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Improving Coffee Productivity in Ethiopia

The Impact of a Coffee Tree Rejuvenation Training Program on Stumping

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Abstract

Coffee is Ethiopia's most important export commodity, cultivated by over 6 million smallholder farmers in the country, and accounting for about one-third of the country's commodity exports. While coffee production has increased over the last decade, coffee yields are low and several constraints to improved productivity remain. With two-three decades old and low-yielding coffee trees in particular, the sector cannot attain its full potential. In this paper, we assess the short-term impact of a coffee tree rejuvenation training program in Sidama on adoption rate and intensity of stumping – currently the best practice to revitalize ageing coffee trees and substantially improve their productivity. Using baseline and follow-up data and a difference-in-difference approach, we find that the adoption rate and intensity of stumping has increased by about threefold during the first year of the rejuvenation training intervention.

Keywords: Coffee Farm College, rejuvenation, coffee, Ethiopia.

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1. Introduction

Coffee is Ethiopia's most important export crop, accounting for 28.7 percent of the country's commodity exports in 2018/19 (NBE, 2019). It is estimated that its highly valued Arabica coffee is cultivated by over 6 million smallholders in the country and employs about 15 million people across the value chain (CSA, 2020; FSA/USDA, 2018). Moreover, coffee income has been shown to lead to improved food security in the country (Kuma et al., 2019). While coffee production and exports have increased over the last decade (Minten et al., 2019), there are a number of constraints still holding the sector back from attaining its full potential.

Low-yielding aged coffee trees and poor farm management and agronomic practices are among the main constraints. Most coffee trees currently grown in Ethiopia were planted over two-three decades ago, and farmers have rarely been taught on how to rejuvenate their coffee trees to sustainably improve their yields (Minten et al., 2019; Amamo, 2014; Woldetsadik and Kebede, 2000). In 2019, official coffee yields estimate in Ethiopia were on average 61 percent below that of Brazil (the world's number one coffee producer) and 29 percent below the world's average yield (FAOSTAT, 2021).

We study the effect of a tree-rejuvenation training program in the Sidama zone of Ethiopia. The program aims to address the constraint of ageing trees and thereby increase coffee yields through an intensive coffee agronomy training program. The program is promoted through TechnoServe's Coffee Farm College training approach, which aims to improve coffee productivity and resilience by promoting proven agronomic practices such as rejuvenation, shade management, composting, and coffee nutrition and health through participatory and experiential learning methods. The core elements of this approach are: (i) trainings held in small groups at a focal farmer's demonstration plot, which is used for practical sessions and where coffee farmers can see first-hand the results of implementing best agronomic practices on the health and productivity of coffee trees; and (ii) repeated trainings during the season, each time with new topics or lessons that are relevant to the particular coffee production calendar.[1]

We assess the program's short-term impact on the adoption rates and intensity of stumping, a practice that entails properly cutting of old and unproductive coffee trees at its base for a complete renewal which will result in an increase in the quantity and quality of coffee harvests after a two-

[1] For instance, the rejuvenation training (the main topic among the eight modules) is conducted during the stumping season which spans from January to March.

year period. The program was implemented in two separate cohorts. The first cohort started in January 2019 and comprised 2 districts and 34 sub-districts within. The second cohort started in January 2020 in 3 additional districts and 49 sub-districts (kebeles). All the districts belong to the Sidama coffee zone and share similar coffee production and marketing environment. The implementation process of the program followed the same modalities in both cohorts: from farmer-trainer recruitment and trainer-to-farmer mobilization, training delivery, and follow-up in both cohorts. All coffee farmers in these districts and kebeles were eligible for the training program and participation was voluntary leading to participant and non-participant groups in each cohort.

We recognize that districts selected for program implementation in its first and second phases are not random and that farmer-level participation into training is voluntary. Thus, one concern is that a simple comparison of participant and non-participant groups would yield biased results. To address this issue, we adopt two complementary partial identification strategies. First, we rely on within district (cohort) estimates to compare participants to non-participants, through a difference-in-difference approach, using the program's baseline and follow-up data from both training participants and non-participants. In these estimates, we first match participants and non-participants on a set of observable characteristics likely correlated to both our outcome variables and program participation. We further run these estimates separately for each cohort in order to account for potential placement bias between first- and second-cohort districts.

This strategy is however limited in that it cannot account for self-selection biases, wherein farmers' unobservable characteristics may drive their decision to participate in the program. In a second estimation strategy, we rely on the sub-sample of program participants only, comparing post-treatment outcomes for the first cohort to pre-treatment outcomes for the second one. Although this strategy cannot account for program placement bias, it complements the first one in that it can account for self-selection bias.

