# Impacts of smallholder participation in high-quality coffee markets: The Relationship Coffee Model

Juan N. Hernandez-Aguilera
Ph.D. Student - Charles H. Dyson School of Applied Economics and Management
Cornell University, Ithaca, NY. E-mail: jnh79@cornell.edu

Miguel I. Gómez
Associate Professor - Charles H. Dyson School of Applied Economics and Management
Cornell University, Ithaca, NY. E-mail: mig7@cornell.edu

Amanda D. Rodewald
Associate Professor - Cornell Lab of Ornithology and Department of Natural Resources
Cornell University, Ithaca, NY. E-mail: arodewald@cornell.edu

Ximena Rueda
Assistant Professor - School of Business
Universidad de los Andes, Bogota, Colombia. E-mail: x.rueda@uniandes.edu.co

Colleen Anunu
Master of Professional Studies in Agriculture and Life Sciences
Cornell University, Ithaca, NY. E-mail: cpc28@cornell.edu

Ruth Bennett
Ph.D. Student - Cornell Lab of Ornithology and Department of Natural Resources
Cornell University, Ithaca, NY. E-mail: reb349@cornell.edu

Robert R. Schindelbeck
Extension Associate - Department of Crop and Soil Science
Cornell University, Ithaca, NY. E-mail: rrs3@cornell.edu

Harold M. van Es
Professor - Department of Crop and Soil Science
Cornell University, Ithaca, NY. E-mail: hmv1@cornell.edu

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## Abstract

The Relationship Coffee Model (RCM) is an emerging business model in the coffee value chain that promotes long-term partnerships between coffee buyers and smallholder growers based on transparency, product quality and value sharing. However, to date, there are limited studies assessing outcomes for the smallholder growers participating in high-quality coffee value chains and specifically in models such as RCM. We developed a framework to examine how geography, environmental conditions, production practices and technology affect coffee quality, and consequently, grower's ability to participate in RCM. In turn, we evaluated the impact of RCM participation on key environmental, socio-economic, and technological indicators. Using data collected from 265 Colombian smallholder growers, we examined relationships among socio-economic characteristics, soil quality indicators, coffee landscape characteristics, bird populations, and product quality scores. Our estimation based on propensity score matching indicated that RCM participants employ more environmentally-friendly resource management practices, have better understanding of the coffee business and are more optimistic about the future of the industry, relative to non-participants. Although farm gate prices did not significantly differ between the two groups, RCM participants had increased access to credit. Overall, the estimated impacts suggest that RCM contributes to integrate smallholder growers into global-coffee markets and generates socioenvironmental benefits.



**Keywords:** Specialty coffee; relationship coffee model; sustainable agriculture; cooperatives; propensity-score matching. *JEL Codes*: Q13, Q17, Q20

## 1. Introduction

Coffee is the second most valuable commodity exported by developing countries after petroleum (Haight, 2011). According to the International Coffee Organization (ICO), 25 million smallholders produce 80% of the world's coffee, with the livelihoods of over 100 million people supported in some way by coffee production (Fairtrade, 2012). However, recent drastic changes in global-coffee markets have affected smallholder growers in many coffee-producing countries. In the past, coffee was traded primarily as a commodity, and public policies played an important role in the coffee value chain (e.g., export quota system mechanisms and coffee export boards in exporting countries). Today, in contrast, governments have little influence on global-coffee markets and the product is becoming increasingly differentiated (Lee and Gómez, 2013). With increased global competition, coffee growers are currently exposed to high-price volatility and are challenged to become part of private initiatives and certification schemes required for specialty-coffee value chains (Bacon, 2005; LeClair, 2002; Rueda and Lambin, 2013).

Specialty coffees differ from commodity coffees in two key dimensions, namely product quality and/or production practices (Lewin et al., 2004). In the first dimension, coffee is classified as 'specialty' based on physical and sensorial characteristics (e.g., aroma, flavor, and body), which in turn determine a price premium for the product. In the second dimension, specialty coffees differ from their commodity counterparts based on specific production standards that ensure desired social and environmental outcomes (e.g., fair wages, adoption of environmentally friendly practices). These practices are communicated to consumers through various product labels (e.g., Fair Trade, Rainforest Alliance, Smithsonian-Bird Friendly).

The Relationship-Coffee Model (RCM) is an emerging business model based on product quality and social responsibility. RCM is a type of specialty coffee value chain arrangement where smallholder growers work closely with roasters, buyers and importers to establish a direct, long-term trading partnership for coffees that have high-quality cup profiles. Not only is a price premium offered to growers for quality coffee, but RCM also promotes transparency, traceability, and active engagement of smallholder growers throughout the value chain (Raynolds, 2009). For instance, each year RCM smallholder growers' and coffee roasters meet for five days to analyze the coffee market challenges and agree on trade conditions and quality standards (Sinclair, 2012). Although not always an explicit goal, the RCM model is thought to indirectly incentivize good environmental stewardship given that better environmental conditions will generally produce higher-quality coffee (e.g., Läderach et al., 2011; Oberthür et al., 2011).

Despite the promise of RCM, the extent to it realizes positive social, economic, and environmental outcomes remains to be tested. Most of our understanding of specialty coffee chains comes from studies on the impacts and dynamics of smallholder participation on Fair Trade and Organic certifications schemes (Bacon et al., 2008; Barham et al., 2011; Blackman and Naranjo, 2012; Calo and Wise, 2005; De Janvry et al., 2010; Nelson and Pound, 2009; Podhorsky, 2013; Ruben and Fort, 2012; Valkila, 2009). In contrast, there is limited knowledge of the impacts of emerging business models such as the RCM, which promotes smallholder participation in high-quality coffee value chains (Barham et al., 2011; Calo and Wise, 2005; De Janvry et al., 2010; Donovan, 2011; Raynolds, 2009). Previous studies have generally emphasized how environmental conditions affect coffee quality (e.g., Läderach et al., 2011; Oberthür et al., 2011) rather the smallholder growers who participate in these markets.

Knowledge of socioenvironmental outcomes of RCM is critically needed by private and public decisionmakers and researchers interested in promoting and understanding sustainable and profitable integration of smallholder growers into global food value chains.

To meet this need, we evaluated the economic, social and environmental outcomes of smallholder participation in high-quality coffee value chains, in two important coffee growing regions of Colombia. Initially, we developed a conceptual framework explaining how geographic, environmental, production and technological factors influence smallholder grower ability to produce high-quality coffee and to participate in RCM. Second, we collected farm-level data related to soil quality, biodiversity of plants and animals, landscape utilization, and household socio-economic characteristics. Third, we used a propensity score matching model (Imbens and Rubin, 2014) to examine differences between RCM participants and non-participants on various socio-economic and environmental outcomes.

## 2. Conceptual Framework

We used variables known to affect both coffee quality and participation by smallholder growers to construct our conceptual framework of RCM impacts (Figure 1). Only those growers that exceed a minimum threshold in coffee quality (typically over 80 on a scale from 0-100) are able to participate in RCM. Otherwise, they participate in the commodity market. We then explicitly compared socio-economic, environmental, and technological outcomes observed for RCM participants and non-participants. This framework integrates relationships across key performance indicators found in the specialty coffee markets literature (Blackman and Naranjo, 2012; Nelson and Pound, 2009; Ruben and Fort, 2012; Valkila, 2009; Wollni and Brümmer, 2012) and in studies examining the effect of environmental conditions and production processes on coffee-quality (Castro-Tanzi et al., 2012; De Janvry et al., 2010; Läderach et al., 2011; Oberthür et al., 2011).

**[FIGURE 1 HERE]**

To classify variables as input or outcome variables, we used the notion of stock and flows often employed in approaches linking ecological and economic systems (Häyhä and Franzese, 2014). Accordingly, input variables refer to the stock of human, physical and social capital, the stock of natural resources, and the types of technologies employed to combine these stocks to yield a target product quality level. Outcome variables, for their part, refer to the flow of environmental effects, socio-economic impacts and technological innovations (Costanza and Daly, 1992; Odum, 1994), which we hypothesize depend on growers' ability to participate in RCM.

### 2.1 Input Variables

Several types of inputs can impact coffee quality at different levels. For example, geographic conditions influence coffee quality at a regional scale, while other environmental characteristics such as terrain slope and soil properties, are more relevant when analyzing a particular farm or plot (Läderach et al., 2011; Oberthür et al., 2011). Specifically, soil chemistry and nutrient retention capacity are important factors associated with coffee cup quality (Castro-Tanzi et al., 2012). Consequently, in our framework the first set of inputs comprises biological, chemical and physical soil health indicators, as well as geographic indicators such as farm elevation.

In addition to geographical and environmental conditions, the use of certain production practices as well as pre- and post-harvest technologies affect coffee quality levels. For instance, the literature suggests that pulping exclusively ripe fruits and washing coffee beans improves product quality (Dias et al., 2012; Knopp et al., 2006). In many countries, including Colombia, smallholder growers implement these practices to simultaneously preserve quality and avoid specific crop diseases (Guhl, 2008; Mueller et al., 2013; Rueda and Lambin, 2013). Extension services, education programs and growers associations have all contributed to disseminate and educate growers in these quality-enhancing practices. Accordingly, we defined a second set of input variables that captures critical production inputs, such as grower educational level and training in coffee production, grower exposure to networks (e.g. level of participation in civic organizations) and grower stock of physical capital (e.g. ownership of coffee production machinery). All of these factors influence a grower's ability to learn and adopt specific harvest and post-harvest techniques that preserve and enhance product quality. Furthermore, within this same set, we considered other indicators that reflect the type of technologies used by the growers, such as the production factors more intensively used (e.g. labor: remunerations to contracted workers, land: percentage of the farm allocated to coffee crops), the coffee-varieties grown (e.g. percentage of *Arabica* Vs. *Robusta*), and if they are -or not- endorsed by coffee certifications that validate specific-production practices (e.g. Fair Trade, Organic).

