an average of 29 farmers per CWS, ensuring a balanced representation of male and female producers. This multi-stage approach encompassed 13 districts and 43 CWS (30 privately-owned and 13 cooperatively owned).

Rwanda's coffee sector faces challenges due to an aging workforce at the production level, despite the country's overall youthful population. According to the sampled households in this study, the average age of coffee farmers has risen to 54, with only 11% being young (below 35), and 22% over 65. Female-headed households, comprising older farmers with lower education levels, face disadvantages. While households have significant agricultural expertise, educated youth often opt for non-agricultural employment, posing concerns for the sector's future. There is a larger probability that younger and educated individuals work in off-farm activities.

In Rwanda, coffee farming is characterized by small, scattered plots, with farmers typically owning an average of 0.26 hectares of land dedicated to coffee cultivation. Fragmentation of coffee cultivation is common, with approximately 30% of farmers spreading their coffee across three or more plots, presenting challenges for cultivation and economies of scale. Shade-grown coffee is not widely practiced, with 44% of farms lacking shade entirely, despite its potential benefits for soil fertility and ecosystem health. Intercropping, however, is prevalent among Rwandan coffee farmers, with around 35% intercropping their coffee plots with seasonal crops or permanent cultivations, primarily for additional income and food security. Despite coffee farming being a significant economic activity, many coffee trees are old, with around 39% being 30 years or older, and a substantial proportion of coffee farmers indicating that all their coffee trees are over 30 years old. There's also limited evidence of coffee tree renovation, with only about 19% of coffee farmers reporting rehabilitation or stumping of at least 10% of their trees in recent years.

On average, coffee farmers in Rwanda achieve a productivity rate of 1.69 kg of fresh cherries per coffee tree showing lower levels than in 2016 (1.75 kg), with significant variation noted across farms, following a right-skewed distribution. Yields exhibit comparable levels across provinces, though significant disparities exist within each. These differences are influenced by various factors including farmers' characteristics, geographical factors, wealth indicators, and access to technical assistance and credit. Good agricultural practices positively impact productivity, with activities like resource management, fertilization, and training correlated with higher yields. Additionally, coffee planted at higher altitudes and on less steep slopes tends to yield more, while the presence of older trees hampers productivity.

When considering household labor, wage labor, equipment replacement value, and non-subsidized inputs, the average production cost is around RWF 181.7 (c.a. US$ 0.18) per kilogram of cherry, consistent with previous studies performed by Church and Clay in 2016. Although the mean cost remains unchanged, there's a right-skewed distribution with the median value 18% higher than in 2016. A notable shift is observed in cost structure, with household labor constituting 49%, non-subsidized inputs 33%, paid labor 12%, and equipment depreciation 6%. The bulk of non-subsidized input costs stem from organic fertilizers. The research found that smaller-scale farmers face elevated production costs due to large inefficiencies, especially related to family labor allocation.

To enhance the comprehensiveness of the assessment regarding farmers’ production costs, a variety of cost sources that significantly influence farmers’ decision-making processes, such as the cost of credit, transportation, amortization of coffee trees, and the rental value of land were considered. Full production costs amounted to RWF 234 per kg of fresh cherry produced, representing an approximate 30% increase compared to previous estimations. It turns out that the most productive farmers have a lower average production cost per kilo, and that a higher investment in coffee (increase in production costs) has the potential to result in a twofold increase in yields, consequently boosting incomes.

This research reaffirms farmers as the most vulnerable link in the value chain, compounded by the extreme atomization of coffee plots—characterized by very small and scattered parcels, — low productivity, and their lack of bargaining power. Although farmers boast 25% profit margin, they would still need to come up with innovative approach to make their farms more profitable to respond to the family needs.

This study indicates that coffee washing stations generally achieve a 10% profit margin. Dry mills, though few, play a pivotal role in green bean production with a potential profit margin of around 20%. The assessment also revealed a limited presence of firms and corporations in the Rwandan coffee value chain, with most of them being integrated. These entities oversee various operations, controlling multiple coffee washing stations, dry mills, and exporters, and operate on a large scale.

Improving technical efficiency in coffee farming could significantly boost productivity and decrease production costs. Coffee policies should account for the diversity among producers and be organized around farmer segments. Given the fragmentation of land and the aging farmer population, there is an opportunity to reallocate land within a robust land market to enhance economic sustainability.

Introduction

The International Coffee Organization (ICO) serves as an intergovernmental organization fostering cooperation among coffee-exporting and importing nations. It represents a substantial share of the global coffee production and consumption. The ICO's mission centers around improving the coffee industry through collaboration, market information exchange, and partnerships with regional and international entities. In 2019, the ICO initiated the Coffee Public Private Taskforce (CPPTF), focusing on crucial themes like living and prosperous income, market transparency, policy and national dialogue, and resilient landscapes, all geared toward promoting sustainability within the coffee sector.

With the sponsorship of the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), The Committee on Sustainability Assessment (COSA) and the ICO have united their efforts within the Technical Work Stream on Market Transparency (TWS II) to empower ICO member countries to strengthen their data capabilities and boost transparency. A team of skilled technical experts has developed methodologies and tools specifically tailored for data collection on vital topics, such as coffee production costs, actual total household incomes of coffee farmers, and efficiency within the coffee value chain.

COSA, in partnership with NAEB and its designated research institution, The Highlands Centre for Leadership and Development (HLC-L4D), embarked to pilot the work of the ICO TWS II in Rwanda. Since February 2023, the organizations have collaborated to refine and adapt methodologies and tools to the local Rwandan context, executing fieldwork to collect robust and reliable data on the cost of coffee production and supply chain efficiency. Throughout the process, COSA has focused on knowledge transfer to enable NAEB and HLC-L4D to assume full ownership of the tools for independent use in future endeavors.

The ultimate aim of this work is to provide valuable insights that can sustainably enhance the well-being of coffee farmers in Rwanda. By offering access to data on coffee production costs and value chain efficiency, the initiative allows NAEB to identify opportunities for optimizing coffee production and addressing potential bottlenecks within the coffee value chain, which may otherwise affect farmer income. This comprehensive dataset is essential for directing targeted policy and investment to enhance the efficiency of the coffee sector in Rwanda and uplift the livelihoods of coffee farmers. Furthermore, NAEB is committed to sharing aggregated data with the ICO to contribute to global benchmarking and industry standardization efforts.

1. Background of the coffee sector in Rwanda

Rwanda's geographical features provide nearly ideal conditions for coffee cultivation. The country benefits from fertile volcanic soils, high altitudes, sufficient rainfall, and moderate temperatures. Its competitive advantage in the specialty coffee market is attributed to various factors: consistent good qualities, government support, expanding Coffee Washing Station (CWS) infrastructure, compelling storytelling capabilities and favorable conditions for travel and business operations. The export of coffee has a pivotal role in generating foreign exchange revenue for the nation. For instance, in 2021-2022, Rwanda's export of coffee comprised 15,000 tons, amounting to over US$ 75 million. The following fiscal year, 2022-2023, witnessed an increase in both the volume and value of coffee exports, with 20,000 tons contributing around USD 116 million, equivalent to 13.5% of Rwanda's total agricultural export value (NAEB, 2023).

In the 2015 census, the latest available data, approximately 350,000 smallholder farmers in Rwanda cultivated coffee (NAEB, 2015). Smallholder coffee farming systems are distinguished by various factors including farm size, the number of coffee trees, planting arrangements (monoculture or intercropping), and land management practices. Typically, these systems consist of smallholder farms averaging around 0.76 hectare in size (with a median value of 0.46 hectares), with an average of 600 coffee trees. Given land constraints, most coffee farms adopt intercropping practices, incorporating both perennial and annual food crops (Ngango, 2023). Arabica accounts for 99% of Rwanda's coffee production, with the remaining 1% comprising Robusta beans. Following harvest, the most common practice is that the coffee cherry's pulp is removed to obtain the bean, which is then dried to produce parchment coffee. Two methods are employed in Rwanda: home processing and wet milling.

The National Agriculture Export Board (NAEB) oversees the coffee sector, managing it alongside other agricultural export crops. It implements various programs to support coffee farmers, including the distribution of both mineral and organic fertilizers, alongside efforts to combat pests and diseases. The distribution of mineral fertilizers and pesticides is facilitated by a fund managed by the Coffee Exporters & Processors Association of Rwanda (CEPAR), financed through taxes levied on exported coffee. However, challenges exist, notably concerning the sub-optimal application of fertilizers due to inadequate distribution frequency and quantity. Additionally, some farmers divert fertilizers to alternative crops or sell them for profit. Pest control efforts target four main coffee diseases and are supported by research collaborations and NGO programs. Farmer training initiatives, like 'Farmer Field Schools', aim to educate farmers on Good

Agricultural Practices (GAP), although some farmers refrain from adoption due to perceived lack of economic incentives (Gatarayiha, 2019).

The support of the government to expand wet milling in Rwanda, totaling 313 CWSs in 2021, has significantly enhanced the country's global coffee reputation (Heinen, 2023). The primary objective behind stimulating CWS was to process coffee cherries in this station and incrementally increase the share of fully washed coffee relative to semi-washed coffee. Yet, it isn’t a clear-cut success; stringent government regulations on CWS licensing and pricing have resulted in an oversupply dilemma. Take, for example, Rwanda's export of fully washed coffee in 2022, which totaled around 20,000 tons. This indicates that, on average, each station produces only 64 tons annually.

With many CWS running at 50% of their capacity due to insufficient available coffee, there is a clear need for policy reforms to enhance the operational efficiency of the coffee sector. For instance, in 2016, Rwanda introduced a coffee zoning policy aimed at restricting farmers from selling cherry coffee outside designated zones to CWS. The policy sought to enhance traceability, eliminate middlemen, strengthen relationships between farmers and CWS, and increase coffee supply to CWSs, ultimately improving coffee quality and farmer income. However, this policy inadvertently hampered market efficiency and hindered the growth of farmer income by limiting trade between the CWS and farmers from different zones. It also allowed inefficient CWSs to continue operating, as they were guaranteed a specific volume of coffee cherry. In a move to enhance market dynamics, as of June 2023, NAEB repealed its zoning policy within the coffee sector, affording farmers greater flexibility in selling their coffee cherries.

Moreover, NAEB plays a pivotal role in establishing the annual coffee cherry floor price in collaboration with key stakeholders, including the Association of Coffee Processors and Exporters of Rwanda (CEPAR). Two floor prices are established, one for good quality cherries and another for floaters. The floor prices are defined at the beginning of the picking season and may be adjusted whenever there is a fluctuation of US$ 0.10 per pound (lb.) on the international market price. The pricing model incorporates variables such as the international coffee price (New York "C" Market), exchange rates, processing costs, and other export fees. Additionally, the model accounts for expenses related to fertilizers and pesticides[1].

The government will continue establishing floor prices for cherries, while intensifying efforts to promote the adoption of fully washed processing across the sector. For instance, dealers will need a permit to process coffee that is not fully washed, and licensed dealers of semi-washed coffee will have to pay a 5% fee based on the coffee's value, while the tariff for fully washed coffee with a cup quality score below 80 will be 3%. Specialty coffee, scoring a cup quality of 80 or above, will be exempt from the tariff, serving as a significant incentive for growers to focus on quality (Mertens and Oireire, 2023).

---

[1] In the 2023/24 season, NAEB utilized the findings of this study as one the inputs for determining the floor price.

2. Methodology

As per the findings of the National Coffee Census (2015), coffee is produced by 352,830 coffee farmers in Rwanda exceeding 35,000 hectares[2]. To ensure an accurate portrayal of Rwanda's coffee sector, this study considered the total number of farmers to devise a proportional random sampling methodology. The calculations led to determination of a sample size of 1,344 coffee farmers, which was proportionally distributed across the four provinces as the study area. This allocation was designed to yield a margin of error of 4.2% with a confidence level of 95%, while also accommodating a 10% contingency for potential non-response from farmers. Ultimately, the fieldwork yielded data from 1231 farmers, resulting in a slightly higher margin of error at 4.6%.

The process of sample distribution occurred in three stages. Initially, the focus was on selecting districts within each province. Leveraging insights from the National Coffee Census (2015), districts were categorized based on their deviation from the mean number of farmers within each province[3]. Expert guidance played a crucial role in identifying a representative district for each category. In total, 13 districts were chosen, collectively encompassing 67% of the total number of farmers. Subsequently, attention was turned to selecting a random sample of Coffee Washing Stations (CWS) operating within the districts. This selection process was informed by expert judgment, aiming to maintain a proportional representation of privately-owned and cooperatively-owned CWS within each district. Our final selection comprised 43 CWS (consisting of 30 privately-owned and 13 cooperatively-owned). Finally, using the list of farmers associated with each CWS, a random sampling approach was implemented to select an average of 29 farmers per CWS. Care was taken to ensure a balanced representation of male and female producers within the sample. The resulting sample structure is visualized in the accompanying map[4].

[2] NAEB (2016). *National Coffee Census 2015*. National Agricultural Export Development Board.

[3] For details on the sample design, see Appendix 1.

[4] For details on the fieldwork methodology and composition of the final sample, see Appendix 2.

Figure 1. Map of Rwanda and the sample layout

3. General characteristics of the sample

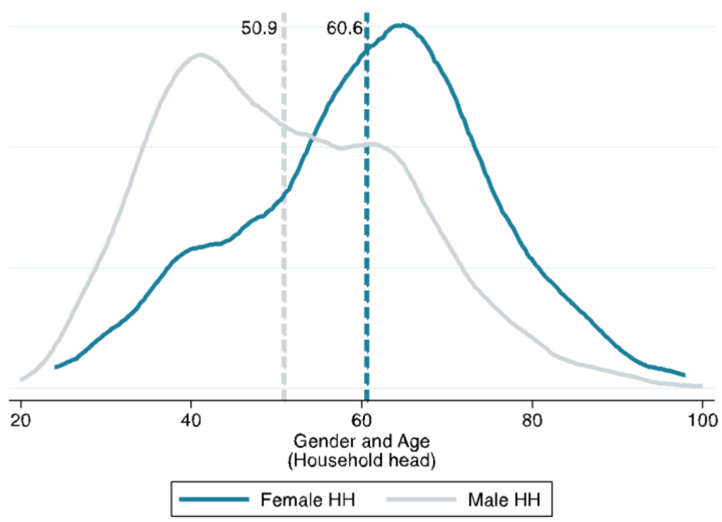
3.1 Farmers and their farms

Gender and age matter

Despite Rwanda being a nation characterized by a predominantly youthful population, the demographic trend among coffee farmers tells a different story, marked by an aging workforce. This poses significant challenges for the future of the countries' coffee sector, particularly in light of a waning interest among the younger generation in pursuing coffee farming. The average age of coffee farmers has risen to 54 years, indicating a notable increase of 3 years since 2016 (Ortega et al., 2019). Remarkably, the demographic distribution reveals a concerning imbalance, with only 11% of respondents falling into the youthful category (below 35 years old), while over a fifth (22%) surpass the age of 65.

Female-headed households emerge as particularly disadvantaged. The research indicates that female coffee farmers, on average, are a decade older than their male counterparts. Approximately 40% of female coffee farmers are aged above 65, as illustrated in Graph 3.1.1. Moreover, female coffee farmers tend to have lower levels of education and live with fewer household members than their male counterparts (resulting in a diminished labor supply for farming activities). A striking disparity emerges when considering that only 15% of female coffee farmers reside with their partners, in sharp contrast to the vast majority of male coffee farmers, where 91% live with their partners (see Graph 3.1.1 below and Table A3.1 in Appendix 3).

Graph 3.1.1: Coffee farmer's age, by gender



Coffee farmers possess limited formal education but boast substantial expertise in coffee farming.

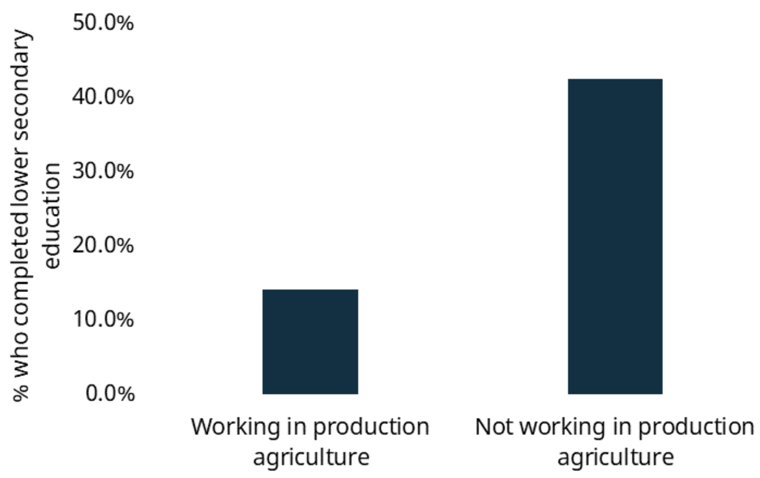
A considerable labor force is available within households, to engage in agricultural activities. Average household size is 4.8 members, about 2.2 work on their farms in coffee and other agricultural or livestock activities, and only 0.8 work in non-agricultural activities.

The family labor force is characterized by its low levels of formal education, a gap compensated for by considerable expertise in coffee farming. While approximately 42% of surveyed coffee farmers have completed primary education, only 5.9% have advanced to lower secondary education. However, farmers demonstrate an impressive average of 24 years of experience in coffee production, providing them with relevant knowledge of coffee production management and key agricultural practices (see Table A3.1 in Appendix 3).

The majority of educated youth within coffee farming households gravitate towards off-farm employment opportunities.