Both identification strategies yield similar results. The training program led to a 15-19 percentage points increase in the share of farmers adopting stumping practice, and an increase in the share of stumped trees on the reference coffee field by up to 3 percentage points. Stumping being rarely practiced in Ethiopia (i.e., low baseline values), these results represent about a threefold increase in the adoption rate and intensity of stumping after the first-year training intervention.[2] These results have significant practical implications, as rejuvenating ageing coffee trees markedly

[2] Two follow-up (additional) training will be provided over the two-year period of the program.

improve the plant vitality and its yield potential (Pohlan and Janssens, 2010; Barham and Weber, 2012; Weber, 2012; Illy et al., 2005).

The reminder of the paper is organized as follows. Section 2 provides a brief description of the intervention and its core components. Section 3 presents the data and related descriptive statistics, followed by the estimation strategy in section 4. Section 5 present estimates of the intervention's main impacts. Section 6 concludes with some practical and policy implications. The appendix section provides supplementary tables and figures.

2. The intervention: Coffee Farm College

To improve the production and productivity of smallholder coffee farmers, TechnoServe in partnership with MIHS/HereWeGrow is implementing its Coffee Farm College agronomy training program in Sidama zone. The Coffee Farm College is built on a participatory and intensive activity-based training approach and aims at improving the adoption of best agronomic practices that can enhance the productivity of coffee trees in a sustainable manner. The Coffee Farm College comprises four main interlinked components: development of curriculum and content, localized monthly training implemented at focal farmer level and provided in group-sessions, provision of the necessary training tools and equipment, and follow-up farm visits and monitoring of adoption.

Curriculum and content development. At the core of the Coffee Farm College is the design of the curriculum and its content. The syllabus is developed by TechnoServe in consultation with the Jimma Agricultural Research Center (JARC) and the Ethiopian Tea and Coffee Authority; and draws on Africa-wide experience in farming coffee and more than 12 years of Coffee Farm College implementation. The syllabus and the contents are validated through a review process by regional training and agronomy advisors and the local Ethiopian TechnoServe team, who know the local context, before they are finalized for instruction. Besides relevance, much emphasis is given in simplifying the lessons to make the content accessible to farmers with limited literacy and numeracy levels. One of the unique features of the curriculum is that it develops topic-specific lesson plans for each best practice and instructs each lesson or module shortly ahead of appropriate time for implementation of a given practice. Training sessions largely rely on activity-based or learning-by-doing instructions that allows active engagement of each farmer in practical applications.

Localized training. Farmers receive the training on coffee agronomy and farm management practices in their locality and in small groups, known as focal farmer (development) groups, to facilitate and ensure active participation. These groups are a semi-formal local administrative structure within each kebele[3] that comprise about 30 coffee farming households, on average, and serve as a grassroots forum to discuss local development initiatives. For this intervention, each group has a Focal Farmer who hosts the demonstration plot, where coffee farmers can see first-hand the results of properly implementing best agronomic practices on the growth and productivity of the coffee trees. The trainings are organized and facilitated by dedicated Farmer Trainers[4] who are trained and continuously mentored by TechnoServe Coffee Agronomists. Each Farmer Trainer works with up to 12 focal farmer groups and conducts training every month for two years, each time with new topics or lessons that are synchronized with the coffee production calendar.

Provision of tools and equipment for training. The project introduces tools (e.g., stumping saw and secateurs) that are necessary for proper implementation of promoted agronomic practices such as stumping. To encourage adoption, the project facilitates farmers' access to the required tools through their respective Farmer Trainers and Focal Farmers, albeit the availability of tools is not always guaranteed.

Follow-up support and monitoring. Farmer Trainers and TechnoServe Agronomists provide follow-up implementation support right after the delivery of a training on specific core agronomic practices. Concurrently, the Farmer Trainers also advise individual farmers on the adoption of agronomic practices covered in the training sessions by visiting their coffee farms.

3. Sampling, data, and descriptive statistics

Sampling and data

The study uses data collected from a sample of 952 households for the 2019-cohort, and another 980 households for the 2020-cohort (i.e., 1932 households in total). The sampled households were randomly selected from five program woredas (districts) and 83 kebeles following similar sample selection strategies for both cohorts. First, we developed a sampling frame of all coffee farmers in

[3] Kebele is the lowest administrative unit in Ethiopia.