### 2.2 Outcome Variables

The potential outcomes derived from RCM participation are not limited to the quality price premium received by growers. For instance, many RCM participants grow coffee under a canopy of trees that, under certain site-specific conditions, increases coffee quality and indirectly promotes sustainable land-use systems (Läderach et al., 2011; Vaast et al., 2006). Furthermore, RCM engages smallholders in commercialization and marketing processes, positively affecting their knowledge of the business model and their expectations about the future of their coffee business (Raynolds, 2009).

Accordingly, we considered three broad outcome dimensions where RCM participation could have a potential impact: environmental, technological and socio-economical. The environmental dimension involves indicators typically associated with sustainable resources management, such as water saving techniques; to sustainable landscape practices, such as crop-tree diversity, and to biological indicators, such as bird biodiversity (Blackman and Naranjo, 2012; Jha et al., 2014; Siebert, 2002; Tscharntke et al., 2011). The technological dimension incorporates outcomes such as the preparation and use of their own organic fertilizers, as well as innovations in the role that smallholder growers have traditionally played in value chain and commercialization activities. This technological dimension is relevant because some literature identifies poor understanding of common instruments, concepts (e.g., price premiums, certifications), and roles in the value chain (Ruben and Fort, 2012). Consequently, our framework includes measures of grower knowledge of downstream value chain activities and functions (e.g. knowledge of the exporter and roaster who buy the coffee that they produce).

Our framework also includes multiple socio-economical variables that reflect short-term (or present) outcomes, with potential effects over human and physical resources in the long term. Consequently, we considered outcomes likely to affect grower health (e.g. use of protection equipment during agro-chemical application) and the availability and access to alternative food sources (e.g. products different than coffee that are produced on the farm for consumption and sell). In the same way, we considered access to microcredit because it constrains physical assets (e.g. quality of their households and facilities and appropriate machinery for production of high-quality coffees) of growers over the long-term (Bacon et al., 2008; Raynolds, 2009). In addition, we measured price premium, the most common indicator analyzed in the literature (Bacon et al., 2008; Barham et al., 2011; Calo and Wise, 2005; De Janvry et al., 2010; Nelson and Pound, 2009; Raluca et al., 2014; Ruben and Fort, 2012), using the farm price received by each grower. Lastly, among the socio-economic outcomes, we evaluated how RCM participation affects grower's outlook about coffee livelihoods, measuring preferences that their children would be involved in coffee business in the future.

Finally, our conceptual framework illustrates the hypothesized ways that human and physical capital, technology, and geography can be affected in by RCM participation as well as the feedback loops between associated outcomes and future participation (Figure 1). For instance, Rueda and Lambin (2013) show that the increasing demand for high-quality and sustainable coffees has driven land-use decisions among Colombian farmers, and growers who sell to these markets have experienced the greatest increase in area planted. Another example is related to the adoption of shade-grown coffee systems to improve product quality. These systems offer an appropriate habitat for many resident and migratory birds that provide pest control services, thereby reducing input costs to growers and reliance on harmful agrochemicals. Recent literature shows that insectivorous birds can halve coffee berry borer infestations, which can save a medium-sized coffee farm up to US$9,400 annually and ultimately modify the cost structure and technologies used on the farm (Karp et al., 2013).

## 3. Data

To evaluate the short-term impacts of the RCM participation, we considered an organization that has been involved in the RCM for six years. This group of RCM participants included 78 growers from a cooperative located in Cauca department, Colombia. The control group included 186 smallholder growers who did not participate in RCM. Of these, 66 growers were located in the same department than RCM participants. The other 120 growers in the control group were located in the Antioquia department and represented growers across a range of coffee quality cup profiles and affiliations with coffee grower associations. We assembled a farm-level database of input and outcome variables and collected information on socio-economic indicators, soil quality, coffee landscape characteristics, bird diversity, and coffee quality scores. These data are described below. (*See supplementary online material for detailed data description*).

### 3.1 Socio-economic variables

Between August 2013 and January 2014, we conducted a voluntary survey eliciting detailed socio-economic information of the household. For each farm in our sample, we interviewed the head of the household and collected information on family composition, health status, education level, family members working in the farm, among other household characteristics. In addition, the survey incorporated questions about production factors and endowments such as availability and use of machinery and equipment, farm size and farm ownership, among others. The survey also included questions related to production, harvest and post-harvest practices, common crop diseases and risks, use of paid labor, and farm gate prices, among others. Finally, the survey included information on community characteristics, including participation in civil organizations, security conditions in the region, and desire that their children continue in the coffee business in the future.

**3.2 Soil-quality variables**

During the same span of time, we collected soil samples from fertile and less fertile areas on each farm, that were identified by the growers, following the protocols and transportation requirements for its posterior analysis (Gugino et al., 2009). These analyses provided soil physical indicators such as aggregate stability and water capacity; biological soil indicators including organic matter, active carbon and potentially mineralizable nitrogen; and a standard soil chemical composition soil test. A protein analysis was conducted for each sample to determine storage of organic nitrogen for later use by the soil system and plants. In addition to their importance for coffee quality (Castro-Tanzi et al., 2012), these indicators can be also linked to poverty and economic conditions of the growers as a healthier soil contributes to enhance smallholders access to natural resource assets and affects land productivity (Scherr, 2000).

**3.3 Analysis of coffee-growing landscape**

Variation in the method of coffee cultivation, including variety, tree density, and percent shade coverage have been shown to affect coffee quality (Läderach et al., 2011; Oberthür et al., 2011; Vaast et al., 2006; Vaast et al., 2005). Certain land use practices may conserve biodiversity on a landscape when considering the inclusion of native trees in coffee shade composition and the communities of birds and other taxa supported in the coffee ecosystem. In order to establish the differences between land use practices in RCM and non-participant growers, we collected geographical and biophysical data in delimited transects on each farm.

We furthermore sought to link these land-use practices to biodiversity through bird community assessments. We used a paired-match random sampling design to measure coffee trees density and diversity, as well as non-coffee tree species richness, composition, canopy cover and strata, and soil cover. On each farm, we established a 20x50 m quadrant, and at the northwest and southeast corners of the plot were additionally demarcated 10x10 m quadrants. Within each of the 10m$^2$ quadrants, we measured the diameter at breast height (*dbh*) and identified species of each non-sapling tree (i.e., >2m tall at bifurcation), within the quadrants. All quadrants were geo-referenced in their southwestern-most point, where also we recorded the elevation (*See supplementary online material for maps*).

In addition to tree species diversity, we estimated complexity of forest structure by indicating presence/absence of 4 height strata (< 0.5m, 0.5. to 1.5m, 1.5 to 3m, and 3m+) using a modified Relevé method (Mueller-Dombois, 2001). A stratum was marked as "present" when foliage covered at least 20% of the surface area of the 10 x 10m quadrant. Within the larger 20 x 50 m quadrant, we assessed tree species richness by counting the number of different tree species within the entire transect area. At 0.5m-intervals along the longitudinal 50m midline of each transect (100 points total), ground cover was classified as leaf litter, weeds and/or plants, bare soil, and other. From these classifications, a proportional estimation of ground cover composition was calculated.

### 3.4 Bird assessment

Bird communities were surveyed using point-count methodology (Bibby et al., 2000). Using the same protocol to establish habitat-sampling points in the coffee landscape, we randomly established a survey point within each coffee quadrant and another at the nearest edge between the coffee and an adjacent habitat. For each point count, a trained observer recorded all birds seen or heard within a 10-minute period between 0545 to 1100, the period with the greatest bird activity. Distance to each bird, its relative location (i.e., being inside, outside, or on the edge of each coffee plot), and its participation in mixed-species foraging flocks was recorded for each individual detected within 100 m of the point count center. At each point count location, data on weather (e.g., wind, precipitation, and cloud cover) and habitat (e.g. distance to edge of coffee plot, percentage of coffee within 100 meter radius, number of trees within a 100 meter radius, and average canopy height) were also recorded.

We recorded 205 bird species in surveys. Species diversity (i.e., total number of species detected on a farm) and total bird abundance were used as two broad descriptors of the bird community. Because we also were interested in potential pest control services provided by birds, we considered species within three genera identified in feeding trials by Karp et al. (2013) to be predators of the coffee borer beetle: *Setophaga (S. petechial, S. cinerea, S. fusca, S. pitiayumi, S. ruticilla*), *Basileuterus (B. culicivorus, B. luteoviridis) and Pheugopedius (P. mystacalis).* Many of these same species heavily use shade-coffee farms, which also are associated with high quality cup profiles (Vaast et al., 2006).

**3.5 Quality Scores**

A certified coffee cupper in our team (Q grader) verified the coffee quality and quality evaluation protocols followed by the cooperative under RCM participants and non-participants. These quality assessments are actually performed by the roasters when deciding to buy or not specific lots, and follow the Specialty Coffee Association of America standards (SCAA, 2013). Although it was not possible to collect and analyze individual coffee samples for each grower, it was verified that the coffee gathered and exported by the cooperative under RCM fulfilled the required standards. In addition, in the control group, we found growers with quality scores that potentially would allow them to participate in the RCM.

**4. Preliminary data statistics: Selection into RCM**

We found evidence that RCM participants and non-participants differ in key geographical, environmental and technological inputs. Table 1 shows those differences for a representative set of input variables. In particular, soil iron content of RCM participants was lower, and both protein and soil respiration were higher, in comparison to non-participants. These soil conditions provide an advantage and a better soil endowment to RCM participants, since higher indicators of protein and soil respiration are associated to desirable soil characteristics like the ability to make nitrogen available by mineralization, soil aggregation and water movement (Gugino et al., 2009).

RCM participants also exhibited greater human capital, in terms of better training in agricultural production. On average, RCM participants received some training in agricultural production from twice as many institutions or organizations (1.88 institutions for RCM participants Vs. 0.85 for non-participants). Social capital also was higher among RCM participants since they participated more in formal and informal networks with other coffee growers than non-participants. Not only social capital, but also physical capital of RCM participants was greater, as indicated by higher rates of ownership of coffee production machinery and more informal saving stocks compared to non-participants. Collectively, these differences suggest the possibility of a positive selection bias in our sample, given that more education, better machines and a higher social cohesion may growers to performance in the coffee business better, regardless of whether or not they participate in RCM.