Less educated youth often remain within the agricultural sector. Roughly, a quarter of household members fall within the young demographic bracket, aged between 18 and 35 years old, with around half of them (53%) employed in agriculture. Interestingly, data indicates that younger and better educated individuals tend to refrain from engaging in coffee production, as depicted in Graph 3.1.2, primarily due to lower expected returns.[5] This trend raises concerns regarding the long-term viability of coffee farming, particularly given the aging demographic of coffee farmers, who are often hesitant to engage in activities aimed at enhancing productivity (as outlined in Table A3.1 in Appendix 3).

Graph 3.1.2: Next generation's education and employment



[5] For example, the remuneration for agricultural labor typically ranges between 1000 and 1200 RWF per day. According to our survey data, alternative employment in different sectors generates an average of 3000 RWF per day.

Land policy and tenure regularization allows for enhancing resource allocation, contributing to overcome smallholder’s constraints in augmenting their agricultural incomes.

In Rwanda, most coffee farmers operate as smallholders, with the average farm size typically spanning 0.76 hectares, thus heavily concentrated on smaller plots (with a median value of 0.46 hectares). Notably, male-headed farmers have 44% more farm area compared to their female counterparts (averaging 0.83 hectares versus 0.57 hectares), underscoring the heightened vulnerability of the latter group, which constitutes a quarter of Rwanda’s total coffee farming population.

Despite the modest size of landholdings in Rwanda, the research reveals that 24% of coffee farmers decided to rent land to plant seasonal crops. Average land rental is about 0.13 hectares, which represents on average 20% of total owned land (see Table A3.3 in Appendix 3). Conversely, 1.8% of sampled coffee farmers engage in renting out (renting to others) portions of their farms. Rwanda boasts a fairly vibrant land market ecosystem, partly attributable to the advantages of land tenure regularization. Prior studies by Bizoza and Opio-Omoding (2021), focusing on Rwanda and Ethiopia, confirm that land tenure regularization has significantly contributed to the active land markets, especially in terms of land rental markets.

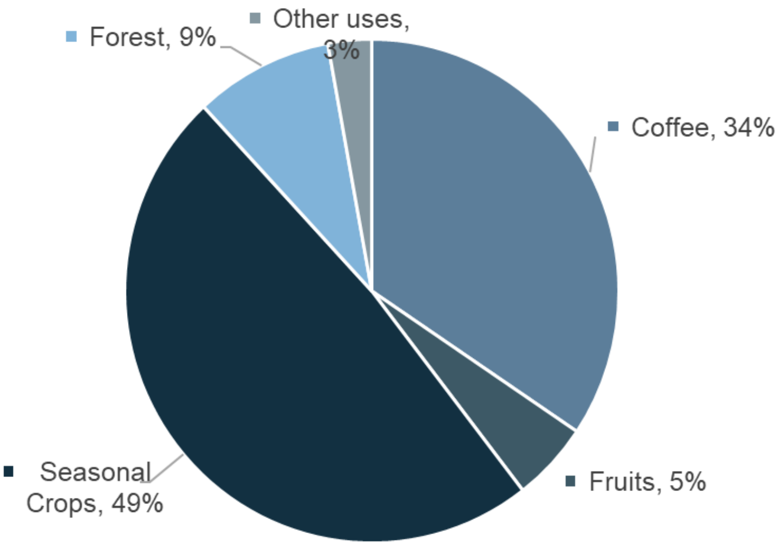
Findings indicate that farmers with smaller land holdings or limited cultivable land, coupled with larger household sizes (thus providing a greater labor supply), are more inclined to enter into land rental agreements to enhance their agricultural output. Additionally, female farmers exhibit a higher likelihood of engaging in such contracts to augment their agricultural production. However, among farmers engaging in leasing land, larger smallholders demonstrate a greater propensity to rent more land.[6]

Agricultural land dedicated to the cultivation of coffee

Farmers allocate much of their land to cultivating seasonal crops, with coffee cultivation representing a comparatively smaller portion. On average, the area dedicated to coffee cultivation spans 0.26 hectares, which represents 34.5% of the total farm area. In contrast, seasonal crops occupy an average of 0.37 hectares, accounting for about 48.5% of total farm area. The remaining area is apportioned among forested areas (9% of total area), fruit cultivation (5%), and other uses (3%), (see graph 3.1.3 and Table A3.2 in Appendix 3).

[6] For a comprehensive analysis of the factors influencing land rentals, and the extent of land rent by coffee farmers to supplement their agricultural earnings, see Table A3.3 in Appendix 3.

Graph 3.1.3: Land use



Smaller-scale farmers tend to allocate a larger portion of their land for coffee cultivation and harvest fewer crop varieties per season compared to larger farms. On average, farmers with less than 0.185 hectares allocate around 60.1% of their total land area to coffee cultivation, whereas those with over 1.105 hectares allocate only 31.7% to coffee, with more than 50% dedicated to seasonal crops. While there is a statistical difference between larger and smaller farms, the magnitude of this difference is relatively minor.

Assessing crop diversification using the Herfindhal Index,[7] it was observed that coffee farmers in Rwanda have relatively little diversification in their crops. The most important crops grown by coffee growers in Rwanda include beans – cultivated by 82% of the sampled farmers, followed by bananas (40.6%), maize (38.2%), and sweet potatoes (34.3%). Additionally, coffee farmers engage in the cultivation of various other crops, albeit to a lesser extent, such as sorghum, potatoes, peas, amongst others (see Table 3.1.1).

[7] The Herfindhal Index (HI) can be expressed as HI = j = 1Jpj2, where J is the total number of crops, *p* is the proportion of the area of crop *j* over the total cultivated area. A value closer to zero indicates specialization, while a value closer to 1 indicates full diversification.

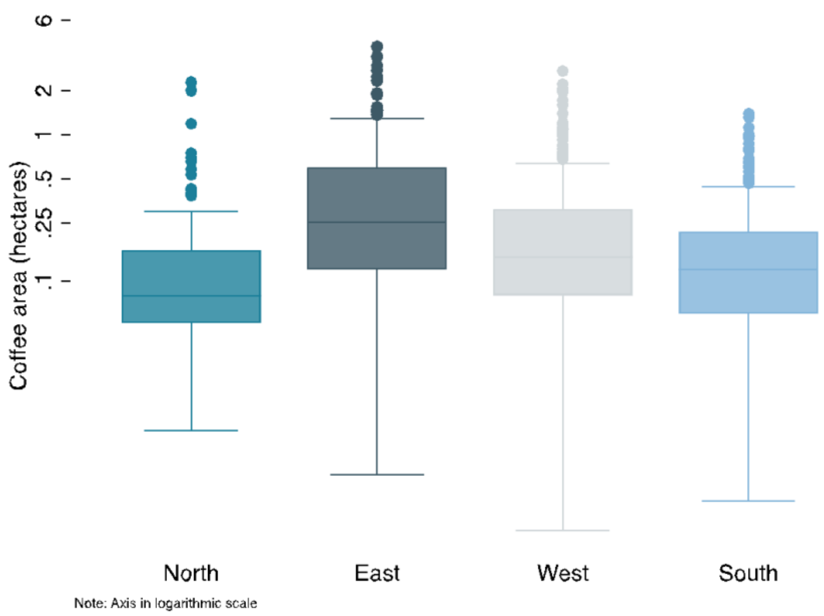
Table 3.1.1: Crop diversification and land size

Farm Area (has)	Cofffe area / Total farm area	Number of crops harvested per season	Herfindahl Index of crop diversification
< 0.185	0.601	2.316	0.184
0.185 - 0.350	0.487	2.656	0.167
0.350 - 0.580	0.413	3.061	0.203
0.580 - 1.105	0.362	3.017	0.233
> 1.105	0.317	3.386	0.224

Coffee is typically cultivated in small plots devoid of shade.

In Rwanda, coffee is cultivated across small and scattered gently sloping plots of land. On average, farmers tend to possess 0.26 hectares of coffee. In the Eastern province, coffee farms tend to be larger, averaging 0.48 hectares, whereas in the North and South regions, smaller plots prevail (with average sizes of 0.17 and 0.18 hectares respectively). The distribution of the coffee cultivation area exhibits a right-skewed pattern, with the median value of 0.14 hectares. One-third of coffee farms have less than 0.1 hectares planted with coffee trees. Smaller farms are concentrated in the North, where 56% of coffee farms occupy less than 0.1 hectare. Conversely, larger farms are more prevalent in the East, where 30% of coffee cultivation areas are larger than 0.5 hectares (see Graph 3.1.4).

Graph 3.1.4: Coffee Area (hectares), by province



Coffee cultivation typically occurs within an altitude range of 1300 – 2150 meters above sea level (m.a.s.l.). Generally, coffee is cultivated in gently sloping terrains (64%). However, it was found that around 23% of coffee trees are situated on steep slopes, mostly in the West (31.2%) and in the North (27.9%) regions. On average coffee is planted across two different plots, although approximately 30% of coffee farmers spread their coffee cultivation across three or more plots. This fragmentation not only atomizes coffee production but also disperses it, presenting challenges in cultivation and hindering the achievement of economies of scale.

Shade-grown coffee is not a widespread practice in Rwanda, despite its potential benefits for ecosystem health and soil fertility. Shaded environments can provide essential nutrients to coffee trees and soil, while also serving as a natural deterrent to pests. Approximately 44% of farmers cultivate their coffee in shade-less farms, with less than 5% dedicating more than half of their coffee cultivation under shade.

Intercropping is a common practice among Rwandan coffee farmers as it is a potential source of income and enhances food security. Intercropping is particularly relevant when coffee is yet to be productive. Around 35% of coffee farmers intercrop their coffee plots with seasonal crops or permanent cultivations such as fruit trees. Moreover, approximately one-third of farmers consciously utilize intercropping as a means to enhance nitrogen levels in their coffee plots (see Table A3.4 in Appendix 3).

Coffee trees are old, and aging trees are typically associated with diminishing productivity levels.

Around 83% of coffee trees are currently in production, while the remainder have undergone rehabilitation or stumping (7.4%), have recently been planted (4.9%), or are unproductive (4.2%). Furthermore, there is limited evidence of coffee tree renovation, with only about 19% of coffee farmers reporting that they have rehabilitated or stumped at least 10% of their coffee trees in recent years.

On the one hand, only 36% of total coffee trees are in their most productive range (3–15 years). This proportion is significantly higher in the East (52%) and in the North (45%) regions. On the other hand, a substantial portion of coffee trees in Rwanda is old, with 39% of coffee trees being 30 years or older. Alarmingly, over 26% of coffee farmers indicate that all their coffee trees are older than 30 years.

Tree density adheres to international norms.

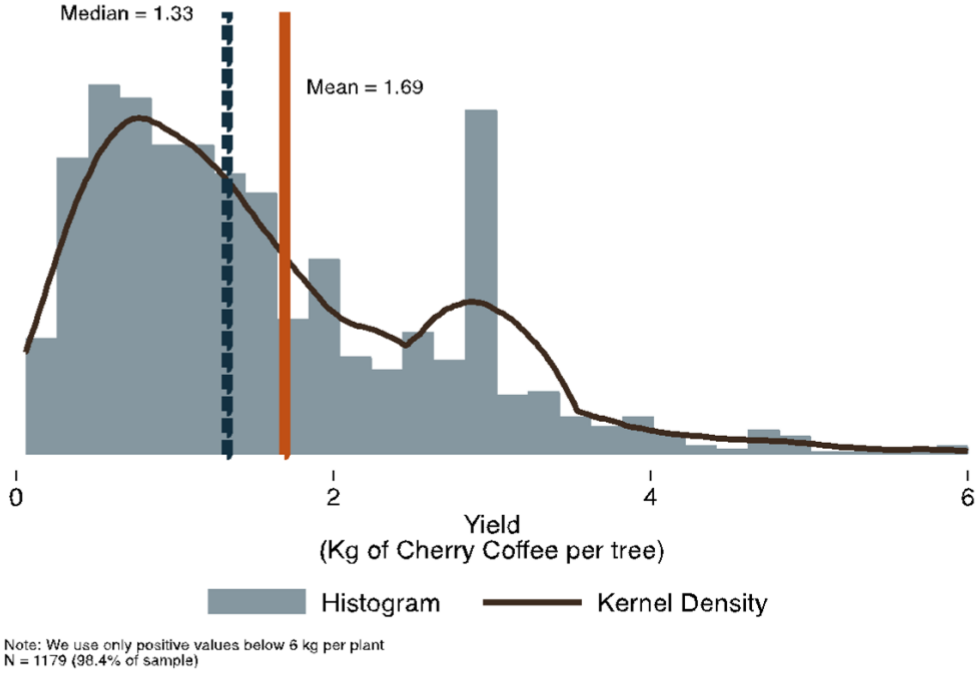
On average, farmers maintain 613 coffee trees, with half of them possessing fewer than 320 trees, and over two-thirds having fewer than 500 trees. Coffee trees are planted in general at intervals of 2 meters by 2 meters (77%), resulting in an average density of around 2500 trees per hectare. Tree density appears higher in the East (2800 trees per hectare) compared to the North (2200 trees per hectare), although all provinces exhibit a median value of 2500 trees per hectare. Moreover, it was observed that the variance in tree density in the East is nearly triple that of other provinces, indicating a greater dispersion of values around the mean. In fact, the study found that 10% of farmers in the East maintain a tree density exceeding 5000 trees per hectare, significantly higher than the 3000 trees observed in the other provinces.

3.2 Coffee productivity

Productivity levels continue to be both low and varied across different areas.

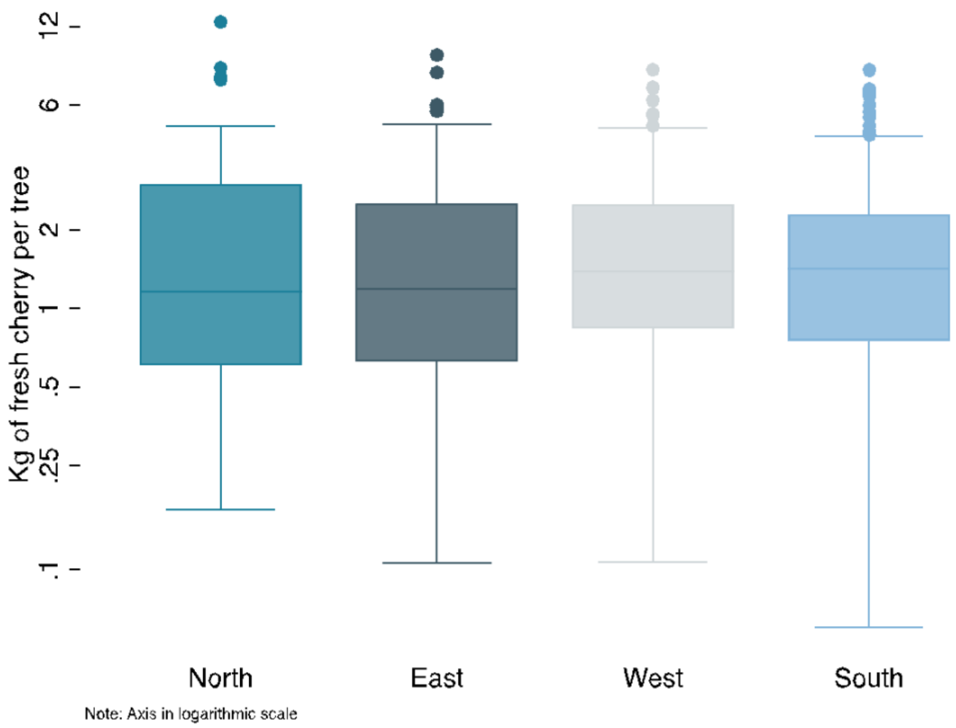
On average, farmers achieve a productivity rate of 1.69 kg of fresh cherries per coffee tree. However, coffee yields exhibit significant variation and follow a right skewed distribution. Specifically, the median productivity stands at 1.33 kg per coffee tree, with approximately 34% of coffee farmers yielding less than 1 kg. Conversely, over 20% of coffee farmers achieve yields exceeding 3 kg per tree (see Graph 3.2.1).

Graph 3.2.1: Distribution of production per productive plant



Yields exhibit comparable levels across provinces, with no statistically significant differences observed. However, notable disparities exist within each province (see Graph 3.2.2 below). The heterogeneity in yields is strongly linked to various factors, including farmers' characteristics (experience, empowerment), geographical factors (altitude, slopes), wealth indicators (value of assets), occurrences of shocks, implementation of good agricultural practices (fertilization, soil management, pest control), as well as access to technical assistance and credit. For a detailed assessment on the topic, please consult Appendix 4.

Graph 3.2.2: Distribution of production per productive coffee tree, by province



The age of trees and geographical factors significantly impact productivity.

Overall, there is a positive correlation between productivity and the implementation of good agricultural practices. Farmers who engage in activities such as resource management, fertilization, and mulching tend to achieve higher productivity levels. Moreover, training and technical assistance, which are closely associated with good agricultural practices, are strongly correlated with increased yields. Additionally, geographical factors play a significant role. Coffee planted at higher altitudes and on less steep slopes tends to yield higher harvests. The presence of older trees has a considerable adverse impact on yields. This correlation is clearly demonstrated in Table 3.2.1 and Appendix 4.