[4] Farmer trainers are locally recruited personnel that organize and facilitate training sessions at the level of focal farmer group. They are trained by TechnoServe agronomists on coffee agronomy basics and on adult training techniques through an 8-day Training of the Trainer and Agronomy course before they become trainers. The Farmer Trainers receive continuous mentorship and supervision throughout the two-year program. For instance, Farmer Trainers receive a monthly training on each monthly coffee agronomy topic that they will subsequently deliver to the focal farmer groups.

all development groups of each program kebele (since having a coffee farm is the eligibility criteria to participate in the training program). Second, the sampled households were selected using a two-stage sampling process: 5-7 development groups were randomly selected in each kebele, from which 4 coffee farming households were randomly selected.[5] During the follow-up survey, all households sampled for the baseline were revisited, and more than 90 percent of the sample households were interviewed.[6]

The data was collected at two points in time. The *baseline* data was collected right at the beginning of the training intervention for both cohorts (January/February 2019 and 2020) and collected information on stumping rates *before* the training intervention began (i.e., stumping rate during 2018 for the 2019 cohort and stumping rate during 2019 for the 2020 cohort). The *follow-up (midline)* data was collected after the training and the stumping season were completed (Figure 1). An inherent advantage of stumping is that a person with basic training can observe and easily distinguish whether the tree was stumped recently or a year ago.

Figure 1. Survey and implementation timeline for rejuvenation training[7]

While the baseline data covered a wide range of topics (including household demographics, asset ownership and income, access to services and infrastructure, adoption of best agronomic practices,

[5] An average kebele constitute about 25 development groups and most development groups have about 25-30 member households. While 7 development groups per kebele were randomly selected for 2019-cohort, the number of development groups were reduced to 5 for 2020-cohort mainly because the later covered more numbers of kebeles.

[6] Samples from six kebeles in cohort-1 (168 sample households) were excluded during the follow-up survey mainly because a closely related but separate data collection was underway at the same time. Seventeen households were not interviewed during the follow-up survey because they moved out of their original kebele and enumerators were not able to reach them during the survey period. Five households were dropped during the analysis due to missing values for some of the covariates we have accounted for.

[7] The follow-up survey for 2020-cohort is conducted sometime after the stumping season is completed and it has no implication on recall, since enumerators counted the actual number of stumped trees and one can easily know a tree stumped few months ago and a year ago.

and respondents' preferences), the follow-up data focused on measuring adoption of stumping. The unique feature of the follow-up data is that enumerators actually measured the main variables of interest, as opposed to farmers self-reporting. Main outcome variables included the total number of coffee trees, the number of stumped coffee trees, and the area of the coffee plot. Follow-up surveys also collected information on the year and time of stumping to better identify the effect of the rejuvenation training on adoption of stumping.

Training participation

Table 1 presents the summary statistics on sample farmers' participation rate in the rejuvenation training by cohort and in total. The training participation rates, based on farmers' self-reported attendance, indicate that about 31 percent and 62 percent of the sample households reported participation in the rejuvenation training in the 2019 and 2020 cohorts, respectively. The training participation rate for the pooled sample is 48 percent. More importantly, *at least* 75 percent of the sample focal groups were reached by the rejuvenation training during the first year of the program.

Table 1. Farmer-reported attendance at rejuvenation training

		Farmer-reported attendance at rejuvenation (stumping) training		
		2019-cohort	2020-cohort	Pooled
Rejuvenation training (*yes=1*)	%	31	62	48
	N	243	593	838
Total	N	783	959	1742