In addition, both groups differ in grower’s housing infrastructure and access to facilities, coffee varieties produced in the farm and percentage of coffee-crop area. On average, non-participants allocated a higher proportion of their farms devoted to coffee production compared with RCM participants (0.71 non-participants Vs. 0.54 participants). However, the greatest difference between both groups refers to the enrollment on labor-related certifications such as Fair Trade. Almost all RCM participants (97%) are certified while only 30% of the non-participants are. Overall, these results suggest important differences in the input variables between RCM participants and non-participants that will contribute to over -or under- estimate the outcome effects of RCM participation. In order to reduce these biases, and before estimate any outcome difference, we defined a set of comparable RCM participants and non-participants. As explained in the next section, we used Imbens and Rubin (2014) algorithm to predict the participants and non-participants probabilities of RCM-participation and then, to compare similar growers.

**[TABLE 1 HERE]**

## 5. Empirical model

We followed Imbens and Rubin (2014) methodology to assess outcome differences between RCM participants and non-participants and reduce the bias due to confounding variables. Initially, we selected the relevant input variables to predict RCM participation based on a large set of candidate variables. Subsequently, to ensure comparable groups of RCM participants and non-participants, we verified that selected input variables were similar (i.e. balancing and overlapping properties). Finally, we estimated the outcome differences between equivalent participants and non-participants.

A critical assumption of this methodology is referenced by the literature as *unconfoundedness* (Imbens and Rubin, 2014). This assumption implies that, given the potential outcomes and the observed inputs, the probability ($Pr$) of RCM participation equals the probability of participation given only the observed inputs. Mathematically:

$$\Pr(W_i = 1 |\, Y_i(0), Y_i(1), X_i) = \Pr(W_i = 1 | X_i) = e(X_i) \qquad (1)$$

In equation (1) $W$ represents the participation in the RCM (0=non-RCM participants, 1=RCM participants); $Y_i(0)$ and $Y_i(1)$ the outcome variables for grower $i$ if not enrolled and enrolled in the RCM respectively, $X$ the inputs or observed variables used to predict participation, and e the probability of participate in the RCM, or the propensity score (*p-score*).

The *unconfoundedness* assumption is not testable because it is impossible to simultaneously know for the same grower his outcomes if he participate and not participate in the RCM $\left(Y_i(0), Y_i(1)\right)$. However, to support this assumption, we collected as much information as possible from each grower, assuming that even latent variables (i.e., unobservable characteristics) could be properly accounted through the use of the observable input variables.

One of the main advantages of propensity score methodology is that it matches numerous observable characteristics among RCM participants and non-participants to a single measure, reducing the dimensionality problem (Rosenbaum and Rubin, 1983). This methodology has been widely used in previous studies (Blackman and Naranjo, 2012; Mendola, 2007).

**5.1 Input variables and the selection algorithm**

First, we specified a logistic regression where the dependent variable $W$ was equal to one if a grower participated in RCM or it was equal to zero otherwise. In general, participation is initially defined as a function of all possible input variables and their interactions *(see online material for a description of the complete set of input variables)*. Following Imbens and Rubin (2014), we verified whether the inclusion of each input variable and interaction improved the goodness of fit (measured by the likelihood ratio test statistic), and contributed to preserve similar input characteristics (i.e. mean, standard deviations) between RCM participants and non-participants.

Furthermore, we verified that RCM participants and non-participants shared a common support, which refers to an initial block of comparable *p-scores* among participants and non-participants (Heckman et al., 1997). Accordingly, non-participants with propensity scores below the lowest probability estimated among participants, and RCM participants with *p-scores* above the highest propensity score estimated for non-participants were dropped. This procedure, called trimming, ensures the existence of comparable probabilities between groups, and improves the consistency of the estimated parameters, but at the cost that the original sample will be reduced.

Finally, we compared the means of the estimated propensity scores for RCM participants and non-participants in the initial trimmed block. Generally, when this difference is not statistically different from zero, sub-blocks of participants and non-participants are defined looking for comparable paired participants and non-participants. New sub-blocks are defined until further splitting of the initial block (at the median of the respective p-scores) is not possible because these new blocks are too small.

**5.2 Input Variables Balancing and Overlapping**

To test for balancing, we verified that the means of input variables for participants and non-participants were similar. We used two methods to test for balancing of our data. First, for each input variable, we tested the hypothesis that the difference in means between participants and non-participants was not statistically different than zero. Generally, if values of this statistic are substantially larger in absolute value than one, the stratification does not lead to satisfactory balance in the covariates. Second, we tested the hypothesis that the input variable means do not depend on program participation. When values in this statistic are concentrated towards more negative values relative to a normal distribution there is less evidence of a good balance (*Appendix A summarizes the main equations related to these tests*).

Furthermore, we verified that input variables for RCM participants and non-participants overlapped and shared similar dispersions on their distributions. We reported four measures to assess overlapping for each input variable: 1) the difference in means by treatment group normalized by the square root of the average within group variance; 2) the ratio of the participants and non-participants standard deviations; 3) the proportion of participants outside the 0.025 and 0.975 quantiles of the non-participants' distribution; and 4) the proportion of non-participants outside the 0.025 and 0.975 quantiles of the participants' distribution. In general, higher values in measures three and four imply that it will be relatively difficult to predict missing potential outcomes for participants and non-participants groups since there will be a higher proportion of comparable observations at the tails of the distributions.

### 5.3 Propensity score matching

After verifying balancing and overlapping in the inputs, we matched participants and non-participants according to the estimated propensity scores. We estimated outcome differences between the two groups based on several criteria including: a single match on *p*-score with no bias reduction assuming homoscedasticity for the standard errors; a single match on *p*-score with no bias reduction assuming heteroscedasticity; a *Mahalanobis* distance matching designed to minimize differences on all covariates employed in estimating the *p* scores; and multiple matches based on *p* scores using two, three and four matches (Imbens and Rubin, 2014; Morgan and Harding, 2006).

## 6. Results and discussion of outcome differences

Table 2 summarizes the fifteen relevant input variables that were selected by the Imbens and Rubin (2014) algorithm to predict grower RCM participation (*see Appendix B for the logit model specification and estimation*). After trimming, the final subsample of comparable RCM participants and non-participants is constituted by 25% of the initial sample, and p scores in this block goes from 0.00023 to 0.92. Although the difference in p scores means' between participants and non-participants was different than zero, the block was not amenable for additional splitting.

**[TABLE 2 HERE]**

We proceed by checking balancing and distribution overlapping for the fifteen input variables selected. In general, RCM participants and non-participants' inputs were balanced (Table 3) and overlapped (Table 4). However, this was not the case for labor-related certifications (i.e., participation in Fair Trade certifications), which was the variable with the greatest mean difference between both groups before trimming (Table 1). In particular, Table 4 shows that labor-related certifications variable has the largest mean difference between participant and non-participants relative to its variance (0.828). In contrast, other related measures, such as the environmental-related certification variable, were balanced and overlapped among RCM participants and non-participants (although were not selected by the algorithm to predict RCM participation).

**[TABLE 3 HERE]**

**[TABLE 4 HERE]**

Table 5 compares the variables before and after the application of Imbens and Rubin's method. The results show that, after establishing the comparable subsample of growers, there are not significant differences in input variable means between participants and non-participants. The only exception is the labor-related certifications variable, which confirms that participation in Fair Trade certifications is highly associated to RCM-participation.

**[TABLE 5 HERE]**

### 6.1 Outcome differences between RCM participants and non-participants

Once balancing and overlapping properties were verified in the input variables, we estimated the difference in outcomes between RCM participants and non-participants. Table 6 describes the outcome variables reported.

**[TABLE 6 HERE]**

Our findings suggest that RCM participation is associated with environmentally friendly and sustainable resources management practices (Table 7). Specifically, RCM participants' used on average at least one additional technique to save water, compared with similar non-participants. Furthermore, around 36% to 56% more of RCM participants, affirmed that they used more biological control methods compared with other growers in the area (four out of the six matching alternatives suggest significant differences). In addition, RCM growers prepared in higher proportion their own organic fertilizers (between 27% to 42%); affirmed in a higher proportion that they used organic fertilizers during the last crop (between 43% to 59%), and implemented more times organic fumigation alternatives against coffee rust (between 28% to 65%).

**[TABLE 7 HERE]**

Moreover, RCM farms had greater tree diversity than non-RCM farms. We identified in the small quadrants of 10x10 meters, about 0.54 to 0.80 more trees species on average. Furthermore, RCM participants had increased volumes of *Inga* trees for shading planted on their farms, with around 20 centimeters more in the average diameter of the trees measured in the small quadrants. This tropical tree species contributes to nitrogen-fixing (Rhoades et al., 1998) and also is preferred by many foraging birds (Newell et al. 2014).

In general, the higher tree diversity within RCM coffee crops is considered a sustainable agro-ecological practice since it conserves soil health and reduces nutrient leaching and forest fragmentation (Wezel et al., 2014). Simultaneously, this crops tree diversity contributes to break the dependence to chemical inputs due to adaptation and resistance developed by pests (Carvalho, 2006; Méndez et al., 2009). Indeed, we found evidence of less intensive use of chemicals, as reflected by the lower levels of potassium in RCM soils (52.9 *ppm* less compared to non-RCM soil samples table 7).

Although RCM participation is thought to be associated with price advantages, we did not find any significant differences in farm gate prices received by RCM participants and non-participants (table 7). That said, RCM participants may have indirectly received the price premiums, through their cooperatives. For example, RCM participants had 30% to 60% greater access to microcredit for, than non-participants.

We also identified outcomes that affect human capital and grower's health and access to food sources. Specifically, RCM participants used more protective equipment during fumigation and, on average, for nearly 50% more of the comparable RCM participants over half of the food that they daily consume was produced in their own farms. Furthermore, RCM participants sold and consumed a greater number of products (different than coffee) produced on their farms compared to non-participants. The increased diversity of trees and products observed in RCM farms may expand the set of goods that growers can consume and represents an additional source of income.