Table 3.2.1: Coffee yields (kg of fresh cherry per productive tree) by trees age

	Less than 30% of their coffee trees older than 30 years	More than 30% of their coffee trees older than 30 years	Diff
< 300 Trees	2.05	1.69	***
< 500 Trees	1.91	1.67	**
< 1000 Trees	1.81	1.67	**
< 2000 Trees	1.76	1.65	*
< 3000 Trees	1.76	1.64	*

4. Key Findings

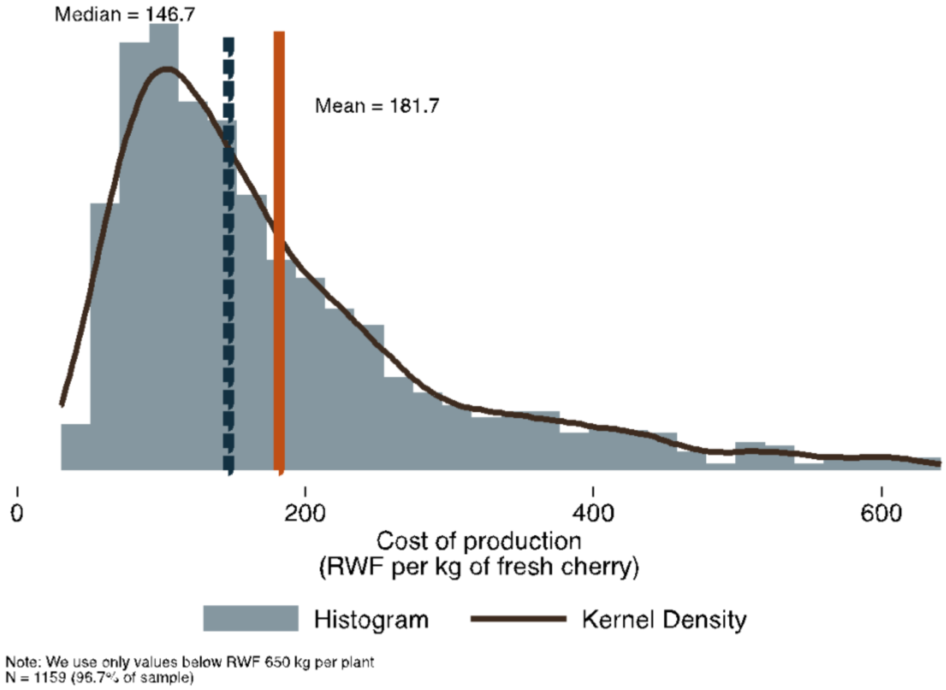
4.1 Costs of production

Coffee farmers' average production costs remain unchanged over time, mirroring findings from earlier studies. The average production cost stands at RWF 181.7 (c.a. US$ 0.18) per kg. of fresh cherry.

For comparative analysis, the study adopted the methodology outlined by Church and Clay (2016) to evaluate production costs based on four key elements: (i) Household labor (by task), (ii) wage labor (by task), (iii) replacement value of equipment (including pruning tools, shears, sprayers, etc.); and (iv) value of non-subsidized inputs (fertilizers, pesticides, mulch, etc.).[8]

The estimation reveals a mean cost of production in RWF 181.7 per kg of fresh cherry produced, a figure consistent with the research findings of Church and Clay (2016) (see Graph 4.1.1). However, costs exhibit heterogeneity and follow a right-skewed distribution. Although average results align closely, the median value is 18% higher compared to the estimate from 2016 (RWF 143 as compared with RWF 122).

Graph 4.1.1: Distribution of costs of production per kg of cherry



[8] Some other costs provided in the survey were excluded for comparison purposes, such as transportation (marketing cost), cost of credit, the cost of land and the amortized cost of replanting coffee, which were considered in the next section. For more detail on production costs, please see Appendix 5.

There has been a notable shift in the structure of production costs as well. Household labor now accounts for approximately 49% of total costs of production (CoP), with non-subsidized inputs comprising 33%, paid labor around 12%, and the depreciation or replacement value of equipment making up 6%. Notably, there has been a transition from reliance on paid (wage) labor to greater dependence on household unpaid labor, as illustrated in Table 4.1.1.

The expenditure on non-subsidized inputs encompasses both the direct purchases of inputs and the opportunity costs associated with their utilization instead of selling them in the market. Around 90% of the total costs of non-subsidized inputs originate from organic fertilizers: namely manure (46%), mulch (36%) and compost (18% while the remaining 10% stems from the purchase of non-subsidized NPK (nitrogen, phosphorus, potassium) fertilizers.

Table 4.1.1: Total cost of production per kg of cherry

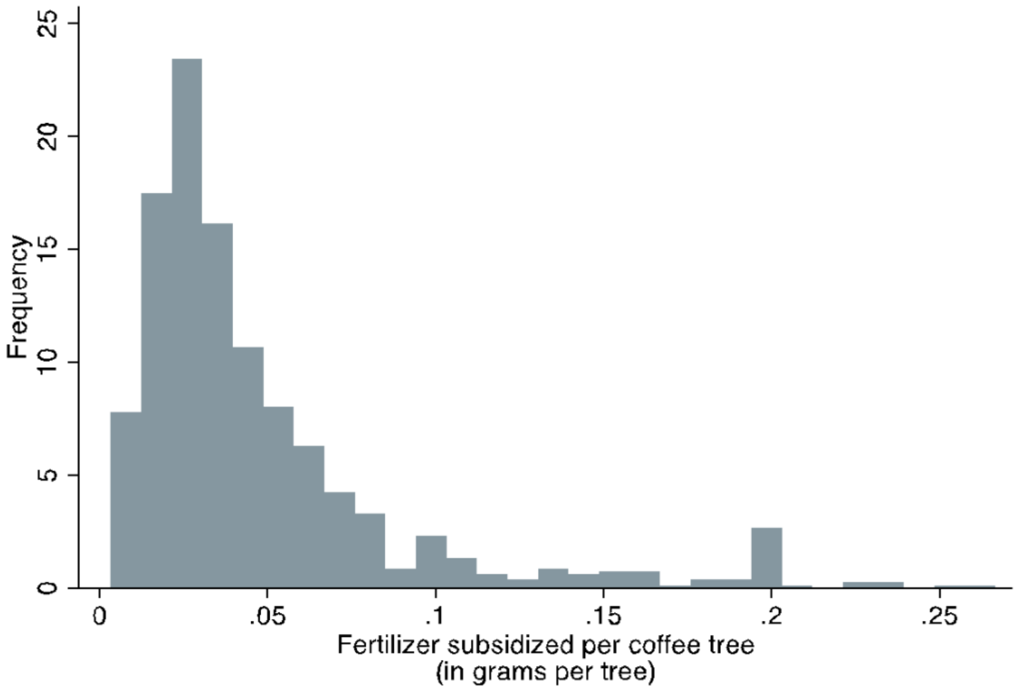
	Church et al (2017)		COSA (2023)	
	RWF per kg	%	RWF per kg	%
Household labor	76.0	42.5%	87.7	48.3%
Paid labor	61.0	34.1%	20.8	11.4%
Depreciation	27.0	15.1%	10.8	5.9%
Cost of Inputs	15.0	8.4%	62.4	34.3%
Total Costs of Production	179.0	100.0%	181.7	100.0%

Production costs vary between provinces, as outlined in Appendix 5, table A5.4. However, the primary source of variation arises from factors related to farmers' characteristics (experience), farm characteristics (number of trees, density, farm size, distance to markets), agroecological factors (such as altitude and agroecological zone), and the quantity of subsidized inputs per coffee tree (See Appendix 5, table A5.5 for an overview of the determinants of production costs).

NAEB, in collaboration with the Coffee Exporters & Processors Association of Rwanda (CEPAR) administers the distribution of subsidized inputs to coffee farmers through CWSs. These inputs are supplied to farmers without requiring upfront cash payment, as NAEB deducts the costs from the minimum price set for each production year. The allocation of coffee inputs is determined based on the number of coffee trees owned by each farmer. Farmers anticipate receiving these inputs annually. NAEB advises farmers to apply approximately 200 grams of fertilizer per coffee tree in two doses throughout the production year.

The actual amount of fertilizer distributed by NAEB to farmers is considerably less, though. For the 2021/2022 season, the average allocation of subsidized inputs was 36.8 grams per coffee tree for the whole population of coffee farmers sampled in this study. However, only 77% of them received subsidized fertilizers from their respective CWS.[9] Among those who did receive fertilizers, the average allocation per coffee tree was 48 grams. Graph 4.1.2 illustrates the distribution of the quantity of subsidized fertilizer provided to farmers.

Graph 4.1.2 Allocation of subsidized fertilizer distributed to farmers



Note: Data shows farmers that received subsidy (N=947)

When considering a more robust set of variables to assess production costs, the average total production costs for Rwandan farmers amount to RWF 234 (c.a. US$ $0.23) per kg of fresh cherries.

To enhance the understanding of the assessment regarding farmers' production costs, a variety of cost sources that significantly influence farmers' decision-making processes was integrated in the cost analysis. Full production costs amounted to RWF 234 per kg of fresh cherry produced, representing an approximate 30% increase compared to the simpler cost estimation outlined before. The additional components considered were the following:

- **Cost of credit:** The study incorporated the annual cost of credit used for regular coffee production activities or investments in coffee production equipment.[10] It

[9] The data reveals that only 12 farmers have less than 30 trees, with 8 of them not receiving fertilizers. Conversely, 268 farmers with more than 30 trees did not receive fertilizers. The analysis indicates a greater likelihood of not receiving subsidies for farmers with fewer trees. For instance, 49% of farmers with less than 100 trees (146 farmers) did not receive subsidized fertilizers, while only 19% of farmers with over 100 trees (204 out of 1077) did not receive fertilizers.

[10] Using survey data, a nominal interest rate of 8% for a period of 180 days was estimated.

was found that although 48% of farmers had access to credit, only a fifth of them utilized it for their coffee-related activities.

- **Cost of transportation:** While transportation is usually recognized as a commercialization expense, the farmers’ involvement concludes upon delivering the fresh cherry to the CWS. Therefore, the price for hiring transportation services was incorporated, and if the farmer personally delivers their coffee, the opportunity cost of transportation was calculated.
- **Cost of amortization:** The cost of labor linked to the process of coffee nursing, land preparation and coffee planting was incorporated into the assessment.[11]
- **Cost of land:** To address the opportunity costs of land, the marginal productivity of land was estimated, which, in equilibrium, equates to the annual rental price of land.[12]

Table 4.1.2: A comprehensive account of production costs

	Cost per kg of fresh cherry (RWF)	
Household labor	87.7	Total comparable cost per kg of fresh cherry = RWF 181.7
Paid labor	20.8	
Depreciation	10.8	
Cost of Inputs	62.4	
Cost of Credit	1.4	Added costs per kg of fresh cherry = RWF 52.1
Cost of Transportation	12.2	
Amortized cost of planting coffee	20.4	
Opportunity cost of land	18.1	
Total cost per kg of fresh cherry	233.7	

The most productive farmers, who yield an average 3.25 kg of fresh cherry per coffee tree, tend to incur lower expenses per kilogram compared to their counterparts (See Table 4.1.3 below). On average, a 20% higher investment in coffee (increase in production costs) has the potential to result in a twofold increase in yields, consequently boosting incomes. In other words, farmers are currently underinvesting in coffee, indicating substantial potential for improvement.

[11] It was assumed that all activities, including nursing, land preparation, and planting, would necessitate a total of 150 labor-days per hectare per year. Additionally, farmers were presumed to allocate 20% of their coffee acreage to renovation.

[12] For details regarding the estimation of the marginal productivity of land, see Appendix 5.

Table 4.1.3: Comparing production costs and productivity

	Average	Most productive
Household labor	87.7	55.2
Paid labor	20.8	13.2
Depreciation	10.8	4.3
Cost of Inputs	62.4	23.7
Cost of Credit	1.4	1.1
Cost of Transportation	12.2	12.3
Amortized cost of planting coffee	20.4	5.4
Opportunity cost of land	18.1	8.9
Total cost per kg of fresh cherry	233.7	124.2
Average yields (kg per coffee tree)	1.4	3.3

Smaller-scale farmers tend to have higher productivity levels, but also encounter elevated production costs attributed to diminished efficiency.

Productivity demonstrates an inverse correlation with farm size (See Table 4.1.4). The prevailing argument in the literature suggests that in environments characterized by surplus labor and limited technological advancement, small-scale farmers are able to cultivate their plantations more intensively (e.g., spending more time on their plots) perhaps influencing productivity. Interestingly, smaller farmers perform, on average, less agricultural practices than larger farmers, but use significantly more labor (see Table 4.1.4). For instance, a higher percentage of smaller farmers maintain older trees and a lower percentage undertake practices such as mulching, pruning or resource management. However, smaller farmers tend to use more labor per tree and allocate a higher proportion of family labor to their coffee-related activities. These inefficiencies among smaller farmers manifest in higher production costs, which are significantly higher than those of larger farms, (for instance, purchasing 200 grams of fertilizer may prove more costly than acquiring 1 ton, while hiring labor to harvest 50 kg could be more expensive than harvesting 1000 kg.) and in lower levels of technical efficiency.[13]

Table 4.1.4: Inverse relationship between size and productivity

	Less than 180 trees	180 - 300	300 - 500	500 - 1000	More than 1000 trees
Yield (kg of fresh cherry per productive tree)	2.01	1.64	1.65	1.60	1.37
+80% of coffee trees older than 30 y.o.	44%	37%	25%	21%	11%
% mulching	69%	84%	89%	93%	91%
% pruning	48%	54%	59%	56%	62%
Number of resource mgm practices [1 - 6]	0.64	0.83	1.05	1.15	1.12
Total labor per 100 trees (labor-days)*	5.6	4.0	3.3	2.6	1.8
% family labor from total labor*	89%	87%	82%	76%	64%
Coffee cost per kg of fresh cherry (RWF)	223	210	220	194	182
Technical efficiency [Min = 0, Max = 1]	0.70	0.74	0.75	0.79	0.79

(*) Excluding harvest labor

4.2 The importance of coffee in total household income

Farmers often diversify their income sources, yet the net income from coffee represent 43.4% of total household income.

About 95% of coffee farmers engage in the cultivation of other crops (typically beans, maize, bananas, rice, sorghum, potatoes, peas, ground nuts, amongst others). While on average, seasonal crop farming employs around 37% more land than coffee (0.37 hectares compared to 0.26 hectares, respectively), it is 36% less profitable (see Table 4.2.1). Other crops represent an average of 28% to the total household income while the net income from coffee represents 43.4% of the total household income as depicted in Table 4.2.1.

The labor market is sluggish, with only 47% of households having at least one member employed for a salary. Wage income, on average, constitutes 20% of the total household income. Merely 10% of households declare having at least one family member engaged in a family-owned business unrelated to their typical agricultural activities. The limited

[13] Technical efficiency is the capacity of a producer to achieve the maximum possible production with a minimum set of inputs, within a specific technological framework. It is a relative measure as it assesses efficiency in comparison to the best performers within the sample. For details, see Appendix 7.

number of farmers with business income results in its contribution to the total income averaging around 3%. Around 22% of households declare to have livestock. Income generated from the commercialization of livestock by-products (such as milk, eggs, meat, etc.) contributes an average of 5% to the total income.

Table 4.2.1: Total household income

(In RWF)	Provinces				Average
	North	East	West	South	
Net income from coffee	142,253	351,496	302,768	234,612	270,212
Wage income	138,662	90,938	123,169	140,742	125,484
Business income	9,081	17,790	26,005	15,715	19,252
Seasonal crops and fruits net income	240,583	267,246	162,692	119,162	173,556
Livestock Net income	31,119	52,839	25,010	34,142	33,505
Total household income	561,697	780,310	639,644	544,372	622,008

4.3 Value chain efficiency

Farmers' profit constitutes nearly 25% of the total Free on Board (FOB) value of coffee.

Farmers mainly engage at the first stage of the value chain. Farmers typically generate a profit of about US$ 1.76 per kg of Green Bean Equivalent (GBE), while their total production costs amount to around US$ 1.14. Farmers' profit constitutes nearly 25% of the total Free on Board (FOB) value of coffee. However, due to the fragmented nature of coffee farming, with an average production of 100 kg GBE per farmer, farmers find it difficult to gain profits or benefits from the economies of scale. In addition, the presence of some technical inefficiencies mainly linked to the adoption of agricultural best practices has greater likelihood to increase the costs of production and hence lower the profit margins.

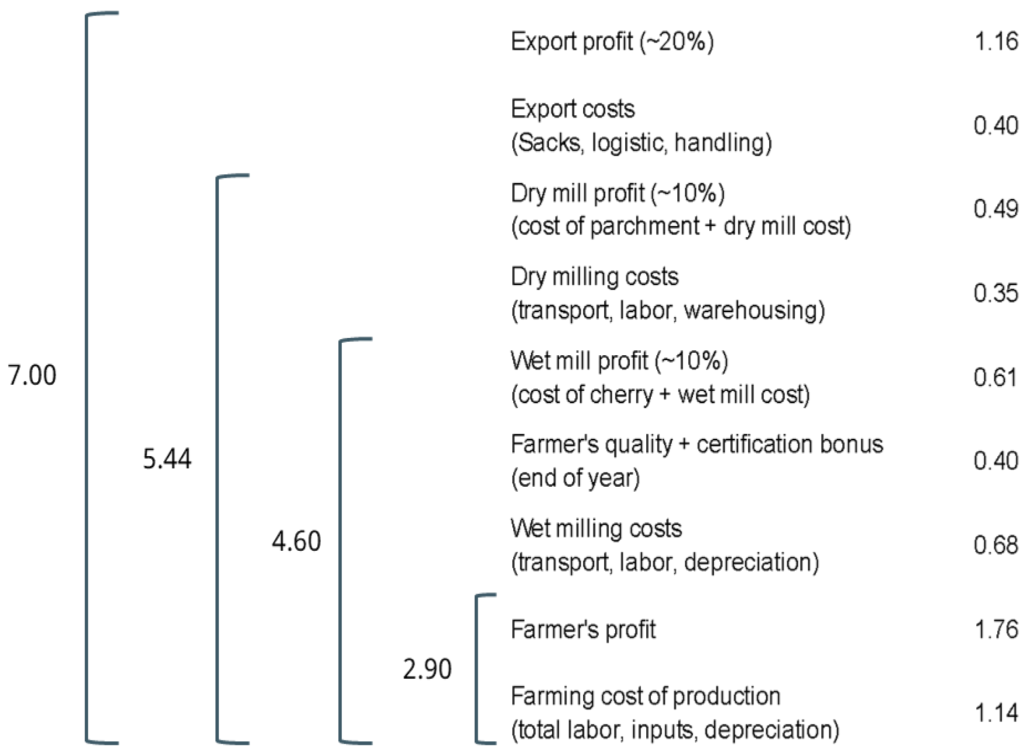
CWSs purchase fresh cherries from farmers, at a rate of around US$ 0.43 per kg of fresh cherries, or US$ 2.90 per kg of GBE. The total wet milling costs include various expenses such as transportation, labor (especially during the harvest season), equipment maintenance and depreciation, as well as regular utilities. While these costs fluctuate depending on factors like the scale of the wet mill operation, the average estimated cost of US$ 0.68 per kilogram of GBE. CWSs may offer farmers extra bonuses for certification or quality, averaging around US$ 0.40 per kilogram of GBE. Finally, a 10% profit margin is factored in.