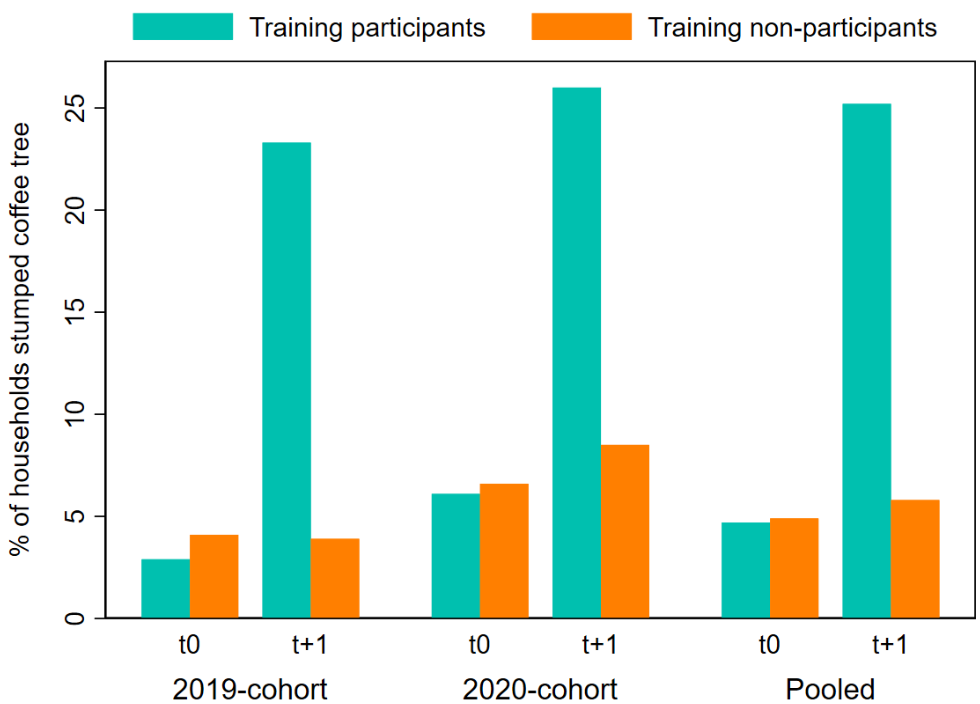
Note: Sample households are considered trained if one or more member of the household attended a training session by the Coffee Farm College program on rejuvenation, at the focal farmer group level or at her/his own individual farm by TechnoServe's Farmer Trainer.
Source: Authors' calculation based on 2019 and 2020 coffee agronomy baseline and follow-up survey data.

Measurements of main outcomes

While the program's primary outcome of interests includes the adoption of eight best agronomic practices, this paper focuses on measuring the short-term impact of Coffee Farm College's rejuvenation training on stumping (the lead outcome of the program) after the first of the three rounds of trainings on stumping that will take place during the lifespan of the agronomy program. Figure 2 presents the rate of adoption of stumping at baseline (t0: a year before the training intervention) and follow-up (t+1: after the rejuvenation training was conducted, and stumping season ended) by cohort and for the pooled sample.

The results clearly indicate that the adoption rate of stumping have increased substantially after the training intervention. While the stumping adoptions rates are comparable between training participants and non-participants at baseline (t0), it has increased by about 19 percentage points at follow-up (t+1) for those sample farm households that participated in the rejuvenation training. The bar graphs also show similar results (about 20 percentage points difference) when we compare stumping rates of training participants at baseline and follow-up, while the stumping adoption rates by non-participants are more or less the same between the two periods.

Figure 2. Adoption rate of coffee tree stumping, by training participation and cohort

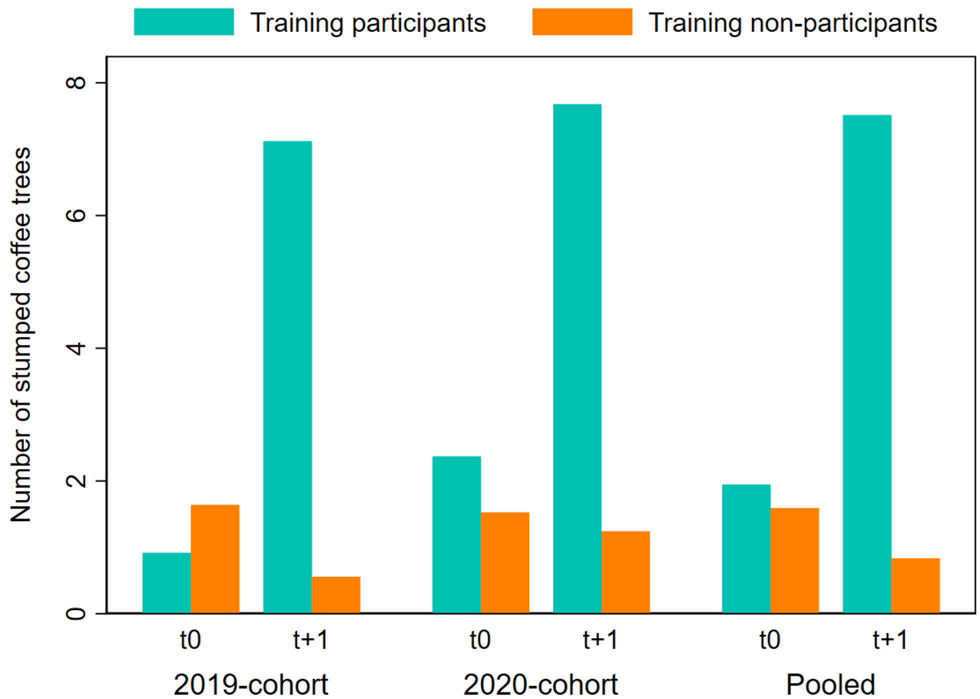


Note: Sample households are considered trained if one or more member of the household is trained by the Coffee Farm College program on rejuvenation. t+1=after the training and t0=before the training.
Source: Authors' calculation based on 2019 and 2020 coffee agronomy baseline and follow-up survey data.