Innovations in the business model have also impacted the way as smallholder growers' link to global markets, affecting their expectations of the coffee business and their perception and empowerment on the value chain. RCM participants had better knowledge of the value chain in which they participated and also a higher proportion of participants (at least 35% more participants than non-participants) expect that future generations will be involved in the coffee business (Table 7). RCM principles of transparency and traceability play an important role on these outcomes.

We estimated bird survey differences for the full sample, and the refined sample that considers comparable RCM participants and non-participants (Table 8). We found similar abundance and species richness of birds in participant and nonparticipant farms for the refined sample. Because bird-friendly habitat can take years to develop fully, biodiversity benefits are best examined over longer time scales.  Interestingly, the most common genus of documented borer predators, *Setophaga*, was nearly 60% more abundant on participant farms on average (1.92 Vs. 1.19). Though this trend was not statistically significant, it hints that pest control services may be realized on RCM farms.

**[TABLE 8 HERE]**

As mentioned before, Fair Trade enrollment was significantly higher among RCM-participants. In order to determine if the observed differences by RCM participation are explained by Fair Trade certification, we ran the Imbens and Rubin (2014) algorithm for certified (treatment) and non-certified (control) smallholders using the original input variables and adding the RCM participation variable as an input. We found that all input variables were relatively well balanced and overlapped (see appendix C). In addition, we did not find significant differences in outcomes between certified and non-certified participants (Table C2 in appendix C). The only outcome variable that was significantly higher among certified smallholders was the use of protective equipment during fumigation. This is not surprising given that Fair Trade certification is oriented to protect workers safety conditions.

Thus, while outcomes associated with RCM-participation are unlikely to be completely explained by Fair Trade, we recognize that Fair Trade certification standards are aligned with many of the same principles, such as cooperative practices, supported by RCM. Likewise, Fair Trade certification may facilitate participation in RCM, and the initial matching between the cooperatives and the RCM importer (as we suspect may have been the case for our RCM cooperative). What we argue, is that RCM and certifications such us Fair Trade can complement one another by emphasizing different attributes (e.g., product quality, conditions for growers, environmental health).

Currently, Fair Trade certification does not recognize product quality. Instead, this certification generally targets economically disadvantaged producers, with limited capital, reduced market access and low bargaining power. In this context, Fair Trade price premiums appear relatively more appealing for producers selling lower-quality coffee since they will receive a fixed amount with the certification, without any concern about product quality investments (Raluca et al., 2014). In the long run, the market is likely to react to the lower quality, driving down the price premiums for Fair Trade growers (De Janvry et al., 2010). Some experiments show that buyers are willing to pay 50 cents extra for a pound of Fair Trade coffee (Hertel et al., 2009; Verteramo et al., 2014). Nevertheless, empirically, has been also proved that consumers reduce their willingness to pay for a lower quality Fair-Trade coffee. For instance, a 9 percent increase in price result in a 30 percent decline in demand for a product with lower quality, while the demand for more expensive an higher quality coffee is insensitive to price (Hainmueller et al., 2014).

RCM better ensures the viability of the business model by actively promoting the smallholder participation in high-quality coffee value chains; while, third party certifications, provide relevant information about growers' organizations and grower's working conditions to importers, roasters and final consumers (Nelson and Pound, 2009; Raluca et al., 2014)  In addition, when growers consider alternatives such us the inclusion of diverse trees in coffee shade composition to improve coffee quality, economic and environmental goals are aligned. Sustainability is not just about fair trade practices and production methods that foster environmental protection. It is also about product quality to promote sustainable participation of smallholders in high-quality value chains.

Although smallholder participation in high-quality coffee value chains such as RCM seems to be an alternative for the growers and the environment, this model faces its own set of challenges. One of the main difficulties for the model is how to allocate the price premiums associated to high-quality coffee. In our interviews, and other similar studies (Prevezer, 2013), growers enrolled in cooperatives often complained of the lack of communication about the allocation of price premiums and the decision making process. We must better understand the consequences of improvements in coffee quality and different payout schemes for premiums (e.g. directly to growers to induce individual efforts to improve coffee quality or to the cooperatives to support infrastructure or programs). Although cooperatives are crucial to link farmers to high-value markets (Wollni and Brümmer, 2012), ownership and governance of these cooperatives ultimately may determine who benefits from such quality differentiation (Neilson, 2007).

In addition, besides the long run benefits of higher tree diversity and more organic alternatives (in terms of pest control, soil health and food availability), these forms of production also imply a significant reduction in coffee yields and higher labor costs in the short term (Atallah and Gómez, 2014; Valkila, 2009). Quality price premiums and business models should justify and recognize those transitions. The development of dynamic models over specific relations like shade plantations, coffee quality, birds populations services, consumers preferences and price premiums would contribute to understand those long-term interactions and the most effectively way to insert growers into sustainable global markets.

## 8. Conclusions

After using propensity score matching to control for self-selection bias among smallholder coffee growers in Colombia, we found evidence that RCM participation was associated with several socioenvironmental benefits. First, RCM farms had greater tree diversity which should improve the ability of these farms to support other biodiversity, the access and availability of food for growers, as well as reduces dependency on agrichemicals. Second, RCM participants employed more water-saving practices and organic fertilizers than non-participants. Third, participants had better access to credit, were more knowledgeable of downstream segments of the value chain, and felt more optimistically about the future of the coffee business relative to non-participants.

The results show that high-quality coffee production systems are complementary to traditional certifications schemes, achieving similar desirable outcomes in social and environmental terms, but in addition, incorporating the coffee quality aspect that consumers are demanding. Future research should identify efficient mechanisms to distribute quality-based price premiums across cooperative members and alternative mechanisms to incentivize growers' efforts to increase product quality individually and collectively. In addition, future research would contribute to understand the dynamic behind growers' decision to adopt sustainable coffee agro ecosystems, given the potential interactions between neo-tropical birds populations and pest control services. For that purpose, it is required to study in more detail the smallholder growers' production costs and their behavior in terms of discount rates, cooperation and risk attitude.

Finally, our results are relevant to other crops beyond coffee. Cocoa production, for example, is similar in many respects to specialty coffee production (Anglaaere et al., 2011). In general, the integration of efficient agricultural production with biodiversity conservation is a global challenge (Railsback and Johnson (2014) and research and policy decisions are striving to link sustainable agriculture production with sustainable livelihoods (Jha et al., 2014). Future studies focusing on cooperation to increase quality and additional impact evaluations in other countries can contribute to identify appropriate structures to elevate product quality.

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## Appendix A. Balancing and Overlapping Tests

**[Appendix A Here]**

## Appendix B. Logit Model Estimation

**[Appendix B. Table B1 Here]**

## Appendix C. Labor-related certifications comparable groups and outcomes

**[Appendix C. Table C1 Here]**

**[Appendix C. Table C1 Here]**

## Appendix D. Supplementary material (online version).

### D1. Initial Input Variables Set

**[TABLE D1 HERE]**

### D2. Survey

**[*PDF ATTACHED*]**

### D3. Complementary information on birds watching

### D3. Geo-referenciation RCM participants and non-participants farms

**[FIGURE D1 HERE]**

**[FIGURE D2 HERE]**

**[FIGURE D3 HERE]**

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**Figure 1. Conceptual Framework - RCM participation.**