Dry mills receive dry parchment from CWSs at an equivalent price of US$ 4.60 per kg of GBE. The overall milling costs cover expenses such as transportation, labor, warehousing and equipment maintenance and depreciation. The average estimated cost of US$ 0.35 per kg of GBE, along with a 10% profit margin.

Finally, dry mills supply the green beans to exporters, who incur export costs, including expenses for exporting materials, logistics, handling, among others, totaling approximately US$ 0.40 per kg of GBE. The study considers an export profit of roughly 20%.[14]

The assessment reveals the presence of a limited number of firms and corporations operating within the Rwandan coffee value chain. Most of these firms are vertically integrated, owning multiple CWSs, dry mills and exporters, operating on a large scale.

Graph 4.3.1: Value Chain Income distribution (farm gate to FOB) - in US$ per GBE



[14] The data was collected through interviews conducted with 13 different institutions, ranging from cooperative and private wet mills to dry mills, exporters and traders. These interviews were designed to enhance comprehension of the value chain, including its associated costs and profits. For details, see Appendix 6.

5. Insights and recommendations

5.1 Technical efficiency

Improvements in technical efficiency may boost productivity while simultaneously lowering production costs.

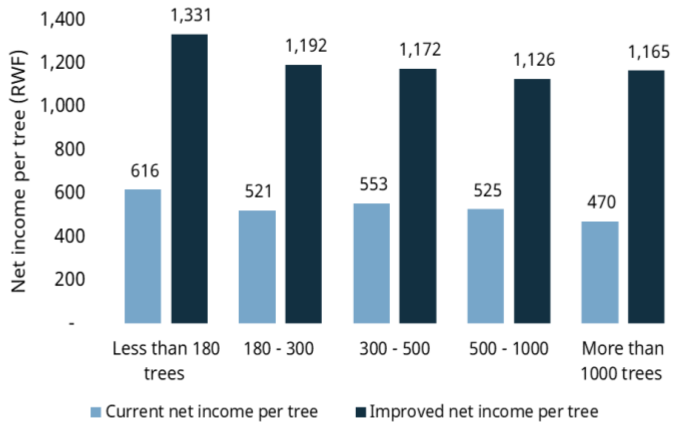
Achieving a technical efficiency[15] of 0.9 for all farmers could greatly boost productivity and decrease production costs per kilogram. As a result, coffee net incomes (keeping prices constant) will more than double (See Graph 5.1). A technical efficiency model was estimated to assess possible improvements in productivity and lower production costs in farmers income associated with better input management which may turn into higher productivity and lower production costs. A referential maximum feasible productivity for coffee farmers was estimated, revealing that average productivity can almost double to reach 3 kg per productive tree (+83% on average).[16] Similarly, cost of production (RWF per kg of fresh cherry) for this group of farmers is on average RWF 114, about 40% lower than less efficient farmers, as a result of both a better combination of inputs and higher production.

The increase in productivity primarily hinges on the implementation of good agricultural practices (such as fertilization, mulching and pruning), appropriate utilization of inputs (in terms of quantity, quality, and timing), and a more productive age of coffee trees (See Appendix 4, table A4.1). Likewise, cost reduction can be achieved through the more efficient utilization of inputs, thereby contributing to the reduction of per kilogram costs.

[15] Technical efficiency is the ability of a producer to obtain the maximum production possible from a minimum set of inputs under a specific technology. Technical efficiency is a relative measure as it compares efficiency with the best performers from the sample. For details, please see Appendix 7

[16] We utilized the productivity of the most efficient quartile among farmers with a technical efficiency greater than 0.9. as a reference point, see for more details Table A7.2 in Appendix 7.

Graph 5.1: Improvements in net income per coffee tree



5.2. Vertical integration models and efficient use of family labor

Farmers participation in vertical integration models could substantially enhance their coffee incomes, allowing for a more efficient distribution and productivity of family labor.

Farmers have the potential to triple their coffee income through participation in vertically integrated models. While the efforts required for vertical integration are substantial and demand significant time and resources, there exist successful experiences to draw lessons from.

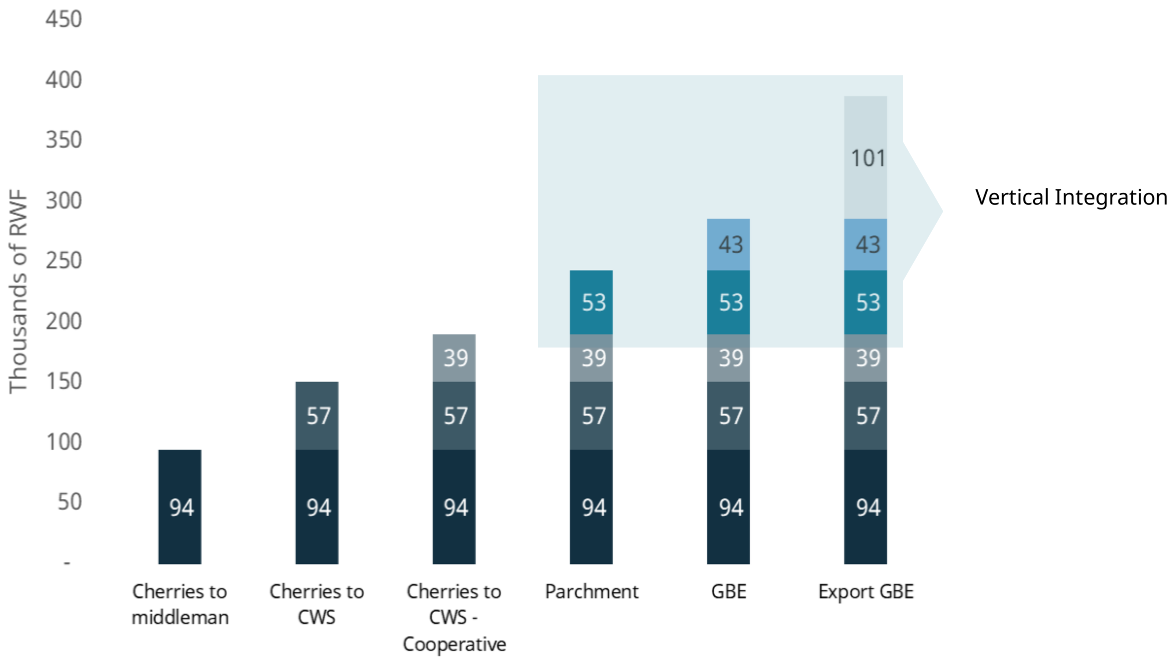
In fact, effective functioning of a cooperative system relies on good governance, accountability, and transparency to foster trust between the farmer and the organization. Additionally, cooperatives should offer valuable services such as training and technical assistance to farmers, such that they develop strong and long-lasting relationships, based on mutual benefits. In order for cooperatives to expand into dry-milling and exporting activities, they may require capital and a thorough accompanying process that supports their endeavors. This is a gradual process that needs to be accomplished step-by-step.

Farmers, to be able to benefit from the vertical integration, may need training at all stages of the value chain. On the one hand, farmers need to enhance both the quantity and quality of their production to provide the cooperative with sufficient quality coffee to make the structure profitable enough. On the other hand, to engage in various aspects of the value chain, farmers and their families may need to acquire knowledge of processing and quality control aspects of the business, as well as develop negotiation skills and gain insights into business operations and international markets. This engagement process can lead to more diversified income streams and enable family members (especially the younger generation) to become part of the coffee business.

Graph 5.2 below illustrates an example of a typical farmer with 300 trees and a production of 1.69 kilograms of fresh cherries per tree, under various scenarios of vertical integration.

Assuming a participation proportional to the farmer's production, the graph demonstrates that expected income for this typical farmer with vertical integration is RWF 387,000, as compared with non-integrated ones, which may get on average RWF 151,000.

Graph 5.2: Total coffee income and vertical integration



5.3. Who qualifies as a coffee farmer?

The size of the coffee farm plays a crucial role: smaller-scale farmers, characterized by those with fewer than 300 coffee trees, often lean more heavily on alternative income sources (comprising 73% of their income) due to the insufficient size of their coffee plots.

Smaller coffee farmers tend to rely less on coffee income for their livelihoods (see Table 5.1), exhibit lower efficiency in coffee production (see table 4.1.4).

While efficiency improvement and vertical integration are expected to help coffee farmers increase their total income, these measures may not be sufficient to sustain the coffee farming activities. A key driver for coffee farming lies in increasing the number of productive coffee trees on the farm, which may not be feasible for all farmers. These observations raise pertinent questions regarding the focus of coffee policies, particularly concerning who can be considered a coffee farmer. This question is relevant in contexts where around 50% of farmers have fewer than 300 coffee trees, with their main sources of income being seasonal crop farming (39%) and wage income (27%), and where there are significant incentives to allocate inputs to other crops rather than coffee.

It is crucial to broaden the scope of revenue sources available to farmers to ensure coffee farming remains a sustainable source of income. This entails exploring a diverse range of income streams, encompassing various agricultural pursuits such as honey production, cultivating high-value crops, and participating in government food procurement initiatives. Additionally, non-agricultural activities at both the community and individual levels, such as tourism, handcrafts, and leveraging technology or technical trades, offer additional avenues for income generation. Investing in carbon-sequestration businesses can provide yet another valuable source of revenue (e.g., Acorn-Rabobank model).

The reality is that many coffee farmers operate on a small scale, making it challenging to achieve sustainable livelihoods solely through coffee cultivation. Even if they were to achieve exceptional levels of productivity and efficiency, the income generated may still fall short of meeting their needs. As a result, there's a risk that farmers may eventually abandon coffee farming or reduce their efforts, seeking alternative livelihoods, especially when considering the younger generations.

Relying exclusively on coffee production is not a viable long-term strategy for farmers. By diversifying income streams, both within and beyond agriculture, farmers can create a more resilient economic foundation. This approach not only mitigates the risks associated with fluctuations in coffee prices but also generates additional resources that can be reinvested in coffee cultivation. Ultimately, promoting a diversified income portfolio enhances the overall sustainability and prosperity of coffee farming communities.

5.4. Farm size and its role in coffee farming sustainability

The family heritage process offers an opportunity for reallocating land, particularly within a highly developed land market system.

The size of farms plays a pivotal role in both the economic advancement of coffee farmers and the long-term viability of the coffee sector. As farmers age, it is anticipated that land fragmentation will persist, contributing to the continued division of land holdings.

Given the robustness of land markets, there exists a significant opportunity to encourage smaller and less productive farmers to rent their land to larger and/or more productive counterparts. Considering current strategies for income diversification and coffee management, it is estimated that a minimum of 800 to 1000 coffee trees is necessary for farmers to sustain coffee farming activities and secure more income to improve their livelihoods.

6. Some final remarks

1. The cost of coffee production among coffee farmers has relatively remained constant over the last decade while coffee income has a higher weight in total household income. Going forward, site specific coffee support programs are needed to address the issue of aging coffee trees and to increase the yield per coffee tree.
2. Efforts to enhance efficiency at the farm level by boosting productivity and reducing production costs, while maintaining other sources of farm and non-farm income constant, as well as enabling farmers to engage in vertical integration and capitalize on various stages of the value chain may yield an increase in coffee related income.
3. Promoting investment in good Agricultural Practices (regenerative practices, fertilizing, pruning), as well as sound resource management practices (mulching, water drainage systems, hilling around coffee trees, shade trees, amongst others), is crucial, as existing research literature suggests these practices have positive impacts on productivity. Farms that include natural forest, fruit and other shade trees or that are interested in reforestation could also capitalize from carbon sequestration credits (e.g., Acorn/ Rabobank model).
4. Socio-demographic disparities (gender, education, age), highlight the importance of crafting policies and interventions in the coffee farming sector that take into account the unique socio-demographic profiles of farmers (farmer archetypes), particularly female-headed households. Evidence suggests that young farmers are more inclined to adopt new and better practices and are more likely to engage in the agricultural technological revolution, which is critical to productivity enhancement and professionalization of the farming business.
5. One effective strategy for increasing income from coffee farming involves expanding the number of coffee trees on the farm while maintaining robust income diversity and farm diversification. This approach leverages the profitability of coffee cultivation and is associated with significantly higher incomes, proving to be a valuable strategy for coffee farmers. This can be achieved through increasing the number of coffee trees on the farm – which is limited – or by utilizing land markets to seek for more efficient land allocation.
6. Exploring alternative agricultural and non-agricultural sources of income can also play an important role not only in improving coffee productivity, but also in expanding opportunities for development of rural households.
7. It is critical to clearly define the beneficiaries of the coffee policies and identify who qualifies as a coffee farmer (e.g. what is the minimum number of trees required to define a person as a coffee farmer?) to mitigate targeting issues. Smaller/

economically disadvantaged farmers can benefit from different programs, such as the graduation model, which involves designing specific policy tools for different stages of development (see Carter and Michouda, 2020).

Appendices

Appendix 0. Additional background information on Rwanda's coffee sector

Appendix 1. Sample design

Appendix 2. Fieldwork methodology and composition of the final sample

Appendix 3. Coffee farmers and their operations

Appendix 4. Productivity

Appendix 5. Costs of production

Appendix 6. Supply chain efficiency

Appendix 7. Technical efficiency

Appendix 8. Main insights and recommendations

Appendix 0: Additional background information on Rwanda’s coffee sector

Agricultural exports

In the fiscal year 2022-2023, Rwanda's agricultural exports totaled around USD 857 million. Within this context, the export of 20,000 tons of coffee contributed approximately USD 116 million, representing 13.5 % of Rwanda’s total agricultural export value (NAEB, 2023). Rwanda’s coffee sector shows considerable potential for enhancing quality improvements and processing efficiencies (Jenkins, 2023).

Farmer characteristics

According to the 2015 census, the average age of coffee farmers was 51 years, a relatively advanced age considering Rwanda’s demographic profile. Additionally, the coffee farming profession is predominantly male, with men constituting 68% of coffee farmers.

Intercropping

Given land constraints, most coffee farms adopt intercropping practices, incorporating both perennial and annual food crops. These crops, including bananas, sweet potatoes, taro, cassava, yams, and beans, among others, are cultivated amidst rows of coffee plants (Ngango, 2023. This traditional practice reflects smallholder farmers' efforts to maximize the productivity of their limited land holdings. Large-scale coffee plantations are uncommon.

Association

Only about 20% of coffee growers are currently enrolled within one of the country's 267 coffee associations and/or cooperatives. A pivotal organization in this landscape is the Rwandan Coffee Cooperatives Federation (RCCF), established in 2009, acting as a representative entity for both producers and CWS cooperatives. With its 17 unions and 89 primary cooperatives, the RCCF boasts a substantial membership of 38,000 individuals, offering a wide variety of services to its members. Nonetheless, the relatively modest level of cooperative enrollment presents hurdles, undercutting the effectiveness of farmers' organizations and hindering training and oversight endeavors within the coffee sector.

Furthermore, this limited membership dilutes the collective influence of farmers in shaping agricultural policy development processes.

Coffee cultivation

In Rwanda, coffee cultivation is often limited to steep slopes and low-fertility soils, as fertile lands are prioritized for staple food crop cultivation (Nzeyimana, 2020). Arabica accounts for 99% of Rwanda's coffee production, with the remaining 1% comprising Robusta beans. Arabica coffee cultivation spans across all districts of Rwanda, with the western provinces surrounding Lake Kivu boasting the highest concentration of production. Among the various varieties grown in Rwanda, Bourbon and Typica are the most predominant. Coffee trees typically begin producing fruit around three years after being planted, with their productivity declining significantly after approximately thirty years.

Regular pruning and occasional rejuvenation are necessary maintenance practices. Various inputs and agronomic techniques are recommended for optimal growth, including the application of organic and chemical fertilizers, pesticides, mulching to prevent erosion, lime application to improve soil fertility, regular weeding, and planting shade-providing trees alongside coffee trees. Biological challenges such as leaf rust, insect pests, and the unique 'potato taste defect' prevalent in the African Great Lakes region pose significant threats (Bigirimana et al., 2019).

Coffee cherries are harvested typically over a four-month period subject to geographical and climatic variations. The primary coffee harvest typically takes place from April to July, with certain exceptionally fertile areas, such as those in the Northwest, experiencing a second, smaller harvest from September to November.