Similarly, the descriptive results on intensity of stumping as measured by the number and share of stumped coffee trees shows a sizable increase after the first rejuvenation training. On average, training participants stumped about 6 - 7 more coffee trees after the training compared to their baseline value (Figure 3).[8]

[8] The average number of stumped coffee trees increase to 27 when the sample is restricted to households that adopted stumping after the first training, which is significantly higher compared to the adoption rate for the whole (unrestricted) sample (4 percent). The corresponding number for households that took part in the training and adopted stumping is 30.

Figure 3. Number of coffee trees stumped, by training participation and cohort

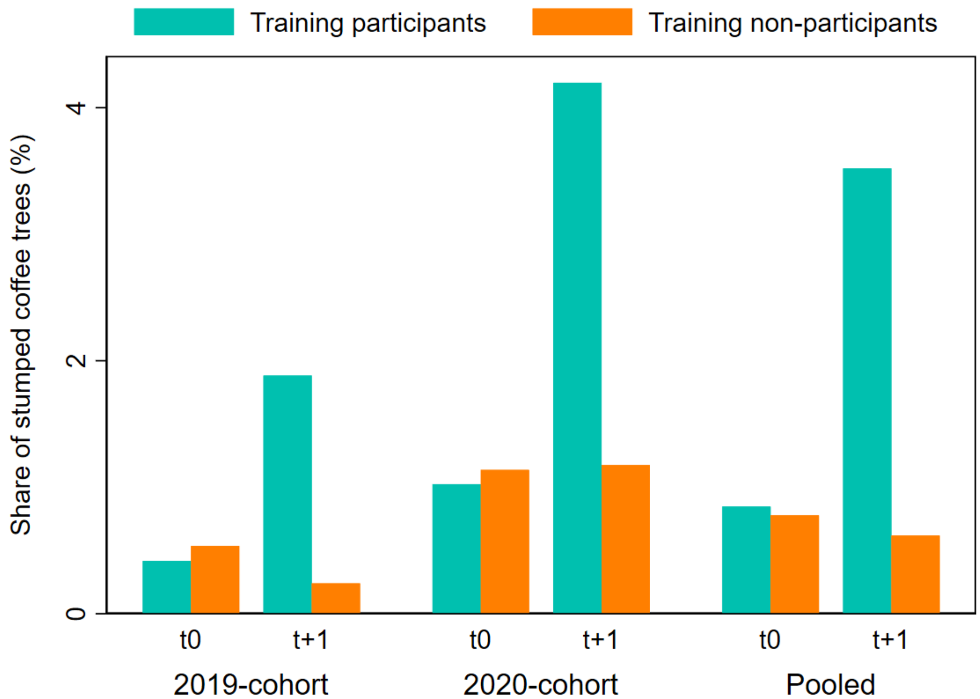


Note: Sample households are considered trained if one or more member of the household is trained by the Coffee Farm College program on rejuvenation. t+1=after the training and t0=before the training.
Source: Authors' calculation based on 2019 and 2020 coffee agronomy baseline and follow-up survey data.

Likewise, the share of coffee trees stumped by training participants is higher than non-participants by about 2 - 3 percentage points, on average (Figure 4).[9] These descriptive results may however hide issues of potential social, economic, and contextual confounding factors, which we address below.

[9] The average share of stumped coffee trees increases to 13 percent when the sample is restricted to households adopted stumping after the first training, which is significantly higher compared to the share for the whole (unrestricted) sample (2 percent). The corresponding number for households that took part in the training and adopted stumping is 14 percent.

Figure 4. Share of coffee trees stumped, by training participation and cohort



Note: Sample households are considered trained if one or more member of the household is trained by the Coffee Farm College program on rejuvenation. t+1=after the training and t0=before the training.
Source: Authors' calculation based on 2019 and 2020 coffee agronomy baseline and follow-up survey data.