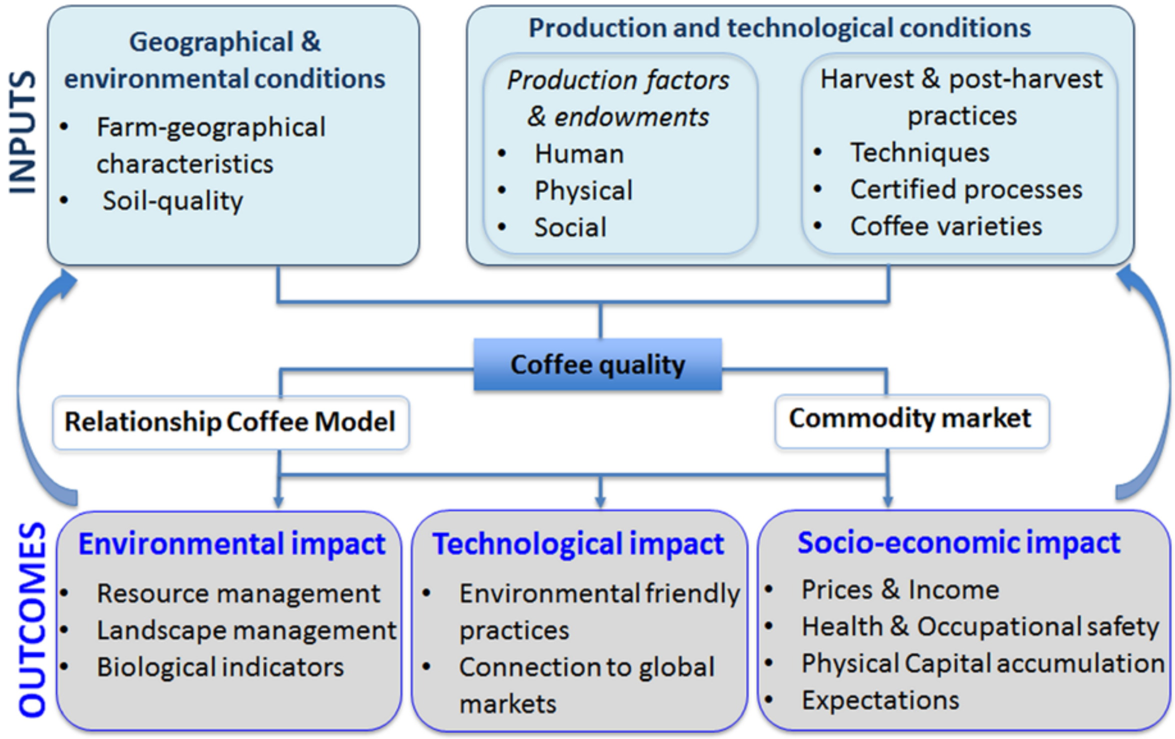

**Table 1. Differences between RCM-participants and non-participants' inputs.**

| Input variables description | Non-participants (N=186) Mean ± SD | RCM-participants (N=78) Mean ± SD | T-test |
|---|---|---|---|
| ***Geographical and Environmental conditions*** | | | |
| Crop elevation | 1805 ± 574 | 1709 ± 111 | -1.46 |
| Soil-iron content | 36.9 ± 32.7 | 21.1 ± 12.4 | -4.14* |
| Soil respiration | 0.954 ± 0.21 | 1.03 ± 0.24 | 2.61* |
| Soil protein score | 45.6 ± 15.5 | 52 ± 18.2 | 2.92* |
| ***Production and Technology conditions*** | | | |
| Health status | 2.35 ± 1.59 | 2.44 ± 1.65 | 0.38 |
| Agricultural training | 0.85 ± 0.85 | 1.88 ± 0.88 | 8.89* |
| Housing infrastructure and access to facilities | 7.93 ± 2.64 | 6.41 ± 1.38 | -4.82* |
| Ownership of production machinery | 3.51 ± 1.08 | 4.04 ± 0.95 | 3.71* |
| Informal savings | 0.176 ± 0.38 | 0.372 ± 0.48 | 3.49* |
| Application to credit in the informal sector | 0.042 ± 0.20 | 0.025 ± 0.15 | -0.66 |
| Participation in civic organizations | 1.73 ± 1.28 | 2.49 ± 1.36 | 4.34* |
| Percentage of coffee-crop area/farm | 0.715 ± 0.34 | 0.548 ± 0.27 | -3.82* |
| Remuneration to contracted workers | 1713.4 ± 3491.4 | 1134.2 ± 1509.4 | -1.41 |
| Percentage of *Arabica* varieties | 0.215 ± 0.34 | 0.070 ± 0.23 | -3.29* |
| Coffee certifications related to labor conditions | 0.278 ± 0.52 | 0.974 ± 0.16 | 11.30* |

* Statistically significant differences at a 0.05 level. SD: Standard deviation.

**Table 2. Input variables selected according to Imbens and Rubin (2014) algorithm.**

| Category | | | Variable | Description |
|---|---|---|---|---|
| Geographical and Environmental Conditions | | Farm-geographical characteristics | Crop elevation | Crop elevation from sea level measured in each farms. Unit: Meters |
| | | Soil-quality assessment | Soil-iron content | Quantification of particles per million of iron calculated after chemical evaluation of soil |
| | | | Soil respiration | Measure of metabolic activity from microbial community of the soil |
| | | | Soil-protein score | Quantification of protein content |
| Production & technological conditions | Production factors & endowments | Human capital | Health status | Index that aggregates: diabetes, heart diseases, dental diseases, eyes diseases, pressure and circulation problems, respiratory sicknesses and gastric illnesses. |
| | | | Training in agricultural production | Number of institutions in which the farmer has taken some training. |
| | | Physical capital | Housing infrastructure and access to facilities | Index that aggregates: electricity, gas pipes, natural gas, telephone, cell phone, water and sewage, garbage collection, internet, cable TV and or national TV. |
| | | | Ownership of coffee production machinery | Index that aggregates: coffee cherry depulping machine, mucilage-taker, dryer (3 types), fumigation equipment, lawn trimmer, power saw, grass-sting, silo |
| | | | Informal savings | Maintain savings by his/her own, family or friends or with not regulated groups (1 if true) |

| | | | |
|---|---|---|---|
| | | Application to credit in the informal sector | Requested a credit at the informal sector during last 12 months. Includes not regulated borrowers, family and friends (1 if true) |
| | Social Capital | Participation in civic organizations | Index that measures participation in civic organizations. Includes: coffee growers formal and informal organizations, religious, recreational and/or educational groups. |
| Harvest and post-harvest practices | Factor shares | Percentage of coffee-crop area/farm | Percentage of coffee hectares in relation to the total farm size. |
| | | Remunerations to contracted workers | Includes: payments during the last crop to workers contracted to coffee beans collection plus payments to daily workers (Thousands of COL pesos) |
| | Coffee varieties | Percentage of Arabica | Percentage of Arabica trees in a representative quadrant. |
| | Certified processes and standards◆ | Certifications related to labor and business conditions. | Index that aggregates: Fair Trade, Utz and 4C Common. |
| ** Not selected by the algorithm* | | * Environmental related certifications. | Index that aggregates: Rainforest Alliance, Organic, UTZ, 4C Common, Smithsonian Bird Friendly. |

◆For the RCM participants labor related certifications basically refer to Fair Trade. The cooperative and almost all of their 700 members are certified (in the sample 96% affirmed to be Fair Trade certified). Any of them have Utz or 4C certifications. In the case of environmental related certifications, the most common is Organic, although, only 11.5% in the cooperative members are certified or in process of certification. This proportion is similar to the percentage of growers in the RCM participants' sample who affirm to be organic certified (12.8%).

**Table 3. Balancing test for RCM-participants and non-participants' input selected variables according to Imbens and Rubin (2014) algorithm.**

| Input variables description | Balancing Method 1 T-test (z-values) [a] | Balancing Method 2 F-test (z-values) [b] |
|---|---|---|
| | ***Geographical and Environmental conditions*** | |
| Crop elevation | -1.092 | -0.589 |
| Soil-iron content | -0.631 | 0.075 |
| Soil respiration | 0.745 | -0.106 |
| Soil protein score | 0.897 | -0.326 |
| | ***Production and Technology conditions*** | |
| Health status | -0.643 | 0.055 |
| Agricultural training | 0.905 | -0.338 |
| Housing infrastructure and access to facilities | -0.512 | 0.279 |
| Ownership of production machinery | 0.402 | 0.492 |
| Informal savings | -0.874 | -0.294 |
| Application to credit in the informal sector | -0.743 | -0.102 |
| Participation in civic organizations | -0.628 | 0.079 |
| Percentage of coffee-crop area/farm | -0.028 | 2.005* |
| Remuneration to contracted workers | -0.278 | 0.778 |
| Percentage of *Arabica* varieties | 0.636 | 0.066 |
| Coffee certifications related to labor conditions | 2.264 * | -1.931 |
| ◆ Environmental related certifications | -0.467 | 0.362 |

[a] Non-satisfactory input balance when values are substantially larger in an absolute value than one.
[b] The p values associated with the F statistic are converted to a z-value. Non-satisfactory balance when there are large positive values.
◆Not selected as an input by Imbens and Rubin algorithm, but balanced between RCM participants and non-participants.

**Table 4. Overlapping test for RCM-participants and non-participants' input selected variables according to Imbens and Rubin (2014).**

| Input variables description | Mean differences [a] | SD sample ratio [b] | Proportion outside quartiles for covariate distribution [c] | |
|---|---|---|---|---|
| | | | Non-participants | RCM-participants |
| ***Geographical and Environmental conditions*** | | | | |
| Crop altitude | -0.355 | 0.837 | 0.392 | 0.067 |
| Soil-iron content | -0.144 | 0.670 | 0.098 | 0.067 |
| Soil respiration | 0.204 | 1.328 | 0.000 | 0.133 |
| Soil protein score | 0.252 | 1.196 | 0.000 | 0.133 |
| ***Production and Technology conditions*** | | | | |
| Health status | -0.219 | 0.811 | 0.020 | 0.000 |
| Agricultural training | 0.275 | 0.553 | 0.294 | 0.000 |
| Housing infrastructure and access to facilities | -0.138 | 0.923 | 0.098 | 0.067 |
| Ownership of production machinery | 0.080 | 0.814 | 0.098 | 0.000 |
| Informal savings | -0.316 | 0.966 | 0.000 | 0.000 |
| Application to credit in the informal sector | -0.283 | 1.040 | 0.000 | 0.000 |
| Participation in civic organizations | -0.157 | 0.812 | 0.020 | 0.000 |
| Percentage of coffee-crop area/farm | 0.018 | 0.501 | 0.059 | 0.000 |
| Remuneration to contracted workers | 0.060 | 0.847 | 0.059 | 0.000 |
| Percentage of *Arabica* varieties | 0.182 | 1.335 | 0.000 | 0.133 |
| Coffee certifications related to labor conditions | 0.828 | 0.419 | 0.098 | 0.000 |
| ◆ Environmental related certifications | -0.189 | 0.857 | 0.020 | 0.000 |

[a] Values around zero reflect a better overlapping.
[b] Ratio equal to 1 if control and treatment covariates have the same standard deviation (SD).
[c] In a randomized experiment this measures are equal to $\alpha$ in expectation and only $\alpha \times 100\%$ of units have covariate values that make the prediction of missing potential outcomes relatively difficult.
◆Not selected as an input by Imbens and Rubin algorithm, but overlapped between RCM participants and non-participants.