Coffee processing

Following harvest, the coffee cherry's pulp is removed to obtain the bean, which is then dried to produce parchment coffee. Two methods are employed: home processing and wet milling. Home processing involves rudimentary tools for depulping cherries before drying them on tarpaulin, yielding parchment of lower and less consistent quality. Conversely, the wet method entails transporting cherries to nearby Coffee Washing Stations (CWS) promptly after harvest to prevent fermentation. Farmers living nearby the mill usually bring their coffee cherries directly to the mill's gate. For those living farther away, they bring their cherries to collection points, where coffee traders, often called "collectors," gather them and transport them to the wet mill. These collectors have the flexibility to purchase coffee either for their own account or on behalf of the CWS (Macchiavello and Morjaria, 2022).

Parchment coffee (depulped coffee beans) undergoes subsequent processing as dry mills, where it is hulled, thereby removing its parchment layer and rendering it suitable for export as green coffee. Dry milling represents the culminating phase in the processing of green coffee prior to its sale and shipment to the roaster. Within this stage, there are a total of twelve dry mills, four of which are privately owned. The majority of these mills are strategically situated in close proximity to Kigali, leveraging its advantageous location. Serving as the ultimate checkpoint for quality assurance, the dry mill conducts thorough assessments before forwarding samples to The National Agricultural Export Development Board (NAEB) for quality certification, a prerequisite for export. All green coffee is exported via road transport to the ports located in Mombasa (Kenya) or Dar es Salam (Tanzania). Presently, there are 88 registered export companies, though only half are actively engaged in coffee exportation. These companies can be classified into three distinct categories based on their operational scale:

1. Those exporting over 500 metric tons (MT) of green coffee, estimated to constitute approximately 85% of the total
2. Those exporting between 100 and 499 MT, estimated at around 10%
3. Small-scale exporters handling less than 100 MT of green coffee per season, accounting for an estimated 5% of the total.

Challenges

Rwandan agriculture encounters significant challenges that impact the overall performance of its coffee sector. These challenges include:

1. The reduction of agricultural land due to increasing population pressure, leading to competition between the utilization of land resources for urban development and agricultural purposes.
2. Land fragmentation into smaller areas and holdings, diminishing the efficiency and productivity of agricultural operations.
3. Limited increases in total production stemming from a scarcity of arable land and suboptimal utilization of land productivity.
4. The overexploitation of land and improper agricultural practices on steep terrains, resulting in erosion and soil degradation.
5. Inefficient use of inputs, hindering efforts to increase productivity within the agricultural sector.

To ensure long-term sustainability and efficient resource utilization, Rwanda has revised its land governance law and developed the National Land Use and Development Master Plan (NLUDMP 2020–2050). NLUDMP seeks to achieve equilibrium between natural resources, arable lands, built-up areas, and transport infrastructure. It recognizes the dual role of agricultural land in generating income and food security while acknowledging the challenges posed by Rwanda's small size. NLUDMP outlines conditions to ensure food security by protecting agricultural land, enhancing productivity, and promoting sustainable agricultural practices. These include land consolidation, irrigation, education, and climate-resilient farming methods.

Appendix 1: Sample design

The final sample of farmers comprises 1344 individuals, proportionally distributed across all agricultural provinces. The study employs a sampling approach consisting of four steps:

- Determination of sample size;
- Selection of sample districts;
- Selection of Coffee Washing Stations (CWS) within sampled districts;
- Stratified random selection of respondents.

Step 1: Sample size

According to the National Coffee Census (2015), there are 352,830 smallholder farmers in Rwanda.[17] The sample size was estimated using simple random sampling for finite populations, using the following formula:

$$n = \frac{Nz^2_{1-\frac{\alpha}{2}}\sigma^2}{(N-1)e^2+z^2_{1-\frac{\alpha}{2}}\sigma^2} = \frac{Nz^2_{1-\frac{\alpha}{2}}c^2}{(N-1)\varepsilon^2+z^2_{1-\frac{\alpha}{2}}c^2} \qquad (1)$$

Where:

- N represents the total population
- $z^2_{1-\frac{\alpha}{2}}$ is a percentile value of the normal distribution accumulating to the left, it represents a probability of $1-\frac{\alpha}{2}$
- σ is the standard deviation of the object of estimation (average cost of production)
- e is the sampling error $e = \varepsilon \underline{x}$, where $\underline{x}$ is a sample mean of the population of study.

Given that the coefficient of variation is c=x, where x represents the sample mean, one can express the sample size in terms of the coefficient of variation. With a confidence interval of 95%, the value of z1-22 is 1.96, an estimation error of 3.75% and a coefficient of variation of 0.75 for the average cost of production estimate, the total sample size is 1530.[18] Considering the nature of the smallholder coffee sector in Rwanda, a contingency of 10% is applied to account for potential non-response. Therefore, the final target sample will be:

[17] NAEB (2016). *National Coffee Census 2015*. National Agricultural Export Development Board.

[18] The coefficient of variation of 0.75 was extracted from the study on Kenyan smallholder coffee farmers in Mount Elgon: De Los Rios, C.A. (2019). *Impact of Certification of Small Coffee Farmers in Western Kenya (2014 – 2017)*. ISEAL Alliance.

n = 1530 + (1530 * 0.10) = 1683 smallholder coffee farmers

Pre-testing of the data collection instrument revealed that, due to budget and time constraints, the sample size had to be adjusted, albeit at the expense of increasing the margin of error. The final sample size was 1222, corresponding to a margin of error of 4.2%. Additionally, a contingency of 10% was accounted for in anticipation of non-response. The final planned sample size was as follows:

n = 1222 + (1222* 0.10) = 1344 smallholder coffee farmers

Step 2: Selection of sample districts

After determining the final sample size, the districts were selected. Using data on farmer distribution by province from the National Coffee Census conducted by NAEB in 2015, districts were categorized based on deviations from the mean number of farmers. Guided by expert judgment, a district was categorized as Very High if the deviation from the average was significantly positive and high, High if the deviation from the average is positively high, Low if the deviation was negatively low, and Very Low if the deviation was significantly negative and low.

From each category, the most representative districts in each province were selected. This allowed for variation related to clustering economies of coffee producing communities within each province. For efficiency and representativeness, four districts were excluded due to a very low concentration of farmers, where the proportional sample size distribution ranged from 2 to 16 potential respondents. The final selected districts represented, on average, 67% of the total number of coffee farmers as identified by NAEB (2016) in the National Coffee Census conducted in 2015.

Table A1.1: Selected districts

Province	Total number of farmers	Category of districts				% of total farmers represented by selected districts
		Very high	High	Low	Very Low	
West	125,547	Nyamasheke	Rutsiro	Karongi	Nyabihu [1]	70%
South	121,423	Kamonyi	Huye	Ruhango	Nyamagabe	56%
East	58,722	Gatsibo	Rwamagana	Kirehe	Nyagatare [1]	61%
North	42,522	Gakenke	Gicumbi	Rulindo	Musanze [1]	96%
Kigali	4,616	Gasabo			Kicukiro [1]	81%
TOTAL	352,830					67%

1/ Originally these districts were selected. However, for efficiency issues, we excluded these districts from the study.

Respondents were proportionally distributed within provinces. Subsequently, within each province, respondents were proportionally distributed according to the number of farmers in each district, as per NAEB (2016) data.

Table A1.2: Sample distribution within districts

Province	Total number of farmers (NAEB, 2016)	Farmer's distribution within provinces	Final planned sample size per province	Distribution within districts				
				Selected district category	District	Number of coffee farmers	Within province weight (%)	Final planned sample size
West	125,547	35.6%	479	VH	Nyamasheke	43,148	0.491	235
				H	Rutsiro	28,761	0.327	157
				L	Karongi	15,911	0.181	87
South	121,423	34.4%	462	VH	Kamonyi	24,864	0.366	169
				H	Huye	18,849	0.277	128
				L	Ruhango	12,343	0.181	84
				VL	Nyamagabe	11,963	0.176	81
East	58,722	16.6%	224	VH	Gatsibo	19,494	0.543	121
				H	Rwamagana	8,648	0.241	54
				L	Kirehe	7,768	0.216	49
North	42,522	12.1%	161	VH	Gakenke	17,445	0.428	69
				H	Gicumbi	11,709	0.288	46
				L	Rulindo	11,561	0.284	46
Kigali	4,616	1.3%	18	VH	Gasabo	3,748	1.000	18
TOTAL	352,830	100.0%	1,344			236,212		1,344

Step 3: Selection of Coffee Washing Stations

The starting point for this study was the Coffee Washing Stations (CWS). The viability and future growth of the coffee sector in Rwanda depended on CWS's ability to enhance technical capacities, operate profitably, and create incentives for more farmers to supply the fully-washed channel rather than processing cherries themselves for the semi-washed markets (Ortega et al., 2016)[19].

From each district, a random sample of CWS operating within the district was selected. Throughout this process, representation of the agro-ecological zones was ensured to

[19] Ortega, D. L., Bro, A. S., Clay, D. C., Lopez, M. C., Church, R. A., and Bizoza, A. R. (2016). *The role of cooperatives on adoption of best management practices and productivity in Rwanda's coffee sector* (No. 1879-2017-1894).

account for the biophysical characteristics of the sample area. In the sampled districts, private and cooperatively managed CWSs are geographically dispersed. It was observed that the concentration of these CWSs aligned with the coffee production areas in each district. There was greater likelihood that some CWSs received production from farmers in more than one district, depending on how the zoning was structured and implemented. The selection of CWSs maintained the proportion of privately-owned and cooperatively-owned CWS within each district.

Table A1.3: Sample CWS per districts

Province	Category	District	Final planned sample size	Coffee Washing Stations		
				Private	Coop	Average number of farmers per CWS
West	VH	Nyamasheke	235	8	3	21
	H	Rutsiro	157	3	1	39
	L	Karongi	87	1	1	44
South	VH	Kamonyi	169	2	1	56
	H	Huye	128	3	1	32
	L	Ruhango	84	1	1	42
	VL	Nyamagabe	81	2	1	27
East	VH	Gatsibo	121	3	1	30
	H	Rwamagana	54	1	1	27
	L	Kirehe	49	2	1	16
North	VH	Gakenke	69	1	1	35
	H	Gicumbi	46	1	0	46
	L	Rulindo	46	1	0	46
Kigali	VH	Gasabo	18	1	0	18
TOTAL			1,344	30	13	

Step 4: Random selection of respondents

The study employed the list of farmers registered in each CWS and implemented a random sampling process to ensure proportional representation of male and female producers among the selected coffee farmers within each CWS.

Appendix 2: Fieldwork methodology and composition of the final sample

Indicators & methodology validation process

The Committee on Sustainability Assessment constituted a group of experts representing research institutions, economists, coffee experts and governmental institutions known as the Technical Advisory Panel (ITAP). The ITAP met recurrently in 2022 and 2023 to validate the indicators and methodologies employed in the study which formed the basis for the deployment of the questionnaire on the field. Members included:

- Ric Rhinehart, Strategy Director of Agri-commodities- IDH and COSA board member
- Daniele Giovannucci
- Carlos de los Ríos, Senior Research Coordinator – COSA
- Jessica Mullan, Senior Measurement Systems Director – COSA
- Sylvia Calfat, Senior Project Manager- COSA
- Rodrigo Carcamo
- Dock No, Chief Statistician- International Coffee Organization
- Maciel Aleomir da Silva, Coordinator for crop production- Brazilian Confederation of Agriculture and Livestock (CNA)
- Hernando Duque, Technical Director- Colombian National Federation of Coffee Growers
- Vera Espíndola Rafael, Development Economist, serving as an advisor for the Mexican Secretary of Agriculture on specific coffee related activities
- Janina Grabs
- Anna Laven
- Dr. Sarada Krishnan
- Christophe Montagnon, Founder - RD2 Vision
- Koen Sneyers, Coffee expert
- Puvan Selvanathan, Founder- BlueNumber Foundation.

Key components of the survey questionnaire

The survey questionnaire was specifically designed to gather pertinent information from farm households. Conducted by Highlands Centre for Leadership and Development (HLC-

L4D) during February and March 2023, it focused on the coffee production period of 2021-2022 in Rwanda. Covering a wide range of topics, the questionnaire sought insights into various aspects, including:

- Household demographics
- Farm characteristics (such as farm area, land use, land tenure, rentals, and forestation)
- Coffee production (including coffee area, coffee trees (age, variety, production state, slope of coffee fields, location, coffee production and sales)
- Coffee costs of production
- Farm equipment and assets
- Actual income (including income from sales of coffee, other crops, and livestock as well as wage and business income)
- Access to other services (such as training, credit, producer organization, etc.)

Fieldwork

The Highlands Centre for Leadership and Development (HLC-L4D), in collaboration with the Rwanda National Agricultural Export Development Board (NAEB) and Coffee Exporters and Processors Association of Rwanda (CEPAR), was responsible for conducting field data collection. Fieldwork activities were carried out in 14 districts and 51 sectors across the five provinces of Rwanda. Fieldwork revealed that farmers were scattered, and accessing farms was complicated due to difficult road conditions. Some issues arose with the farmers' list obtained from CWS. Some farmers:

- Were no longer in coffee production, having removed their coffee trees and pursued other businesses
- Had relocated elsewhere
- Had sold their farms
- Were unable to offer sufficient or relevant information
- Were deceased.

As a result of these constraints, HLC-L4D was successfully able to collect 91.6% (1,231 coffee farmers) of the total planned sample:

Table A2.1: Final sample

Province	Category	District	Coffee Washing Stations		Final planned sample size	Final sample	% rate of conducted surveys
			Private	Coop			
West	VH	Nyamasheke	8	3	235	223	94.9%
	H	Rutsiro	3	1	157	152	96.8%
	L	Karongi	1	1	87	75	86.2%
South	VH	Kamonyi	2	1	169	141	83.4%
	H	Huye	3	1	128	126	98.4%
	L	Ruhango	1	1	84	78	92.9%
	VL	Nyamagabe	2	1	81	86	106.2%
East	VH	Gatsibo	3	1	121	120	99.2%
	H	Rwamagana	1	1	54	44	81.5%
	L	Kirehe	2	1	49	41	83.7%
North	VH	Gakenke	1	1	69	57	82.6%
	H	Gicumbi	1	0	46	37	80.4%
	L	Rulindo	1	0	46	43	93.5%
Kigali	VH	Gasabo	1	0	18	8	44.4%
TOTAL			30	13	1,344	1,231	91.6%

Appendix 3: Coffee farmers and their operations

Key demographics of coffee farmers

Table A3.1: Coffee farmer demographics

	Provinces				Gender		Average
	North	East	West	South	Male	Female	
Female HH	26.3%	19.5%	23.3%	30.6%			25.6%
Age HH (years)	53.5	50.7	53.2	54.9	50.9	60.6	53.4
% below 35 y.o.	9.5%	17.6%	9.8%	10.2%	13.1%	5.8%	11.2%
% older than 65 y.o	21.2%	16.6%	21.1%	26.2%	16.3%	39.3%	22.2%
% HH living with his/her partner	65.7%	74.6%	76.0%	67.1%	91.0%	14.7%	71.5%
HH members	4.3	4.7	5.1	4.6	5.2	3.5	4.8
HH Members in agro	2.1	2.3	2.3	2.1	2.4	1.8	2.2
Education HH (primary level)	41.6%	40.0%	40.2%	44.3%	45.4%	31.3%	41.8%
Education HH (lower secondary level)	6.6%	6.3%	5.1%	6.3%	6.8%	3.2%	5.9%
Experience HH (years)	21.4	20.4	25.6	26.0	22.5	30.0	24.4
HH Members young (18 - 35)	19.2%	22.8%	23.9%	23.1%	22.3%	25.6%	23.0%
% young members working in agricultur	58.0%	57.5%	53.8%	48.3%	52.5%	54.1%	52.9%
% with low secondary completed	12.3%	7.1%	15.2%	17.2%	12.0%	21.6%	14.1%

Key farm characteristics

Table A3.2: Farm characteristics

		Provinces				Gender		Average
		North	East	West	South	Male	Female	
Farm Area (has)		0.70	1.18	0.70	0.65	0.83	0.57	0.76
% land with title		77.6%	76.9%	84.8%	75.7%	77.7%	84.5%	79.4%
Uses of land	Coffee Area (has)	0.17	0.48	0.27	0.18	0.30	0.16	0.26
	Fruit Area (has)	0.06	0.08	0.03	0.02	0.04	0.04	0.04
	Crop Area (has)	0.43	0.48	0.33	0.35	0.39	0.30	0.37
	Forest Area (has)	0.04	0.13	0.04	0.08	0.07	0.06	0.07
	Other Area (has)	0.00	0.03	0.03	0.01	0.02	0.02	0.02
% land with coffee		36.1%	49.3%	46.7%	40.1%	44.4%	41.2%	43.6%
% farmers that rent-in land		19.7%	14.6%	25.6%	25.5%	26.5%	13.1%	23.1%

Land rental determinants

The study employed a simple Heckman two-step selection model to estimate the determinants of renting-in land, first examining the factors influencing the decision to rent and subsequently analyzing the determinants of the amount of land rented. Key insights on the determinants of renting land include:

- Renting land shows a negative correlation with the amount of land owned by the farmer. This finding supports the hypothesis that farmers rent land to compensate for the lack of cultivable land.
- A higher number of household members increases the probability of renting land. This is attributed to the need for more land to produce food for additional family members and the availability of more labor supply to work on the rented land.
- Female-headed coffee farmers are generally more inclined to rent land. This tendency may be due to female-headed farmers having less cultivable land on average, motivating them to seek additional land in rental markets for cultivating seasonal crops.
- Older farmers exhibit a higher likelihood of renting land.
- Farmers with a larger proportion of coffee in their total land are less likely to rent land.
- Farmers with a higher portion of recently planted coffee are more likely to rent land to compensate for the lack of income from coffee production.
- Additionally, it is observed that farmers located in the Eastern Plateau[20] and the Eastern Savanna are less likely to rent more land, while farmers in the Congo Nile Watershed and Impala have a higher probability to participate in the land rental markets.