Measurements of covariates

Table 2 presents the household, plot, and location characteristics of our sample. Overall, the average household in our sample is headed by a 43 years old person (mostly men) and includes about 6 family members. About 60 percent of the household heads have attended elementary education and 18 percent have attended secondary education or higher. Only about 36 percent of the sample households are members of cooperatives. The vast majority of households own livestock, with an average of about 2 Tropical Livestock Units. On average, households in our sample cultivate a total of 0.7 hectares farmland, about 2 coffee fields, and 391 coffee trees on the visited (reference) plot. These coffee trees are about two decades old, on average, some being as old as 44 years. Most of the coffee fields are in the vicinity of the household's dwelling. Regarding access to services, sample households reside 8, 27, and 56 minutes away from all-weather roads, wet mills (coffee collection centers), and the closest district capital, respectively (Table 2).

Table 2. Descriptive statistics of covariates

Covariates	2019-cohort		2020-cohort		Pooled	
	Participants	Difference (t-test)	Participants	Difference (t-test)	Participants	Difference (t-test)
Age of household head	43.61	-0.63	43.30	-1.25	43.39	-0.98
	(0.88)		(0.59)		(0.49)	
Gender of head (female=1)	0.08	-0.04*	0.09	-0.06**	0.08	-0.05***
	(0.02)		(0.01)		(0.01)	
Household size	5.34	0.07	5.76	0.27**	5.64	0.27***
	(0.13)		(0.08)		(0.07)	
Head attended elementary	0.63	0.03	0.60	0.10***	0.61	0.05**
education (yes=1)	(0.03)		(0.02)		(0.02)	
Head attended secondary	0.18	-0.02	0.15	0.02	0.16	-0.01
education or higher (yes=1)	(0.03)		(0.01)		(0.01)	
Household is member of a	0.66	0.19***	0.24	-0.04	0.36	-0.03
coop	(0.04)		(0.02)		(0.02)	
Livestock assets (TLU)	1.99	0.05	1.97	0.24**	1.97	0.12
	(0.11)		(0.09)		(0.07)	
Wealth/asset index	0.09	0.13	-0.07	-0.19	-0.03	-0.05
	(0.17)		(0.09)		(0.08)	
Distance to a coffee wet mill	23.89	-6.69***	27.59	1.09	26.51	-2.42*
	(1.51)		(1.23)		(0.98)	
Distance to all weather road	6.99	-1.78*	8.72	1.96***	8.21	0.26
	(0.82)		(0.63)		(0.51)	
Distance to woreda capital	57.69	2.90	55.26	1.04	55.97	1.41
	(4.00)		(2.61)		(2.18)	
Farm size (hectares)	0.78	0.07	0.72	0.10***	0.74	0.06**
	(0.05)		(0.03)		(0.02)	
Number of coffee fields	1.75	0.08	1.63	0.18***	1.66	0.08**
	(0.06)		(0.04)		(0.03)	
Number of coffee trees	581.12	160.85***	312.66	138.11***	391.15	70.36**
	(44.03)		(30.81)		(26.22)	
Age of coffee trees	20.82	-0.56	17.58	-0.62	18.53	-1.57***
	(0.77)		(0.56)		(0.47)	
Distance to coffee fields,	3.82	-1.17**	2.54	0.15	2.92	-1.02***
average (minutes)	(0.30)		(0.16)		(0.15)	
Participants obs.	245		593		838	
Non-participants obs.	538		366		904	

Note: Difference = (training participants) - (training non-participants). TLU refers to Tropical Livestock Units and PCA refers to Principal Component Analysis. Standard errors clustered at the focal farmer (development) group level are in parenthesis. ***, **, and * indicate significance at the 1, 5, and 10 percent critical level.
Source: Authors' calculation based on 2019 and 2020 coffee agronomy baseline and follow-up survey data.

The comparison between training participants and non-participants on observable household, plot, and location characteristics *across* cohorts show statistically significant differences on a few variables. For instance, training participants hold a larger number of coffee trees and are mostly headed by a male. Other areas of difference include household size, head's education, farm size, number of coffee fields, and distance to coffee field and collection centre, albeit these differences are not observed across cohorts.