**Table 5. Input variables comparison between RCM-participants and non-participants. Original sample vs. refined sample after Imbens and Rubin algorithm (2014).**

| Input variables description | Original total sample | | | Refined sample after trimming | | |
|---|---|---|---|---|---|---|
| | Non-participants (N=186) Mean ± SD | RCM-participants (N=78) Mean ± SD | T-test | Non-participants (N=50) Mean ± SD | RCM-participants (N=14) Mean ± SD | T-test |
| Crop elevation | 1805 ± 574 | 1709 ± 111 | -1.46 | 1742.5 ± 123.7 | 1702.0 ± 103.6 | -1.11 |
| Soil-iron content | 36.9 ± 32.7 | 21.1 ± 12.4 | -4.14* | 22.50 ± 11.84 | 21.05 ± 7.93 | -0.43 |
| Soil respiration | 0.954 ± 0.21 | 1.03 ± 0.24 | 2.61* | 0.96 ± 0.18 | 1.00 ± 0.24 | 0.73 |
| Soil protein score | 45.6 ± 15.5 | 52 ± 18.2 | 2.92* | 46.55 ± 13.87 | 50.40 ± 16.58 | 0.87 |
| Growers' health status | 2.35 ± 1.59 | 2.44 ± 1.65 | 0.38 | 2.60 ± 1.71 | 2.26 ± 1.38 | -0.68 |
| Growers' training in agricultural production | 0.85 ± 0.85 | 1.88 ± 0.88 | 8.89* | 1.19 ± 0.91 | 1.40 ± 0.50 | 0.79 |
| Grower's housing infrastructure and access to facilities | 7.93 ± 2.64 | 6.41 ± 1.38 | -4.82* | 6.71 ± 1.87 | 6.46 ± 1.72 | -0.44 |
| Ownership of coffee production machinery | 3.51 ± 1.08 | 4.04 ± 0.95 | 3.71* | 3.64 ± 1.18 | 3.73 ± 0.96 | 0.25 |
| Informal savings | 0.176 ± 0.38 | 0.372 ± 0.48 | 3.49* | 0.49 ± 0.50 | 0.33 ± 0.48 | -1.03 |
| Application to credit in the informal sector | 0.042 ± 0.20 | 0.025 ± 0.15 | -0.66 | 0.03 ± 0.19 | 0.00 ± 0.00 | -0.07 |
| Participation in civic organizations | 1.73 ± 1.28 | 2.49 ± 1.36 | 4.34* | 2.35 ± 1.53 | 2.13 ± 1.24 | -0.04 |
| Percentage of coffee-crop area/farm | 0.715 ± 0.34 | 0.548 ± 0.27 | -3.82* | 0.74 ± 0.46 | 0.74 ± 0.23 | 0.05 |
| Remuneration to contracted workers | 1713.4 ± 3491.4 | 1134.2 ± 1509.4 | -1.41 | 1222.3 ± 1867.0 | 1325.3 ± 1582 | 0.18 |
| Percentage of Arabica varieties | 0.215 ± 0.34 | 0.070 ± 0.23 | -3.29* | 0.10 ± 0.25 | 0.155 ± 0.33 | 0.65 |
| Coffee certifications related to labor conditions | 0.278 ± 0.52 | 0.974 ± 0.16 | 11.30* | 0.471 ± 0.674 | 0.899 ± 0.282 | 2.30* |

**Table 6. Outcome Variables Description**

| | | | |
|---|---|---|---|
| Environmental Impact | Resource management | Water saving techniques | Index that aggregates techniques for saving water and treatment of residual water (goes from 0 to 3). |
| | | Awareness of the use of biological control methods | Compare with other growers in the area the farmer considers that he/she uses more biological control methods. |
| | Landscape management | Crop-tree diversity | Average of the number of tree species identified in the small quadrants of each farm. |
| | | Inga-tree diameter | Perimeter of Inga species trees in the quadrants (average in centimeters). |
| | Biological indicators | Birds abundance and genus | Observed number of specimens from the southwest quadrant point at each farm. |
| | | Bird species diversity | Total number of species detected on a farm |
| | | Soil potassium content | Particles per million |
| Technological Impact | Environmental friendly practices | Preparation of own fertilizer | Farmer prepares organic fertilizers in the farm |
| | | Use of organic fertilizer | Farmer used organic fertilizers during the last crop. |
| | | Use of organic fumigation | Farmer used organic fumigation alternatives against coffee rust. |
| | Connection to global markets | Knows the final buyer/Exporter | The farmer knows who are the final buyer and/or exporter of the coffee that he produces (goes from 0 to 2). |

| | | | |
|---|---|---|---|
| Socio-Economic Impact | Price and income | Price per kilogram | Price received per kilogram of coffee produced during the last crop in Colombian pesos. |
| | Health and safety | Use of protection equipment | Index that aggregates protection gear used during agro-chemicals application. Includes: gloves, mask, coveralls, glasses, boots and caps. |
| | | > 50% of consumed food came from its own farm | In a regular day more than half of food consumed come from the own farm. |
| | | Products different from coffee, are sold and self consumed | Index that aggregates items that are produced for consumption and sell. Includes: cassava, plantain, banana, corn, rice, cane, chickens, pigs, cattle, vegetables, legumes and fruits. |
| | Physical capital accumulation | Access to microcredit | Farmer received a credit from a cooperative or small financial entity during the last 12 months. |
| | Expectations | Farmer expects children will be involved in coffee activities | Farmer wants that his son(s) and/or daughter(s) will be involved in coffee activities. |

**Table 7. Outcomes differences between RCM-participants and non-RCM participants according to Imbens and Rubin (2014).**

| Outcome variables description | Single propensity score Homoscedasticity Mean ± SD | Single propensity score Heteroscedasticity Mean ± SD | Matching single covariate Mean ± SD | Two-match propensity score Mean ± SD | Three-match propensity score Mean ± SD | Four match propensity score Mean ± SD |
|---|---|---|---|---|---|---|
| ***Environmental Impact*** | | | | | | |
| Water saving techniques | 0.57 ± 0.62 | 0.57 ± 0.44 | 0.65 ± 0.42 | 1.03 ± 0.52** | 1.05 ± 0.47** | 1.02 ± 0.46** |
| Awareness of the use of biological control methods | 0.561 ± 0.26** | 0.56 ± 0.36 | 0.18 ± 0.17 | 0.53 ± 0.22** | 0.36 ± 0.21* | 0.37 ± 0.20* |
| Crop-tree diversity | 0.06 ± 0.52 | 0.06 ± 0.80 | 0.74 ± 0.23*** | 0.80 ± 0.47* | 0.63 ± 0.37* | 0.54 ± 0.31* |
| Inga-tree diameter | 19.98 ± 9.39** | 19.98 ±15.39 | 10.45 ± 5.22** | 12.11± 9.12 | 19.27 ± 8.09** | 18.19 ± 6.82*** |
| Soil potassium content (PPM) | -52.91 ± 59.31 | -52.91 ± 17.83*** | -50.37 ± 32.47 | -51.79 ± 47.82 | -55.65 ± 41.82 | -55.23 ± 38.58 |
| ***Technological Impact*** | | | | | | |
| Preparation of own organic fertilizers | 0.42 ± 0.23* | 0.42 ± 0.06*** | 0.27 ± 0.15* | 0.42 ± 0.19** | 0.42 ± 0.17** | 0.38 ± 0.16** |
| Use of organic fertilizers during the last crop | 0.51 ± 0.31 | 0.51 ± 0.38 | 0.53 ± 0.14*** | 0.59 ± 0.24** | 0.43 ± 0.21** | 0.47 ± 0.19** |
| Uses organic fumigations against coffee roast | 0.65 ± 0.28** | 0.65 ± 0.36* | 0.28 ± 0.11** | 0.35 ± 0.21 | 0.28 ± 0.18 | 0.20 ± 0.16 |
| Knows final buyer/exporter of his coffee | 1.48 ± 0.43*** | 1.48 ± 0.73** | 1.37 ± 0.22*** | 1.43 ± 0.35*** | 1.09 ± 0.38*** | 1.12 ± 0.33*** |
| ***Socio-Economic Impact*** | | | | | | |
| Price per coffee kilo | -209.84 ± 399.69 | -209.84 ± 235.48 | 81.71 ± 219.19 | -54.73 ± 305.19 | -39.97 ± 261.95 | 54.06 ± 300.10 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Access to micro credits | 0.65 ± 0.24*** | 0.65 ± 0.38* | 0.28 ± 0.16* | 0.61 ± 0.20*** | 0.36 ± 0.22 | 0.43 ± 0.19** |
| Use of protective equipment during fumigation | 2.90 ± 1.07*** | 2.90 ± 0.76*** | 1.83 ± 0.67*** | 2.35 ± 0.97** | 2.02 ± 0.89** | 2.06 ± 0.78*** |
| >50% of consumed food came from its own farm | 0.56 ± 0.25** | 0.56 ± 0.38 | 0.03 ± 0.13 | 0.21 ± 0.26 | 0.36 ± 0.22 | 0.43 ± 0.19** |
| Products different from coffee, are sold and self consumed | 0.68 ± 1.25 | 0.68 ± 0.75 | 0.63 ± 0.33* | 0.87 ± 0.78 | 0.90 ± 0.63 | 1.28 ± 0.57** |
| Farmer want his/her children to be involved in coffee production | 0.63 ± 0.24*** | 0.63 ± 0.14*** | 0.21 ± 0.16 | 0.62 ± 0.20*** | 0.55 ± 0.20*** | 0.35 ± 0.21* |

S.D: Standard deviation *, p < 0.1; **, p < 0.05, and *** p<0.01

**Table 8. Bird-survey differences between RCM-participants and non-RCM participants**

| Variables description | Original total sample | | | Refined sample after trimming | | |
|---|---|---|---|---|---|---|
| | Non-participants (N=169) Mean ± SD | RCM-participants (N=63) Mean ± SD | T-test [a] | Non-participants (N=41) Mean ± SD | RCM-participants (N=13) Mean ± SD | T-test |
| Abundance | 28.68 ± 16.51 | 34.92 ± 12.76 | 2.71*** | 33.14 ± 17.17 | 32 ± 14.26 | -0.21 |
| Diversity | 14.34 ± 6.81 | 18.73 ± 5.68 | 4.54*** | 16.60 ± 7.36 | 19.46 ± 7.64 | 1.20 |
| Setophaga | 1.19 ± 1.32 | 1.38 ± 1.50 | 0.91 | 1.19 ± 1.34 | 1.92 ± 1.75 | 1.57 |
| Basileuterus | 0.029 ± 0.22 | 0.095 ± 0.42 | 1.49 | 0.048 ± 0.31 | 0 ± 0 | -0.55 |
| Pheugopedious | 0.24 ± 0.61 | 0.36 ± 0.65 | 1.32 | 0.51 ± 0.89 | 0.23 ± 0.43 | -1.08 |

[a] Significance levels adjusted by Bonferroni correction. S.D: Standard deviation *, $p < 0.1$; **, $p < 0.05$, and *** $p<0.01$