Key insights on the determinants of the amount of land rented include that among farmers who rent land, larger farmers tend to rent more land. This is attributed to the greater resources required for renting land. Additionally, farmers with a higher proportion of coffee tend to rent significantly less land. This suggests that farmers specializing more in coffee production are less inclined to rent land for cultivating seasonal crops.

[20] The study uses the definition of agroecological zones used by Mukashema et al (2014), Nzeyimana (2018), and others. In this sense, the study classifies sampled districts and sectors into agroecological zones: Imbo, Impala and Kivu Lake Shore are in the Western Province. The Eastern Plateau and the Eastern Savanna are located in the Eastern province. In the Southern province, there is the Congo Nile Watershed and a large part of the Central Plateau (mainly the districts of Huye, Kamonyi and Ruhango from our sample), which shares area with the Northern province (Gakenke and Rulindo districts from our sample). Finally, the Buberuka Highlands, which are in the Northern province.

Table A3.3: Determinants of land rentals

Heckman selection model - two-step estimates		
	Number of obs	1,222
	Selected	281
	Wald chi2 (9)	35.030
	Prob > chi2	0.000

		Coefficient	Robust S.E.	t	P>|t|	[95% Conf. Interval]	
Amount of land rented (sq meters)	Farm Area (hectares)	1469.788	717.734	2.05	0.041	63.055	2876.522
	Female HH	-21.084	343.778	-0.06	0.951	-694.877	652.709
	% of coffee of total farm area	-1780.980	586.960	-3.03	0.002	-2931.400	-630.560
	Agroecological zone						
	Eastern Plateau	793.635	1019.352	0.78	0.436	-1204.259	2791.529
	Eastern Savanna	636.459	464.519	1.37	0.171	-273.981	1546.899
	Buberuka Highlands	613.642	614.637	1.00	0.318	-591.024	1818.308
	Kivu Lake Border	550.828	339.224	1.62	0.104	-114.040	1215.695
	Congo Nile Watershed	-170.837	337.423	-0.51	0.613	-832.173	490.500
	Impala	388.612	704.905	0.55	0.581	-992.977	1770.201
	Constant	1977.872	790.445	2.50	0.012	428.628	3527.116
Probability of renting in land	Farm Area (hectares)	-0.3000	0.081	-3.69	0.000	-0.459	-0.141
	Number of household members	0.0450	0.020	2.26	0.024	0.006	0.084
	Female HH	0.3567	0.102	3.49	0.000	0.156	0.557
	HH Age	-0.0210	0.004	-5.95	0.000	-0.028	-0.014
	% of coffee of total farm area	-1.1012	0.157	-6.99	0.000	-1.410	-0.793
	% new trees (0 - 2 years planted)	0.7891	0.273	2.89	0.004	0.254	1.324
	Agroecological zone						
	Eastern Plateau	-0.6992	0.365	-1.91	0.056	-1.415	0.017
	Eastern Savanna	-0.1434	0.128	-1.12	0.263	-0.395	0.108
	Buberuka Highlands	-0.3616	0.235	-1.54	0.123	-0.822	0.098
	Kivu Lake Border	0.0952	0.116	0.82	0.412	-0.132	0.323
	Congo Nile Watershed	0.5637	0.134	4.2	0.000	0.301	0.827
	Impala	0.3956	0.188	2.1	0.035	0.027	0.764
	Constant	0.4056	0.251	1.62	0.106	-0.086	0.897
/ mills	lambda	-913.124	481.584	-1.90	0.058	-1857.010	30.763

Note: Clustered errors at the sector level

Key characteristics of coffee production

Table A3.4: Coffee characteristics

	Provinces				Gender		Average
	North	East	West	South	Male	Female	
Coffee Area (has)	0.17	0.48	0.27	0.18	0.30	0.16	0.26
Number of coffee plots	1.80	2.00	2.34	1.97	2.23	1.70	2.09
% of coffee in steep slopes	27.9%	17.1%	31.2%	15.1%	23.6%	20.5%	22.8%
% of coffee without shade	59.1%	41.5%	32.4%	53.6%	41.9%	51.8%	44.4%
% with at least 25% of coffee under shade	12.4%	24.4%	12.0%	9.7%	15.2%	8.0%	13.3%
% Intercrop	32.1%	44.9%	36.0%	30.2%	36.5%	30.7%	35.0%
Average altitude (m.a.s.l)	1,847	1,613	1,684	1,751	1,716	1,708	1,714
Coffee trees per hectare	2,215	2,812	2,580	2,419	2,542	2,462	2,521
Ratio of productive trees	80.4%	79.7%	87.3%	81.6%	83.7%	82.0%	83.2%
Ratio of trees recently added or rehabilitated	14.3%	14.3%	9.1%	14.2%	11.7%	14.4%	12.4%
% Coffee trees 0 - 2 years	5.2%	7.5%	4.8%	5.0%	6.1%	3.3%	5.4%
% Coffee trees 3- 15 years	44.5%	52.4%	34.3%	27.5%	41.2%	21.3%	36.1%
% Coffee trees 16 - 29 years	14.1%	20.0%	22.4%	19.2%	20.7%	17.7%	19.9%
% Coffee trees 30+ years	36.2%	20.1%	38.5%	48.3%	32.0%	57.7%	38.6%

Determinants of keeping old trees

Utilizing a simple linear probability model with clustered errors at the district level, the study examined some of the determinants of keeping old trees.[21] The findings indicated that farmer demographics, empowerment and some characteristics of coffee farming played significant roles in characterizing farmers with a high proportion of old coffee trees. Main insights include:

- Older farmers tend to have a larger proportion of old trees. This is a crucial insight, suggesting the importance of targeting younger producers and educating household members working in coffee farming about the significance of tree renovation for productivity improvement.
- Smaller households tend to have a higher proportion of old coffee trees in their plots. Indeed, households with three or fewer members have 55% of their coffee trees older than 30 years, compared to 32% for larger households.

[21] In table A2.5 the results are presented of a linear probability model aimed at assessing the determinants of having more than 50% of their coffee trees older than 30 years. A sensitivity analysis was conducted with this percentage ranging from 1% to 100%, and the results remained consistent.

- Female-headed households tend to have a higher proportion of old coffee trees. Around 57% of trees owned by female-headed households are older than 30 years, whereas this ratio is around 32% for their male counterparts.
- Farmers who anticipate improving their livelihoods in the next five years are less likely to have old trees.
- A negative correlation is observed between altitude and the proportion of old coffee trees. Farmers cultivating coffee at higher altitudes are less likely to have a high concentration of old trees.
- Additionally, larger coffee areas are associated with a lower likelihood of farmers having old coffee trees. This suggests that individuals who rely more on coffee as their primary source of agricultural income are more inclined to have younger trees.
- Finally, it was observed that coffee farms in the Eastern Plateau, the Eastern Savanna and, to a lesser extent, the Buberuka Highlands and Impala, are less likely to have a large proportion of old coffee trees compared to coffee farms located in the Congo Nile Watershed, Kivu Lake Border and the Central Plateau.

Table A3.5: Determinants of having +50% of coffee trees older than 30 years

Linear probability model	
Probability of having +50% of coffee trees > 30 years	
Number of obs	1,223
R-squared	0.2477
Root MSE	0.4263

	Coefficient	Robust S.E.	t	P>|t|	[95% Conf. Interval]	
Age HH (years)	0.0091	0.001	8.71	0.000	0.007	0.011
Household members	-0.0187	0.007	-2.74	0.009	-0.032	-0.005
Female HH	-0.0881	0.038	-2.32	0.024	-0.164	-0.012
Empowerment (*)	-0.0430	0.008	-5.16	0.000	-0.060	-0.026
Coffee Area (has)	-0.0529	0.031	-1.68	0.099	-0.116	0.010
% of coffee of total farm area	-0.1653	0.055	-2.98	0.004	-0.277	-0.054
Altitude (m.a.s.l.)	-0.0003	0.000	-2.44	0.018	-0.001	0.000
% with +10% of coffee recently planted (0 - 2 years)	-0.1375	0.034	-4.08	0.000	-0.205	-0.070
Agroecological zone						
Eastern Plateau	-0.2203	0.074	-2.98	0.005	-0.369	-0.072
Eastern Savanna	-0.1960	0.045	-4.31	0.000	-0.287	-0.105
Buberuka Highlands	-0.1466	0.032	-4.59	0.000	-0.211	-0.082
Kivu Lake Border	-0.0400	0.036	-1.11	0.271	-0.112	0.032
Congo Nile Watershed	0.0634	0.032	1.95	0.056	-0.002	0.129
Impala	-0.1385	0.038	-3.6	0.001	-0.216	-0.061
Constant	0.7976	0.228	3.5	0.001	0.339	1.256

Note: Clustered errors at the district level

Appendix 4: Productivity

Determinants of productivity

A simple ordinary least squares model (OLS) was employed to assess some determinants of productivity. Models A and B estimated the average coffee production per productive coffee tree. Model A estimates OLS models with clustered errors at the district level, while model B utilizes robust regression modeling.

No correlation was observed between coffee yields and farmers' education and gender. This finding aligns with prior research, which has shown that the decision to adopt Good Agricultural Practices conducive to improving productivity, does not necessarily depend on formal education but rather on farmers’ informal education (experience) (See Bizoza, 2011; Clay et al., 2016). In fact, it was observed that farmers with more experience working with coffee tend to be more productive on average.

Additionally, the research revealed that more empowered farmers typically demonstrate elevated levels of productivity. The underlying rationale is that confidence plays a significant role in the decision-making process aimed at enhancing productivity.

There is also a positive correlation between altitude and productivity.[22] Coffee production at higher altitudes (+ 1850 m.a.s.l.) is associated with significantly higher yields, while lower yields are typically observed below 1600 m.a.s.l. Coffee farming is also more challenging on steep slopes, resulting in less productive coffee trees. On average, yields in plots where more than 50% of their area is located on steep slopes are 12% lower than in flat coffee plots.

Consistent with the literature on farm size and productivity, the study found that smaller coffee farms generally exhibit higher levels of productivity. Additionally, a negative correlation was observed between the number of trees and productivity.

Higher tree density is also associated with lower yields, as competition between coffee trees for nutrients significantly reduces productivity potential. On average, productivity for coffee plots with a tree density greater than 3000 coffee trees per hectare was 30% lower than in the rest of the sample.

It was also discovered that the percentage of productive coffee trees is positively and strongly correlated with tree productivity. Conversely, a higher percentage of productive coffee trees is negatively correlated with productivity when considering only active and productive coffee trees.

[22] The study utilized a self-perception scale for the capacity to achieve one’s own goals as a proxy for empowerment.

Having adequate coffee-related capital is also positively correlated with higher yields. By using the smoothed value of a self-valuation of productive assets on the farm, the assessment found that the larger its value, the greater the productivity per coffee tree.

Shocks and pests also played an important role in determining coffee yields. Farmers who experienced a shock (such as pests, adverse weather, theft, illness, etc.) also had lower production per coffee tree.

Farmers who implemented more resource management practices (such as water drainage channels, hilling around coffee trees, barriers, shade trees) were more likely to have higher yields. Farmers who implemented two or more resource management practices (21% of sampled farmers) were 30% more productive than farmers who did not implement any (31%).

Mulching also had an important effect on coffee yields. Farmers who mulched (84% of sampled farmers), were 15% more productive than farmers who did not. Similarly, farmers using either organic or chemical fertilization on their coffee plots were more productive than those who did not.

The study found that farmers with access to credit were more productive than farmers who did not have access. About 48% of sampled farmers had access to credit (all sources of credit) during the 2021/2022 coffee season. These farmers showed 26% more productivity than those who either did not need or did not have access to any source of credit. Credit played an important role not only as cash for purchasing inputs or paying workers but also as a factor enabling productivity improvements. However, it is important to note that only 12% of farmers received credit from financial institutions.

Technical assistance was critical for farmers to adopt good practices. Farmers who received technical assistance (50% of total coffee farmers in the sample) showed 16% more productivity than farmers who did not receive such services. Conversely, the study did not find any significant effect of group-based training on productivity.

Table A4.1: Determinants of coffee productivity

Ordinary Least Squares	y = ln(Q x productive tree) (Kg Fresh Cherry)		y = ln(Q x productive tree) (Kg Fresh Cherry)	
	Full sample		Total trees < 1000	
	(A) Clustered errors at district level	(B) Robust regression	(C) Clustered errors at district level	(D) Robust regression
HH complete primary school	0.04750	0.05140	0.02810	0.01980
Female HH	0.03790	0.04230	-0.00270	-0.00440
HH Experience (years)	0.0074***	0.0071***	0.0078***	0.0072***
Empowerment expectations [Min = -10, Max = 10]	0.0749***	0.0787***	0.0932***	0.1007***
ln (altitude (m.a.s.l.))	0.9178**	0.7878***	0.7789**	0.6144**
% of coffee planted in steep slopes	-0.1217*	-0.1282**	-0.07480	-0.08010
ln (coffee trees per hectare)	-0.0918**	-0.06070	-0.0809*	-0.05330
% of farmers with +30% old trees	-0.03680	-0.06400	-0.4789**	-0.5100*
ln (total number of trees)	-0.1697***	-0.1684***	-0.1968***	-0.1974***
(% of farmers with +30% old trees) X (ln (total number of trees))	0.00320	0.00610	0.0879**	0.0922*
% productive coffee trees	-0.6457***	-0.5839***	-0.6189***	-0.5496***
Inv. Hiperbolic (Value of assets)	0.0183***	0.0167***	0.0183***	0.0167***
% loss due to plagues	-0.0076***	-0.0083***	-0.0092***	-0.0102***
Number of resource mgm practices [1 - 6]	0.1535***	0.1467***	0.1490***	0.1367***
% Mulching	0.2169***	0.2465***	0.1944***	0.2264***
% Using organic / chemical fertilizer	0.1504*	0.13120	0.2193**	0.1910*
Number of pest mgm practices [1 - 3] / plague = 1	0.1207***	0.1179**	0.1895**	0.1903**
% Credit (all sources, all uses)	0.2091***	0.2351***	0.1994***	0.2093***
% Training - group based	-0.03720	-0.02920	-0.03480	-0.03200
% Training - technical assistance	0.0936*	0.0978**	0.1021*	0.1127**
% Belongs to a Producer Organization	-0.00630	-0.00510	-0.02700	-0.01250
% Prune coffee trees	0.00860	-0.02380	0.02220	-0.01080
Agroecological zone				
Eastern Plateau	-0.2577***	-0.3401***	-0.2675***	-0.3549**
Eastern Savanna	0.1888*	0.1650**	0.2729***	0.2201***
Buberuka Highlands	0.2943***	0.3389**	0.3340***	0.3915***
Kivu Lake Border	0.1974**	0.1737***	0.2026**	0.1743***
Congo Nile Watershed	-0.2125*	-0.2058**	-0.19540	-0.1741*
Impala	-0.2427**	-0.2791***	-0.2786**	-0.3202***
Constant	-5.4425*	-4.7063**	-4.42370	-3.37130
Number of obs	1193	1193	1008	1008
R-squared	0.229	0.226	0.232	0.229

Appendix 5: Costs of production

Estimation of production costs

Household labor

A critical component of any cost of production calculation in agriculture involves estimating household labor and valuing it appropriately. Using survey data, the study compiled farmers' assessments of the number of days worked by each family member involved in coffee farming.[23] While we acknowledge that farmers' recollection may not be precise, it was anticipated that some would overestimate, and some would underestimate their assessments. However, to accurately estimate coffee farmers' profitability, the data needed calibration using information from the survey and parameters from secondary sources.[24] This involved estimating family labor for each household, adjusting for outliers while maintaining average values.

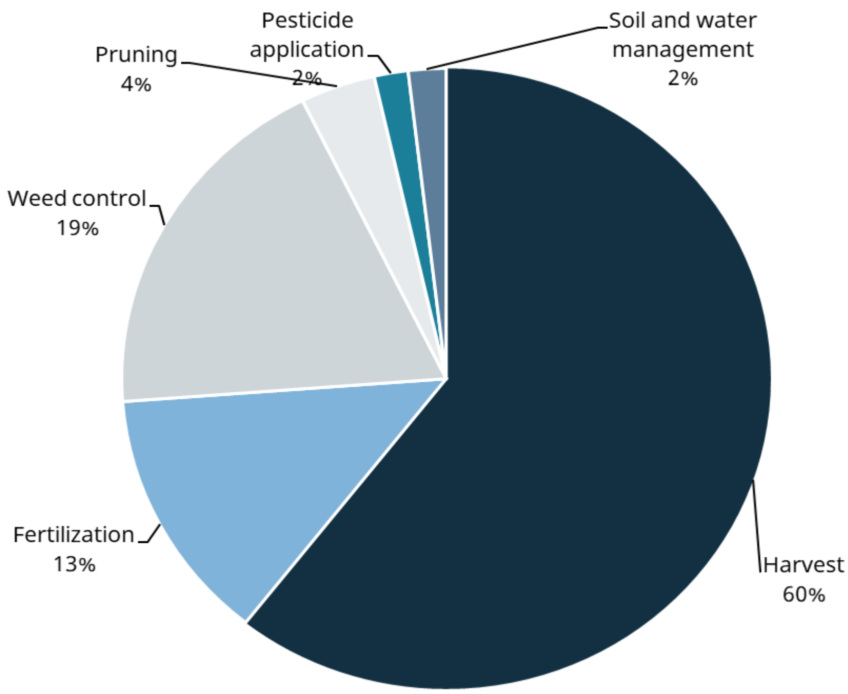
Family labor emerged as a significant component of coffee farming. On average, farmers worked 37 labor-days on their coffee plots, equating to approximately 204 labor-days per hectare. The majority of family labor was allocated to harvest and sorting activities (60%), followed by weeding (19%), fertilization and mulching (13%), pruning and stumping (4%), pesticide application (2%), and resource management (2%).