4. Estimation strategy

First, we exploit the presence of training participants and non-participants in eligible program areas and employ a quasi-experimental difference-in-difference (DID) approach, in which we compare outcomes of interest between participants and non-participants before-and-after the training intervention.[10] The estimated DID is formally represented in Equation (1).

$$y_{ist} = \alpha + \rho Training_s + \tau Post_t + \delta(Training\ x\ Post)_{st} + \theta X_{ist} + \varepsilon_{ist} \quad (1)$$

where y_{ist} is the outcomes of interest (i.e., adoption of stumping, number of trees stumped, and share of trees stumped); $Training_s$ indicates participation status in the rejuvenation training (*Training*=1 if the sample household participated in the training and *Training*=0 otherwise). $Post_t$ indicates the timing of the outcome measures (*Post*=1 if the outcome value is taken at follow-up after the training intervention (i.e., t+1) and *Post*=0 if the outcome value is taken at baseline (i.e., t0)). $(Training\ x\ Post)_{st}$ is the interaction term of training (treatment indicator) and survey round (baseline vs. follow-up), capturing the treatment effect of the training intervention. X_{ist} denotes a vector of household specific/level control variables (i.e., age and gender of the head of the household, household size, household head education, household membership in cooperatives, livestock ownership, asset index, age of coffee tree, farm size, number of coffee trees, and number of coffee fields/plots, distance to mill, distance to all weather road, distance to woreda capital, and distance to coffee fields/plots). ε_{ist} is a random component.

A required assumption in DID is that outcomes of interest (adoption rate and intensity of stumping) would have followed the same trend in the sample of training participants and non-participants in the absence of the training. Although one can think of many reasons why this assumption would not hold, the rate of stumping prior to the training indicates that stumping is not widely practiced by coffee farmers in Ethiopia. Only about 5 of the sample households reported stumping at baseline

[10] A simple 2x2 difference-in-difference (i.e., two time periods and two groups; and while training participants received the training in the second time period, the non-participants have non-yet received the training) and the rejuvenation training (intervention) occurred during the stumping season (January to March).

and both groups have similar trend (there is no statistically significant difference on stumping by training participation before the training) (Figure 2). This is also in line with the historical data in the country and study area. For instance, Minten et al. (2019) show that the share of stumped trees by smallholder coffee farmers in Ethiopia was 2.6 percent in 2014 and 1.5 percent ten years earlier (2004), on average.

Another common concern is that the parallel trend assumption may not be plausible if selection for treatment (training) is associated with household specific characteristics that affect the dynamic of outcome variables. We employed two related methods to address the issue of selection on observables: (i) we estimate DID with matching on pre-intervention covariates (i.e., DID on a matched sample); and (ii) we check the robustness of our results using a semiparametric difference-in-difference (SDID), a reweighting technique that addresses potential imbalance between the training participants and non-participants on observable characteristics that correlate with training participation and affect the state of outcomes of interest (Abadie 2005).

This identification strategy however fails to account for those farmer-level unobservable characteristics that may not only drive their decisions to participate in the program but also their likelihood of stumping in the absence of the program. Thus, in a second identification strategy, we restrict our sample to those farmers who "*choose to participate*" in the program in both cohorts and compare the post-training outcomes of "*training participants*" of the 2019-cohort (t+1) to the pre-training outcomes of "*training participants*" of the 2020-cohort before the training (t0).