## Appendix A. Balancing and Overlapping Tests

In general, the first balancing method tests the hypothesis that the block-weighted difference between participants and non-participants means is not statistically different than zero.

$$z_k = \frac{\sum_{j=1}^{J} \frac{N_{nj} + N_{pj}}{N} . (\bar{X}_{pkj} - \bar{X}_{nkj})}{\sqrt{\hat{V}_k}} \qquad (A1)$$

Where $\bar{X}_{pkj}$ is the participants $(p)$ $k$ input mean in sub-block $j$, $\bar{X}_{nkj}$ is the non-participants $(n)$ $k$ input mean in sub-block $j$, $N_{nj}$ the number of non-participants in sub-block j, $N_{pj}$ the number of participants in sub-block j, $N$ the total number of participants and non-participants in the original trimmed block and $\hat{V}_k$ the estimated sampling variance for input $k$. However, with only one block this test can be simplified to:

$$z_k = \frac{(\bar{X}_{pk} - \bar{X}_{nk})}{\sqrt{\hat{V}_k}} \quad (A2) \; ; \qquad \hat{V}_k = s_k^2 \left( \frac{1}{N_n} + \frac{1}{N_p} \right) \quad (A3)$$

$$and \; s_k^2 = \frac{1}{N_n + N_p - 2} \left( \sum_{i:W_i=0} \left( X_{ik} - \bar{X}_{pk} \right)^2 + \sum_{i:W_i=1} (X_{ik} - \bar{X}_{nk})^2 \right) \quad (A4)$$

In addition, expression (A5) contributes to understand the intuition behind the second balancing test. In this expression the dependent variable is the $k$ input variable $X$ for grower $i$ $(X_{ik})$ while $(B_j.W)$ represents the interaction of the sub-block $B_j$ and the treatment variable $W$

$$X_{ik} = \alpha_{kj}.B_{ij} + \tau_{kj} \; (B_{ij}.W_i) \qquad (A5)$$

According to this test, if any input variable is balanced in a particular sub-block, it is expected that this input variable depend on the sub-block (coefficient $\alpha_{kj} \neq 0$), but not on the interaction between that sub-block and the treatment (coefficient $\tau_{kj} = 0$). In other words, the mean of any input variable for participants and non-participants can be different across sub-blocks but not within sub-blocks. With only one block, this test helps to verify that the inputs average values do not depend of participation in the program.

In relation to overlapping, the first test is represented in equation (A6) where the difference in means by treatment group is normalized by the square root of the average within group standard deviations.

$$\Delta_{pn} = \frac{\bar{X}_p - \bar{X}_{np}}{\sqrt{(s_{np}^2 + s_p^2)/2}} \qquad (A6)$$

In contrast with the first balancing test, which is heavily impacted by N, in this normalized difference the number of treatment and control individuals ($N_n$ and $N_p$) do not divide the estimated standard deviations. The advantage is that we can obtain a good measure of the differences in location of the distribution due to small differences in the covariates and not necessary explained by a larger N

**Appendix B. Table B1. Estimated parameters of Propensity Score**

| Variable | Abbreviation | Coefficient | Std. Error | t-stat |
|---|---|---|---|---|
| Intercept | | 8.30 | 18.31 | 0.45 |
| *Linear Terms* | | | | |
| Crop altitude | altitude | 0.01 | 0.01 | 1.06 |
| Percentage of Arabica varieties | arab | -30.72 | 12.10 | -2.54 |
| Growers' health status | health | -3.67 | 1.55 | -2.36 |
| Grower's training in agricultural production | training | 0.62 | 1.00 | 0.61 |
| Percentage of coffee-crop area/farm | coffee | 4.61 | 2.78 | 1.66 |
| Ownership of coffee production machinery | machine | 0.32 | 0.47 | 0.69 |
| Participation in civic organizations | civic | 3.74 | 1.08 | 3.45 |
| Remuneration to contracted workers | remuneration | 0.00 | 0.00 | -1.72 |
| Soil respiration | respiration | -116.41 | 37.56 | -3.10 |
| Soil protein score | protein | 1.54 | 0.49 | 3.13 |
| Soil-iron content | iron | 2.22 | 1.09 | 2.04 |
| Informal savings | saving | 13.74 | 4.39 | 3.13 |
| Application to credit in the informal sector | credit | -6.31 | 2.77 | -2.28 |
| Certifications related to labor conditions | certification | 31.98 | 8.37 | 3.82 |
| Grower's housing infrastructure and facilities | house | -1.63 | 0.62 | -2.62 |
| *Second Order Terms* | | | | |
| arab_ protein | | 0.35 | 0.17 | 2.07 |
| certification _civic | | -2.43 | 0.83 | -2.93 |
| certification _ arab | | -23.37 | 6.56 | -3.56 |
| certification _ coffee | | -22.08 | 6.57 | -3.36 |
| altitude _iron | | 0.00 | 0.00 | -2.09 |
| arab _civic | | 6.92 | 2.27 | 3.06 |
| civic _ saving | | -3.24 | 1.17 | -2.76 |
| training _ arab | | 1.24 | 0.51 | 2.43 |
| house _ arab_ | | 0.31 | 0.16 | 2.01 |
| *Number of Observations* | 265 | | *LR chi2 (24)* | 277.94 |
| *Log likelihood* | -21.62 | | *Prob > chi2* | 0 |
| | | | *Pseudo R2* | 0.87 |

**Appendix C. Labor-related certifications comparable groups and outcomes**

**Table C1. Balancing and Overlapping tests for certified-participants and non-participants' input selected variables.**

| Input variables description | Balancing Method 1 T-test (z-values) [a] | Balancing Method 2 F-test (z-values) [b] | Mean differences [c] | SD sample ratio [d] | Proportion outside quartiles for covariate distribution [e] | |
|---|---|---|---|---|---|---|
| | | | | | Non-participants | RCM-participants |
| ***Geographical and Environmental conditions*** | | | | | | |
| Crop altitude | 0.003 | 2.852* | 0.001 | 0.741 | 0.243 | 0.000 |
| Soil-iron content | -0.232 | 0.905 | -0.123 | 0.518 | 0.459 | 0.000 |
| Soil respiration | 0.431 | 0.434 | 0.234 | 0.443 | 0.351 | 0.000 |
| Soil protein score | 0.483 | 0.334 | 0.256 | 0.508 | 0.351 | 0.000 |
| ***Production and Technology conditions*** | | | | | | |
| Growers' health status | 1.334 | -0.882 | 0.449 | 1.863 | 0.000 | 0.167 |
| Growers' training in agricultural production | 0.169 | 1.109 | 0.080 | 0.829 | 0.108 | 0.000 |
| Grower's housing infrastructure and access to facilities | 0.469 | 0.362 | 0.176 | 1.462 | 0.000 | 0.167 |
| Ownership of coffee production machinery | 0.203 | 0.995 | 0.098 | 0.766 | 0.108 | 0.000 |
| Informal savings | 0.617 | 0.101 | 0.249 | 1.237 | 0.000 | 0.000 |
| Application to credit in the informal sector | -0.709 | -0.047 | -0.414 | 0.000 | 0.081 | 0.000 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Participation in civic organizations | 0.375 | 0.551 | 0.181 | 0.761 | 0.162 | 0.000 |
| Percentage of coffee-crop area/farm | -0.119 | 1.315* | -0.062 | 0.549 | 0.189 | 0.000 |
| Remuneration to contracted workers | -0.349 | 0.608 | -0.188 | 0.455 | 0.135 | 0.000 |
| Percentage of Arabica varieties | 0.761 | -0.126 | 0.304 | 1.271 | 0.000 | 0.000 |
| *RCM participation* | -0.402 | 0.493 | -0.182 | 0.939 | 0.000 | 0.000 |

[a] Non-satisfactory input balance when values are substantially larger in an absolute value than one.
[b] Non-satisfactory balance when there are large positive values.
[c] Values around zero reflect a better overlapping.
[d] Ratio equal to 1 when control and treatment covariates have the same standard deviation (SD).
[e] $\alpha \times 100\%$ of units have covariate values that make the prediction of missing potential outcomes relatively difficult.

**Table C2. Outcomes differences between certified and non-certified participants**

| Input variables description | Single propensity score Homoscedasticity Mean ± SD | Single propensity score Heteroscedasticity Mean ± SD | Matching single covariate Mean ± SD | Two-match propensity score Mean ± SD | Three-match propensity score Mean ± SD | Four match propensity score Mean ± SD |
|---|---|---|---|---|---|---|
| ***Environmental Impact*** | | | | | | |
| Water saving techniques | 0.58 ± 0.54 | 0.58 ± 0.61 | 0.44 ± 0.52 | 0.51 ± 0.52 | 0.22 ± 0.51 | 0.26 ± 0.52 |
| Awareness of the use of biological control methods | 0.09 ± 0.24 | 0.09 ± 0.21 | 0.23 ± 0.23 | 0.16 ± 0.23 | 0.16 ± 0.21 | 0.12 ± 0.21 |
| Crop-tree diversity | 0.08 ± 0.29 | 0.08 ± 0.36 | 0.01 ± 0.23 | -0.04 ± 0.30 | 0.14 ± 0.30 | 0.03 ± 0.31 |
| Inga-tree diameter | 6.75 ± 8.11 | 6.75 ± 11.66 | 8.24 ± 6.39 | 6.09 ± 7.37 | 13.81 ± 7.76* | 10.29 ± 8.11 |
| Soil potassium content (PPM) | -77.78 ± 60.22 | -77.78 ± 30.60 | -83.73 ± 55.42 | -88.73 ± 60.21 | -92.15 ± 60.22 | -89.25 ± 61.05 |
| ***Technological Impact*** | | | | | | |
| Preparation of own organic fertilizers | 0.02 ± 0.24 | 0.02 ± 0.21 | 0.23 ± 0.17 | 0.15 ± 0.22 | 0.18 ± 0.20 | 0.22 ± 0.20 |
| Use of organic fertilizers during the last crop | -0.09 ± 0.21 | -0.09 ± 0.20 | 0.04 ± 0.22 | 0 ± 0.20 | -0.04 ± 0.19 | 0.02 ± 0.20 |
| Uses organic fumigations against coffee roast | -0.04 ± 0.12 | -0.04 ± 0.06 | -0.02 ± 0.11 | -0.04 ± 0.11 | -0.02 ± 0.12 | -0.03 ± 0.12 |
| Knows final buyer/exporter of his coffee | 0.11 ± 0.39 | 0.11 ± 0.40 | 0.30 ± 0.25 | 0.16 ± 0.34 | 0.32 ± 0.35 | 0.33 ± 0.34 |
| ***Socio-Economic Impact*** | | | | | | |
| Price per coffee kilo | -183.61 ± 353.87 | -183.61 ± 404.79 | -237.14 ± 371.89 | -169.71 ± 366.31 | -148.22 ± 369.12 | -186.73 ± 351.89 |