---

[23] Only the following activities were considered: harvest and sorting, weeding, fertilization and mulching, pruning and stumping, pesticide application and resource management. Other activities such as nursing and planting seedlings have not been included.

[24] Minimum and maximum parameters were utilized for all activities, drawn from literature providing comprehensive information about production costs for each activity. With these parameters and other relevant survey data (such as coffee area, number of trees, agricultural practices, quantities of inputs applied, etc.), the researchers were able to account for the range of possible values to identify outliers. Subsequently, outlier values were imputed to weighted average medians. For detailed information on the estimation process, please contact info@thecosa.org

Graph A5.1: Family labor, distribution by activity



To convert these labor days to value, the researchers multiplied the total family labor by the opportunity cost of labor in each province.[25] Our estimates indicate that the mean value of family labor was RWF 41,942 (US$ 40.7), representing a total cost of family labor per hectare of RWF 225,038 (US$ 218.5).

Paid labor

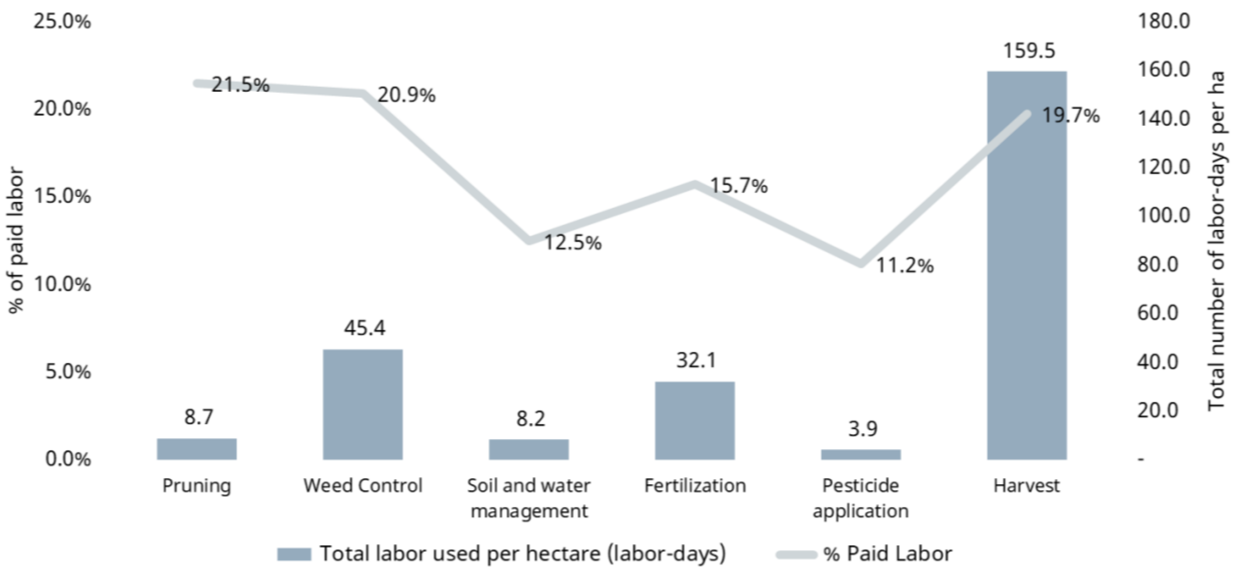
The study compiled farmers' recollection of the days worked for each activity. While we acknowledge that farmers' recollection may not be precise, it was anticipated that some would overestimate, and some would underestimate in their assessments. However, with the objective of estimating coffee farmers' profitability, the data needed to be cleaned from outliers using information from the survey and other parameters from secondary sources.[26]

On average, farmers paid for 15.5 labor-days on their coffee plots, equating to about 47.5 labor-days per hectare. The total labor per hectare amounted to 251.4 labor-days, distributed similarly to family labor: harvest represented 60.4% of total labor, followed by weed control (18.2%), and fertilization and mulching (12.7%). Paid labor, on average, represented 19% of total labor-days employed in coffee production (see Graph A5.2).

[25] Based on survey data, the median daily wage in the West was RWF 1200, whereas in the other provinces it stood at RWF 1000. These prices were utilized to estimate the opportunity cost of family labor.

[26] See footnote 18.

Graph A5.2: Total labor and participation of paid labor



About 56% of farmers paid for labor. Larger farmers with higher productivity and less availability of family labor were more likely to pay for labor, while farmers in the North were less likely to pay for labor (only 31% have paid for labor in the 2021/2022 season). Wages paid ranged from RWF 600 per labor-day to RWF 2500, with an average of RWF 1165 per labor-day (see Table A5.1).

Table A5.1: Wages paid per region

	Wage paid per labor-day (in RWF)			
	Mean	Median	p10	p90
North	1,134	1,000	1,000	1,431
East	1,164	1,095	847	1,550
West	1,235	1,200	1,000	1,500
South	1,089	1,000	1,000	1,345

Depreciation: Replacement value of equipment

Equipment and tools utilized on the farm constitute a significant component of production costs. To maintain the equipment and tools required for coffee farming over time, there are associated depreciation costs that need to be considered, based on the type of asset. In this regard, the survey included inquiries about a broad array of assets used in coffee farming, which were classified according to their replacement time into short, medium, and long-term categories, as follows:

- Short-term replacement assets (3 years): spraying equipment, hoes or machetes, pruning implements, harvest hooks, harvest baskets and drying beds and mats.
- Medium-term replacement assets (10 years): irrigation equipment, wheelbarrows, or wagons.
- Long-term reposition assets (15 years): motorbikes.

Additionally, subjective valuations of these assets were solicited. To mitigate price distortions arising from differences in quality, equipment condition, and personal judgment, the median valuation for each piece of equipment was utilized. For certain assets, the percentage used specifically for coffee production was also taken into account. To achieve this, the proportion of the total farming area dedicated to coffee cultivation was calculated and applied to the value of assets.

Table A5.2 illustrates that farmer predominately own hoes and machetes (99%), harvest baskets (62%), harvest hooks (54%), pruning implements (15%) and spray equipment (6%). The average valuation provided by farmers was considered in the calculation of the total value of assets. As depicted, farmers possess relatively few assets to support their coffee production. The average depreciation cost for farmers was RWF 3813 (US$ 3.7) which translated to RWF 10.8 per kilogram of fresh cherry produced.

Table A5.2: Assets, quantity owned and average value

Assets included		% own	Average quantity	Average value (RWF)
Short term	Spray equipment	6%	1.1	24,568
	Pruning implements	15%	1.3	2,932
	Hoes, machetes	99%	3.5	2,838
	Harvest hooks	54%	1.3	1,168
	Bed or drying mat	9%	1.8	15,674
	Harvest baskets	62%	2.4	1,232
Medium term	Irrigation equipment	1%	1.3	17,531
	Wheelbarrow or wagon	2%	1.1	28,452
	Processing equipment	3%	2.6	4,901
Long term	Motorcycles	3%	1.1	639,395

Value of inputs (non-subsidized)

Key inputs for coffee production include fertilizers (chemical or organic), pesticides, and mulching, which is a common practice among Rwandan coffee farmers. Farmers were asked whether they used each specific input and, if so, about the quantity used, number of applications, amount purchased, and amount produced on their own farm. For purchased inputs, the price paid was also queried. Following the methodology of Church and Clay (2016), only the actual costs incurred by the farmer in coffee production (investments) or the opportunity costs they incur are considered. Therefore, the value of subsidized inputs is excluded from this analysis.

It was found that only 11% of sampled farmers purchase chemical fertilizers, typically to complement the subsidized fertilizers provided via CWS. On average, these farmers purchased 56 grams per coffee tree, resulting in an average expenditure of RWF 34,086 (US$ 33.1). Around 59% of coffee farmers used manure in their coffee plots, with about 18% of them purchasing it in the market. While manure produced on the farm does not necessarily involve a payment, farmers forewent the opportunity to sell it in the market, which represented an opportunity cost (income not earned). Farmers using manure apply an average of 3.4 kg per coffee tree, resulting in an average expenditure of RWF 23,573 (US$ 22.9). Similarly, around 17% of coffee farmers used compost, with about 20% of it purchased in the market and the majority produced on the farm. Farmers applied an average of 3.3 kg per coffee tree and spent on average RWF 32,963 (US$ 32). It emerged that 85% of farmers used mulch, with 65% of it purchased in the market. The average value of mulch was RWF 13,038 (US$ 12.7), and farmers applied an average of 1.3 kg per coffee tree. Furthermore, approximately 64% of farmers used pesticides, with an average expenditure of RWF 656 (US$ 0.6).

Overall, the average input cost for farmers was RWF 34,641 (US$ 33.6). This amount was a combination of cash disbursement and the opportunity cost of inputs. Paid inputs accounted for 45% of the total value of inputs, while the remaining corresponded to the valuation of farm-made inputs (see Table A5.3).

Table A5.3: Value of inputs purchased / produced

Inputs purchased / produced	% apply	Average from the ones who applied			Sample average	
		Average quantity applied (kg)	Average per coffee tree (gr per tree)	Average value of inputs (RWF)	Value of purchased inputs (RWF)	Total value of inputs (RWF)
NPK	11%	42	56	34,086	3,588	3,588
Manure	59%	1,520	3,407	23,573	1,981	13,953
Compost	17%	2,198	3,282	32,963	2,555	5,603
Mulch	85%	869	1,300	13,038	7,202	11,081
Pesticides	64%	94	143	656	417	417

Production costs by province

Production costs exhibited heterogeneity, with sources of variation being more prominent within individuals than between provinces. It was observed that the highest production costs were in the Northern province (RWF 207), while the lowest production costs were in the West (RWF 174).

Table A5.4: Costs of production (RWF per kg of fresh cherry), by province

	Provinces				Average
	North	East	West	South	
Household labor	103	77	89	87	88
Paid labor	17	27	22	17	21
Depreciation	15	8	9	13	11
Cost of Inputs	72	69	54	66	62
Total Costs of Production	207	181	174	183	182

Determinants of coffee production costs

Previous research explored the primary external factors influencing production costs (See Church 2017). In this section, the heterogeneity in production costs associated with farmer/household variables, farm variables, inputs, and agroecological characteristics is examined.

Smaller farmers tend to face higher production costs. In the research results an inverse relationship is observed between the number of trees and the cost of production per kilogram of fresh cherry produced. The larger the proportion of productive trees (indicating more potential production), the lower the production costs. Similarly, higher tree density (indicating greater potential production) is associated with lower production costs. Conversely, larger farms appear to have higher production costs, mainly due to higher input expenditures associated with wealth.

Altitude is also inversely associated with production costs. Higher farms have lower production costs per kilogram of fresh cherry produced. Additionally, a negative relationship between access to markets and production costs was identified. Contrary to the initial hypothesis that closer proximity to a market for goods and services would result in cheaper inputs, it was found that farmers located further from markets are less likely to access inputs for their crops. This leads to lower production costs and higher wages for paid labor.

Furthermore, it was observed that the higher the amount of subsidy a farmer receives, the less likely they are to purchase fertilizers themselves, despite being aware that subsidized fertilizers are insufficient for their coffee trees. This is because the subsidy provided is significantly below the minimum nutrient requirements suggested by NAEB. Finally, more experienced farmers tend to have lower production costs, likely due to more efficient input allocation or lower expenditures on their coffee farms.

Table A5.5: Determinants of production costs per kg of fresh cherry

Ordinary Least Squares	y = ln(Cost per kg of fresh cherry) (Kg Fresh Cherry)	
	(A) Clustered errors at district level	(B) Robust regression
ln (Total number of trees)	-0.0821***	-0.0894***
% productive coffee trees	-0.4320***	-0.4407***
Coffee Trees per hectare	-0.0001**	-0.0001***
ln (Farm Area)	0.0694***	0.0732***
Distance to markets (ordinal)	-0.0686*	-0.0714*
% of coffee planted in steep slopes	0.01510	0.01930
ln (altitude (m.a.s.l.))	-0.5099*	-0.5757***
Inv. Hiperbolic (Value of non-coffee income)	0.00250	0.00140
Belong to a producer organization (=1)	-0.05150	-0.0621*
Herfindhal Index of farm diversification [0 - 1]	0.02100	0.02890
Inv. Hiperbolic (Value of subsidized inputs)	-2.3593***	-2.5096***
Farmer is male = 1	-0.00870	0.00160
Number of years of experience	-0.0036***	-0.0037***
Agroecological zone	0.00000	0.00000
Eastern Plateau	0.12580	0.12920
Eastern Savanna	-0.07560	-0.06560
Buberuka Highlands	-0.2008***	-0.2117**
Kivu Lake Border	-0.04910	-0.05240
Congo Nile Watershed	0.00180	0.02340
Impala	0.2249***	0.2385***
Constant	10.1225***	10.6856***
Number of obs	1158	1158
R-squared	0.118	0.121

Marginal productivity of land

The valuation of land, determined by its marginal productivity, is derived through the estimation of a production function that accurately captures the blend of inputs employed by agricultural producers to generate their agricultural output. In a state of equilibrium and within perfectly competitive markets, the real price of land aligns with its marginal productivity, which is estimated as the impact on output resulting from a unit change in land (**Δ**Q/**Δ**T).

Q=f(T,X), where Q represents a vector of quantities produced by each farmer, T denotes a vector representing the land utilized by the farmer, and X signifies a matrix encompassing all other inputs utilized in coffee production. Through the estimation of the production function, the following formula is derived:

PMgT=**Δ**Q/**Δ**T=Pt, where PMgT is the marginal productivity of land, and Pt stands for the annual rental price of land. In the context of a Cobb-Douglas production function, Pt is the coefficient for land T.

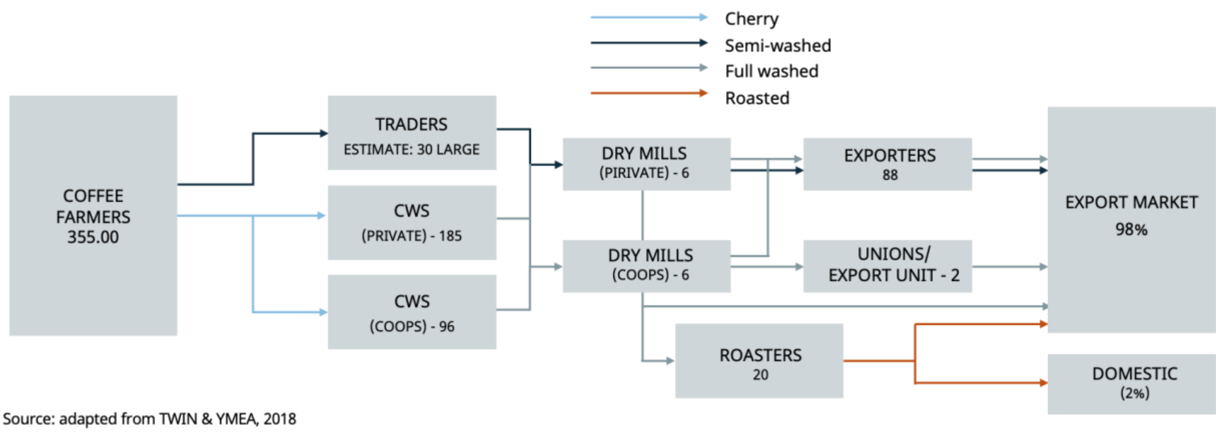
Appendix 6: Value chain efficiency

The coffee supply chain in Rwanda involves multiple stakeholders, including farmers, cooperatives, coffee washing stations, processors/ dry mills, and exporters, each contributing to the value creation within the coffee value chain. By comprehending the intricacies of the coffee value chain, stakeholders can pinpoint bottlenecks and opportunities to ensure equitable distribution of benefits among all participants, particularly smallholder farmers.

Methodology & sample design

To evaluate the relative efficiency of the value chain, semi-structured interviews were conducted with key stakeholders in the value chain. To define stakeholders, the research team considered the various stages of coffee processing as defined by TWIN & TMEA (2018), identifying a diverse subset of direct actors within the coffee value chain in Rwanda (see Graph 1).

Graph 1: Rwandan Coffee Value Chain



Source: adapted from TWIN & YMEA, 2018

To define the interviews assessing the coffee value chain in Rwanda, the team considered the selected CSWs for the quantitative study, along with other actors as indicated in Graph 1.

Role in the value chain	Universe of study	Sample	Interviews
CWS – private	East (9) North (4) South (12) West (14) * In the districts selected for the data collection study	East (1) North (1) South (1) West (1)	MICOF Tropic Coffee NOVA Coffee Nyakizu Mountain Coffee Gitesi Rwanda Trading Company
CWS - cooperative	East (3) North (1) South (4) West (6) * In the districts selected for the data collection study	East (1) North (1) South (1) West (1)	Dukundekawa Musasa KOPAKAKI Abakundakawa
Traders		(1)	RWASHOSCO
Dry mills – private	Private (6)	(1)	Dormans Gasharu Coffee
Dry mills – cooperative	Cooperative (3)	(1)	
Roasters	Roasters (20)	(1)	
Export market		(1)	Ikawa House
Total interviews		13	

Appendix 7: Technical efficiency

The applied research model builds on the work proposed by Aigner, Lovell, and Schmidt (1977), who suggest calculating technical efficiency based on the estimation of a stochastic production frontier, assuming that the production process is subject to both a composite error term that captures both the random effects of the environment and technical inefficiency.

In this model, the error term is composed of two distinguishable random disturbances with different characteristics that deviate the producer from obtaining the maximum possible production volume. One random disturbance (U) captures the uncontrollable effects on producers such as favorable or unfavorable events, luck, weather, measurement and observation errors, among others; on the other hand, a non-negative disturbance (V) captures effects controllable by the producer such as crop management, employee effort, adequate combination of factors, at the right time in the right amount, among others, which are directly associated with technical inefficiency. Thus, we propose a model of the form:

- $Y = f(X) \exp(U_i - V_i)$, where Y is the observed production, X is a matrix of inputs used in production, U is a random disturbance with zero mean; and V is a non-negative disturbance capturing effects controllable by the producer and directly associated with technical inefficiency. Thus, we define technical efficiency as:
- $TE_i = Y_i / Y^*_i$, where TE_i is the technical efficiency; and Y_i is the maximum possible production value of individual i.
- The model assumes that the idiosyncratic errors V_i are i.i.d random variables following a normal distribution $\sim N(0,\sigma^2 V)$ and are independent of U_i.

To overcome potential heteroscedasticity problems associated with specific producer factors and their production units, it is necessary to model the errors (Caudill and Ford, 1993; Caudill et al., 1995). The inefficiency component is modeled based on variables Z_i that allow to explain limitations in the allocation of producers' resources and that are associated with management, as well as socio-economic characteristics; and agroecological variations that affect their production. For the random component, typically scale variables Q_i are included to correct potential heteroscedasticity biases:

- $\sigma^2 V = \exp(Z_i;\epsilon)$
- $\sigma^2 U = \exp(Q_i;\theta)$

Table A7.1: Technical efficiency model

Stochastic Frontier Analysis	Number of obs	1,221
Inverse hiperbolic (Total coffee production in kg of fresh cherry)	Log likelihood	1,730
	Wald Chi-2	0.0000

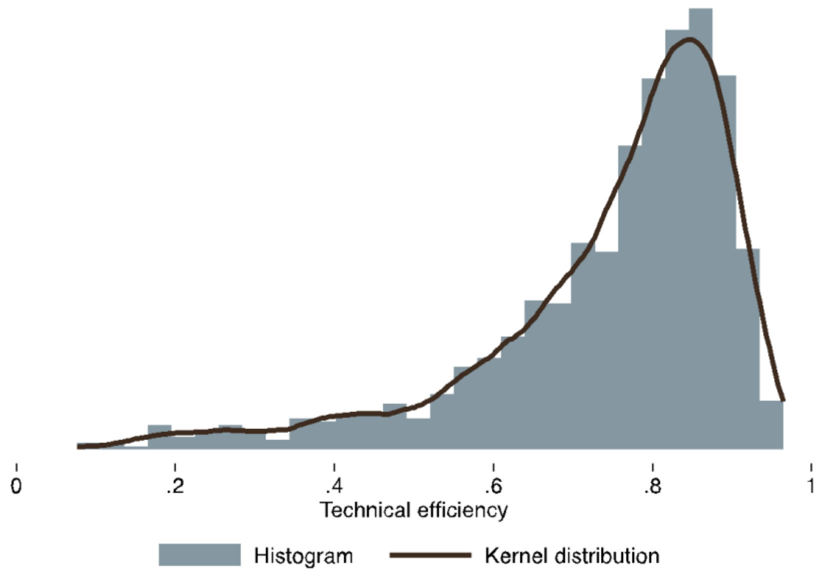
	Coefficient	Robust S.E.	t	P>|t|	[95% Conf. Interval]	
Number of coffee trees (in logs)	0.5920	0.034	17.61	0.000	0.5261	0.6579
kg of chemical fertilizers applied*	0.0586	0.017	3.53	0.000	0.0261	0.0912
kg of organic fertilizers applied (include mulching)*	0.0628	0.011	5.82	0.000	0.0417	0.0840
Number of labor-days paid *	0.1886	0.026	7.15	0.000	0.1369	0.2402
% of family labor to total labor	0.9436	0.200	4.73	0.000	0.5524	1.3347
Agroecological zone						
Eastern Plateau	-0.2530	0.115	-2.20	0.027	-0.4780	-0.0281
Eastern Savanna	0.0977	0.070	1.41	0.160	-0.0385	0.2340
Buberuka Highlands	0.2870	0.157	1.82	0.068	-0.0213	0.5954
Kivu Lake Border	0.1603	0.050	3.19	0.001	0.0619	0.2587
Congo Nile Watershed	-0.1047	0.082	-1.28	0.200	-0.2645	0.0552
Impala	-0.3509	0.080	-4.37	0.000	-0.5083	-0.1934
Constant	0.2193	7.860	7.86	0.000	1.293	2.153

Note: Variables transformed using the inverse hiperbolic function

Determinants of technical efficiency	Coefficient	Robust S.E.	t	P>|t|	[95% Conf. Interval]	
Farmer is male (dummy = 1)	-0.0261	0.007	-3.72	0.000	-0.0399	-0.0123
Experience (years)	-0.6269	0.216	-2.90	0.004	-1.0507	-0.2030
Credit (dummy = 1)	-0.7818	0.125	-6.23	0.000	-1.0276	-0.5361
Number of resource mgm practices [1 - 6]	-1.5274	0.347	-4.41	0.000	-2.2067	-0.8480
% of coffee area / total farm area	-0.9658	0.226	-4.28	0.000	-1.4083	-0.5232
Certification (dummy = 1)	-2.9302	1.118	-2.62	0.009	-5.1213	-0.7391
Inv. Hiperbolic (altitude)	0.7335	0.478	1.53	0.125	-0.2035	1.6705
% of family labor to total labor	-0.0700	0.021	-3.32	0.001	-0.1113	-0.0287
Inv. Hiperbolic (total value of agricultural assets)	-4.3548	0.355	-12.26	0.000	-5.0511	-3.6584
% coffee trees in production	0.0143	0.005	3.06	0.002	0.0051	0.0235
Effect of plague (% of total production)	28.3854	9.126	3.11	0.002	10.4982	46.2725

Results derived from this model, indicate an average efficiency rating of 0.74, underscoring substantial potential for enhancement within Rwandan coffee farming operations, with significant effects in output. Notably, the research analysis reveals considerable heterogeneity in technical efficiency levels across Rwandan coffee farmers, as depicted in Graph A7.1.

Graph A7.1: Technical efficiency distribution



After assessing the determinants of technical efficiency, the following patterns were observed[27]:

- Farmers with greater experience tended to exhibit higher levels of efficiency
- Access to credit for agricultural purposes served as a facilitator for improving efficiency levels, as it minimized liquidity constraints and enables farmers to procure inputs and utilize paid labor effectively
- Adoption of Good Agricultural Practices, such as soil and fertility management, correlated with elevated efficiency levels
- Farmers specializing in coffee cultivation (devoting a larger portion of their land to coffee) demonstrate heightened efficiency
- Certification, which often led to higher prices, was also associated with increased levels of technical efficiency
- Farmers with more tools and equipment for coffee farming tended to display higher levels of efficiency
- Having more productive trees was conducive to greater efficiency

[27] Please note that a negative sign indicates reduced variance. In a non-negative distribution, decreased variance is linked to higher levels of efficiency (as evidenced by a lower value of Vi).

- Negative production shocks exerted adverse effects on efficiency levels
- Having more productive trees is conducive to greater efficiency
- Negative production shocks exert adverse effects on efficiency levels.

Appendix 8: Insights and recommendations

Table A8.1: Feasible productivity and production costs

	Productivity (kg fresh cherry per tree)		Cost of production (RWF per kg of fresh cherry)	
	Efficiency < 0.9, mean	Efficiency >= 0.9, III quartile	Efficiency < 0.9, mean	Efficiency >= 0.9, III quartile
Less than 180 trees	2.03	3.02	195.96	83.84
180 - 300	1.54	3.04	189.74	114.86
300 - 500	1.60	2.54	188.97	119.33
500 - 1000	1.46	2.53	177.80	108.47
More than 1000 trees	1.32	1.77	183.04	120.46
AVERAGE	1.64	2.44	188.36	113.98

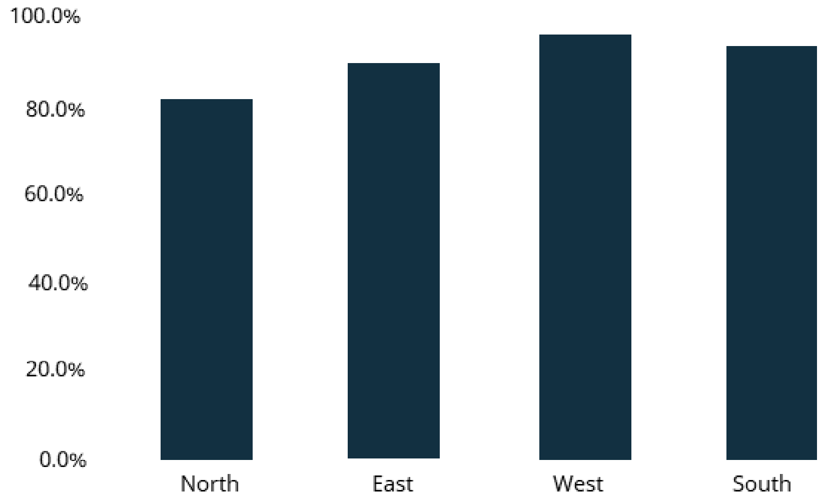
Prices paid to farmers

Farmers received better prices for their coffee when it was sold at the CWS, if it was sold as certified, or if they belonged to a producer organization.

Around 91% of total coffee production was sold to CWS, with the remaining sold in local markets. On average, prices paid at the CWS were 33% higher (RWF 488 per kg of cherry) compared to prices paid elsewhere (RWF 367). While 82% of farmers sold all their coffee to their CWS, it was found that 6% of farmers sold exclusively to local markets. These farmers tended to have smaller operations, fewer trees, lower productivity, and were less likely to practice selective harvesting, instead favoring the sale of dry cherries. This suggested that differences in prices based on the buyer could be attributed to both quantity and quality considerations. Lower-quality coffee and dry cherries were more likely to be sold in local markets, where they may command better prices than at the CWS.

Moreover, 47% of farmers belonged to a producer organization. Farmers affiliated with these organizations received, on average, 4% more than those who were not members. While organized farmers received RWF 488 per kilogram of cherry, the rest received on average RWF 472. Cooperative membership fostered a closer relationship with buyers, often resulting in additional bonuses for farmers at the end of the year (Ortega et al.,, 2016).

Table A8.2: Percentage sold to CWS



List of Abbreviations

CEPAR	Coffee Exporters and Processors Association of Rwanda
CoP	Costs of Production
COSA	The Committee on Sustainability Assessment
CWS	Coffee Washing Station
FOB	Free on Board
GAP	Good Agricultural Practices
GBE	Green Bean Equivalent
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HLC-L4D	Highlands Centre for Leadership and Development
ICO	International Coffee Organization
NAEB	National Agricultural Export Development Board
NCC	National Coffee Census
NPK	Nitrogen- Phosphorus- Potassium
OLS	Ordinary Least Squares model
TWS II	Technical Work Stream on Market Transparency

Bibliography

Agrilogic (2018) "Value Chain Analysis for the Coffee Sector in Rwanda". Report for the CBI - 27 July 2018

Aigner, D.; Lovell, C.A.; and P. Schmidt (1977) "Formulation and estimation of stochastic frontier production function models". Journal of Econometrics 6 (1977) 21-37

Bigirimana, J., Adams, C., Gatarayiha, C.,Muhutu, J., and Gut, L.. (2019) "Occurrence of potato taste defect in coffee and its relations with management practices in Rwanda". Agriculture, Ecosystems & Environment. 269. 82-87. DOI:10.1016/j.agee.2018.09.022

Bizoza, A. and J. Opio-Omoding (2021) "Assessing the impacts of land tenure regularization: Evidence from Rwanda and Ethiopia". Land Use Policy, 100, 104904.

Carter, M. and A. Michouda (2019) "The Distribution of Productive Assets and the Economics of Rural Development and Poverty Reduction". In: Nissanke M., Ocampo J. (eds) The Palgrave Handbook of Development Economics. Palgrave Macmillan, Cham

Caudill, S. and J. Ford, (1993) "Biases in Frontier Estimation due to Heteroscedasticity". Economics Letters , 41 : 17 – 20

Caudill, S; Ford, J.; and D. Groper (1995) "Frontier Estimation and Firm-Specific Inefficiency Measures in the Presence of Heteroscedasticity" Journal of Business & Economic Statistics. Volume 13, 1995 - Issue 1

Clay, D. and A. Bizoza (2018). "Challenge to sustainable growth in Rwanda's coffee sector". Feed the Future Innovation Lab for Food Security Policy. Research Paper 100

Clay, D.; Bro, A.; Church, R.A.; Bizoza, A; and D. Ortega (2016) "Determinants of farmer investment in coffee production: Finding a path to sustainable growth in Rwanda's coffee sector". Feed the Future Innovation Lab for Food Security Policy. Research Paper 32

Church and Clay (2016) "Estimating farmer cost of production for fully-washed coffee in Rwanda". Feed the Future Innovation Lab for Food Security Policy. Research Paper 33

Church (2017) "Estimating farmer cost of production" Implications for sustainable growth in Rwanda's coffee sector". https://artisancoffeeimports.com/sites/default/files/2020-02/RChurch_CoP_MSBProject_2017_wLNX.pdf

De Los Rios, C.A. (2019). *Impact of Certification of Small Coffee Farmers in Western Kenya (2014 – 2017)*. ISEAL Alliance.

Gatarayiha, C. (2019). Current status of the coffee sector in Rwanda and way forward to increase farmers' household income through increased coffee revenues. 17th AFCA conference presentation, Kigali, Rwanda, 13th-15th Feb. 2019. NAEB. https://tinyurl.com/3nn5hy82

Gerard, A; Clay, D; Lopez, M.C.; Bowman, K.; and D. Rukazambuga (2018) "Analysis of distributed coffee inputs in Rwanda: Pesticide access and fertilizer volume" Feed the Future Innovation Lab for Food Security Policy. Research Paper 112

Hainmueller (2012) "Entropy Balancing for Causal Effects: A Multivariate Reweighting Method to Produce Balanced Samples in Observational Studies" Political Analysis, Volume 20, Issue 1, Winter 2012, pp 25 - 46

Heinen, S. (2023). State-led Economic Transformation in Rwanda 2000-2019: An Evaluation of the Role of Policy in coffee-processing, tourism, food crops, and manufacturing. SOAS University of London DOI: https://doi.org/10.25501/SOAS.00039057

Jenkins, G., Mbakop, L., and Miklyaev, M. (2023). Enhancement of coffee quality in Rwanda: A stakeholder analysis of government policies. QED working paper No. 1512. https://www.econ.queensu.ca/research/working-papers/1512

Macchiavello, R., and Morjaria, A. (2020). Competition and relational contracts in the Rwanda coffee chain. *The Quarterly Journal of Economics*, Volume 136, Issue 2, May 2021, Pages 1089–1143. https://doi.org/10.1093/qje/qjaa048

Mertens, B. And Oireire, S. (2023, October 31). Rwanda repeals coffee zoning law to spur production. STIR. https://stir-tea-coffee.com/tea-coffee-news/rwanda-repeals-coffee-zoning-law-to-spur-production/

Mukashema, A., Veldkamp, A, and A. Vrieling (2014). Automated high-resolution mapping of coffee in Rwanda using an expert Bayesian network. *International Journal of Applied Earth Observation and Geoinformation 33 (2014) 331-340*

NAEB (2016). *National Coffee Census 2015*. National Agricultural Export Development Board.

Ngango, J. (2023). Farmers' adoption and perceptions of coffee and banana intercropping system in Rwanda. American Journal of Rural Development, vol. 11, no. 1 (2023): 15-20. doi: 10.12691/ajrd-11- 1-3.

Nzeyimana, I. (2018). Optimizing arabica coffee production systems in Rwanda: A multiple-scale analysis. PhD Thesis. Wageningen University. https://research.wur.nl/en/publications/optimizing-arabica-coffee-production-systems-in-rwanda-a-multiple

Nzeyimana, I., Hartemink, A., Ritsema, C., Mbonigaba, J., and Geissen, V. (2020). Mulching effects on soil nutrient levels and yield in coffee farming systems in Rwanda. Soil Use Manage. 2020;36:58–70. https ://doi.org/10.1111/sum.12534

Ortega, D. L., Bro, A. S., Clay, D. C., Lopez, M. C., Church, R. A., and Bizoza, A. R. (2016). *The role of cooperatives on adoption of best management practices and productivity in Rwanda’s coffee sector* (No. 1879-2017-1894).

Ortega, D; Bro, A; Clay, D; Lopez, M.C.; Tuyisenge, E.; Church, R.A.; and A. Bizoza (2019) “Cooperative membership and coffee productivity in Rwanda’s specialty coffee sector” Food Security, Vol. 11, pp 967-979

TWIN & TMEA (2018) “Coffee Export Capabilities. Assessment of export capabilities of 20 coffee cooperatives in Burundi and Rwanda”. Available at: https://agri-logic.nl/?smd_process_download=1&download_id=171