| | | | | | | |
|---|---|---|---|---|---|---|
| Access to micro credits | -0.02 ± 0.25 | -0.02 ± 0.21 | -0.18 ± 0.16 | -0.09 ± 0.21 | -0.14 ± 0.19 | -0.16 ± 0.18 |
| Use of protective equipment during fumigation | 2.81 ± 0.83*** | 2.81 ± 0.64*** | 2.46 ± 0.93*** | 2.72 ± 0.85*** | 2.41 ± 0.89*** | 2.59 ± 0.88*** |
| >50% of consumed food came from its own farm | -0.09 ± 0.10 | -0.09 ± 0.04* | -0.07 ± 0.08 | -0.08 ± 0.09 | -0.07 ± 0.09 | -0.08 ± 0.09 |
| Products different from coffee, are sold and self consumed | -0.37 ± 0.40 | -0.37 ± 0.47 | -0.34 ± 0.30 | -0.48 ± 0.41 | -0.17 ± 0.41 | -0.35 ± 0.42 |
| Farmer want his/her children to be involved in coffee production | -0.14 ± 0.22 | -0.14 ± 0.208 | 0.023 ± 0.24 | -0.105 ± 0.23 | 0.008 ± 0.218 | -0.029 ± 0.221 |

S.D: Standard deviation *, p < 0.1; **, p < 0.05, and *** p<0.01

**(Supplementary Online Material. Appendix D)**

**Table D1. Input variables description**

| Group | Variable |
|---|---|
| Location | Department |
| Topography | Altitude |
| Soil Characteristics | Aggregate Stability (%), Available Water Capacity (m/m), Organic Matter (%), Active Carbon (ppm), pH, Extractable Phosphorus (ppm), Extractable Potassium (ppm), Magnesium (ppm), Iron (ppm), Manganese (ppm), Zinc (ppm), Sand, Clay, Silt, Textural Class, Protein (mg/g soil), Protein "Score", Respiration (mg/g soil, 4day Total), Protein "Score" (not texture adjusted) |
| Biophysical/Landscape | Percentage of Arabica variety in the quadrant. Includes: Caturra, Typica, Borbon, Catuai and Pacamara |
| | Percentage of Robusta variety in the quadrant. Includes Colombia, Castillo, Catimor, F1, F4, F6, F8, "suprema", 2000 |
| | Numbers of trees in the quadrant. |
| Natural Disasters and Pests | Exposure to natural disasters. Includes: floods, droughts, land slides (last crop, last 3 crops). |
| | Pest exposure and incidence during the last 3 crops. Includes coffee berry borer (CBB) and rust |
| Family Structure | Age |
| | Number of economically dependent members |
| Health | Aggregation of the pre-existing conditions: diabetes, heart, dental eyes, pressure, circulation, gastric or respiratory problems or diseases. |
| Education | Years of education |
| | The farmer knows institutions that provide technical assistances and number of institutions that knows. |
| | Number of institutions farmer assisted for technical capacitation. |
| Fixed Assets | Owner of his own farm |
| | Legal document that supports landholding. |
| | Farm size |
| | Coffee hectares |

| | |
|---|---|
| | Percentage of coffee hectares in relation to farm size |
| | House, apartment, land and/or car possession index. |
| Variable Assets | Index that aggregates the number of animals: weighted according to market value |
| House | Household infrastructure and access to utilities index |
| Saving | Saving in the financial sector |
| | Number of formal financial services used for saving. |
| | Saving in the informal sector: Includes not regulated borrowers, family, friends |
| Credit | Applied for a credit in the last two years |
| | Applied to credit in the financial sector |
| | Applied to microcredit |
| | Requested a credit at the informal sector. |
| Fixed Capital | Index that aggregate the ownership of the following machines: coffee cherry de-pulping machine, mucilage-taker, dryer (3 types), fumigation equipment, lawn trimmer, power saw, grass-sting, silo |
| Political Institutions | Level of participation in presidential, state and city elections, coffee guild representatives, cooperative and federations delegates. |
| Civic Institutions | Level of participation in civic organizations. Includes: coffee growers, religious, recreational, certification, and educational groups or organizations. |
| | Coordinate communal work with other coffee groups. |
| Tradition and Expectations | Farmer's parents where involve in the coffee production. |
| Security | The security conditions in the regions are bad or worse than before. |
| | The farmer has suffered displacement, extortion over assets, or extortion over profits. |
| Cooperatives | Belong to a cooperative of growers where members are under RCM |
| | Time that a cooperative has been involved with the RCM |
| Diversification | Total of food products produced in the farm different than coffee for consumption |
| | Total of food products produced in the farm different than coffee for sale |

| | |
|---|---|
| Income | Household total income below a specific income line |
| Production Factors Remuneration | Payment for coffee beans collection: kilograms produced times payment per kilogram |
| | Payment to per day workers (*jornales*): Days times payment per day |
| | Total labor remuneration: Payment for coffee beans collection plus payment to per day workers (*jornales*) |
| | Household members who help in the coffee production |
| Harvest & Post-Harvest Practices & Management | Tech processing plant to process coffee bean |
| | Percentage of the coffee crops associated with other products. |

**Figure D1. Colombia - Geo-referenciation RCM participants and non-participants farms**

**Figure D2. Cauca - Geo-referenciation RCM participants and non-participants farms**

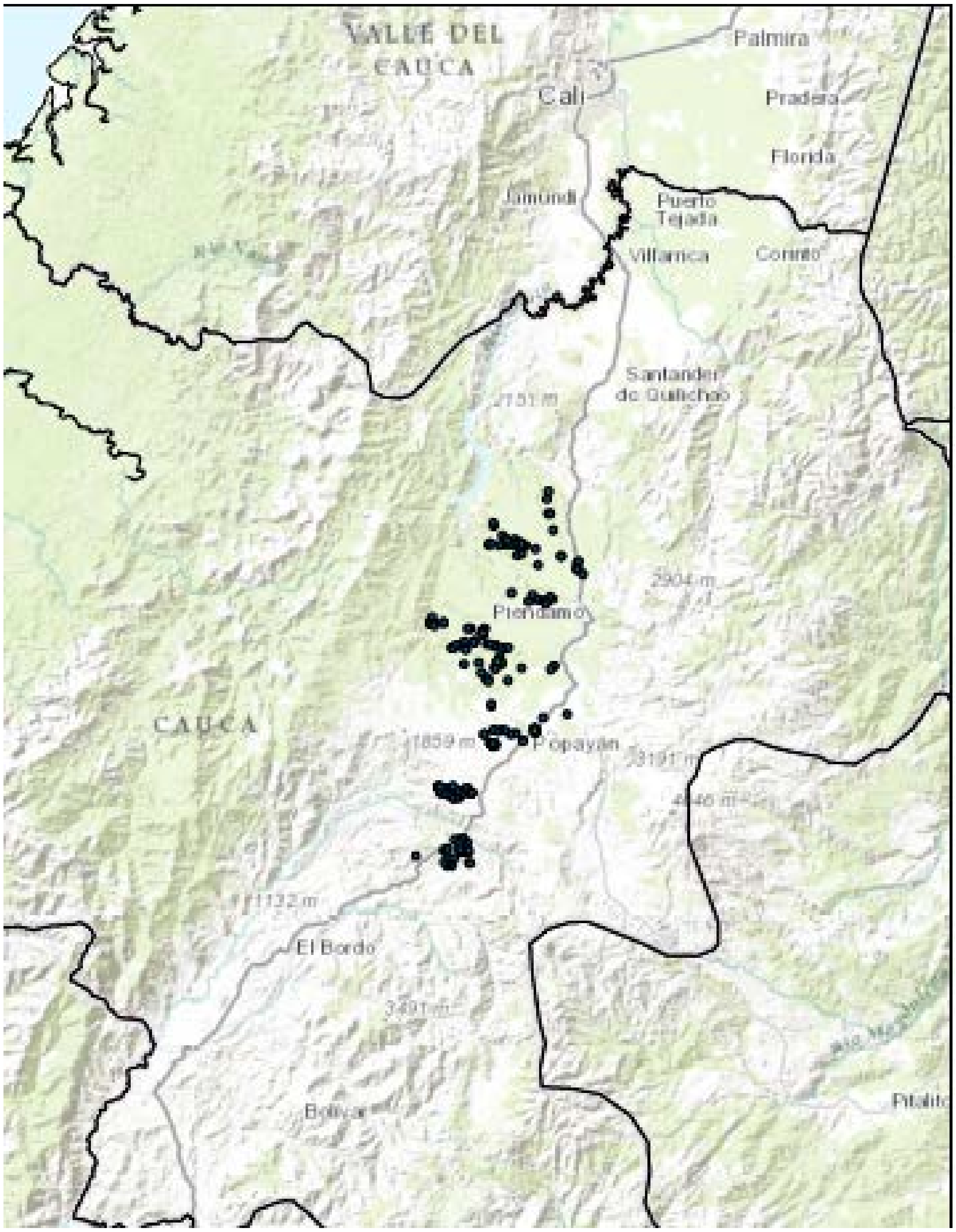

**Figure D3. Antioquia - Geo-referenciation RCM participants and non-participants farms**