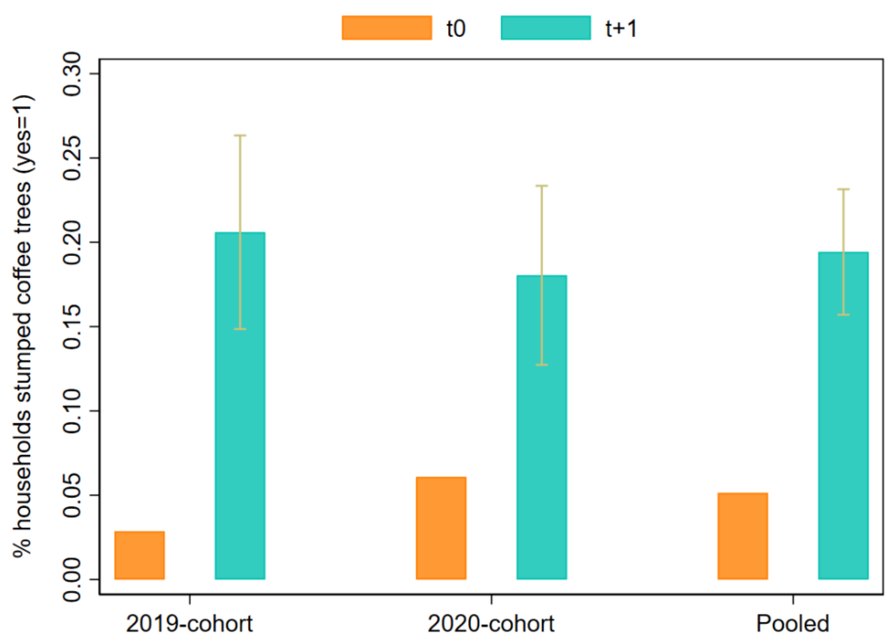
5. Results and discussions

Adoption of stumping

We measure the adoption of stumping by asking sample households whether they have stumped their coffee trees and by observing the main (reference) coffee field/plot where the stumping took place (both at baseline and follow-up). The estimates in Figure 5 show evidence of an increase in the adoption rate of stumping by farmers that participated in the Coffee Farm College's rejuvenation training. The results specifically indicate that farmers who participated in the training are, on average, 18 to 20.5 percentage points more likely to have adopted stumping, after accounting for household, plot, and location characteristics. If, for instance, we take the results of the pooled sample (a 19.4 percentage points increase on stumping adoption rate), the effect of the training on adoption of stumping represents a more than threefold increase over the adoption rate at baseline. We find comparable effect of the training on adoption rates of stumping across cohorts, with a relatively high impact in 2019 (partly because of lower baseline values in 2019-cohort compared to 2020-cohort).

While these are large effects, it is partly due to low baseline values. Stumping old and unproductive trees is a relatively new practice and only about 5 percent of sample households reportedly stumped their coffee trees in the year prior to the training intervention (despite that the average coffee tree in the study area is about 2 decades old). That said, the training intervention was very much effective in creating awareness and expanding the uptake of the stumping practice (i.e., it tripled adoption rates just in the first stumping season after the training).

Figure 5. Estimates of treatment effects on adoption of coffee stumping, by cohort



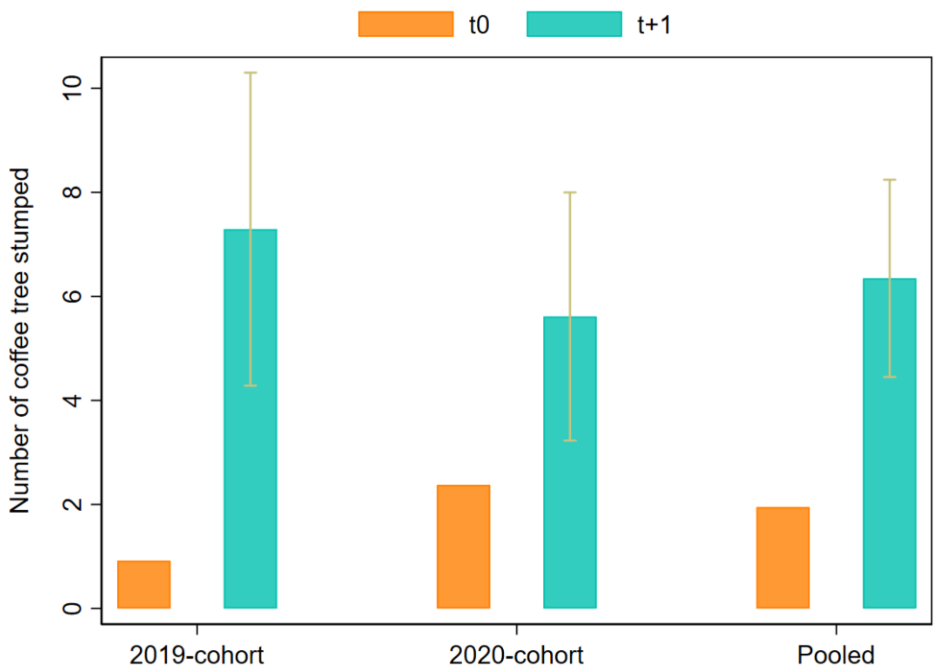
Note: See Table A1 in the appendix for the detailed results. t+1=after the training (regression coefficients from the difference-in-difference estimation) and t0= before the training (outcome for training participants before the training). Capped bars are 95% confidence intervals.
Source: Authors' calculation based on 2019 and 2020 coffee agronomy baseline and follow-up survey data.

Stumping intensity

We further estimate the impact of the rejuvenation training on intensity of stumping (the intensive margin) as measured by the number and share of trees stumped on the main plots where farmers implemented the practices. The number of stumped trees were measured by a direct counting of stumped and un-stumped trees on the plot where the farmer adopted the practice. Figure 6 presents results on the impacts of the rejuvenation training on the number of coffee trees stumped.

We find evidence of an increase in the intensity of stumping by farmers who took part in the training. Specifically, the results indicate that training participants stumped an average of 6 more trees during the first stumping season after the training. Given that the average number of stumped trees were about 2 trees at baseline, this represents a threefold increase on the number of stumped coffee tress due to the training (Figure 6).

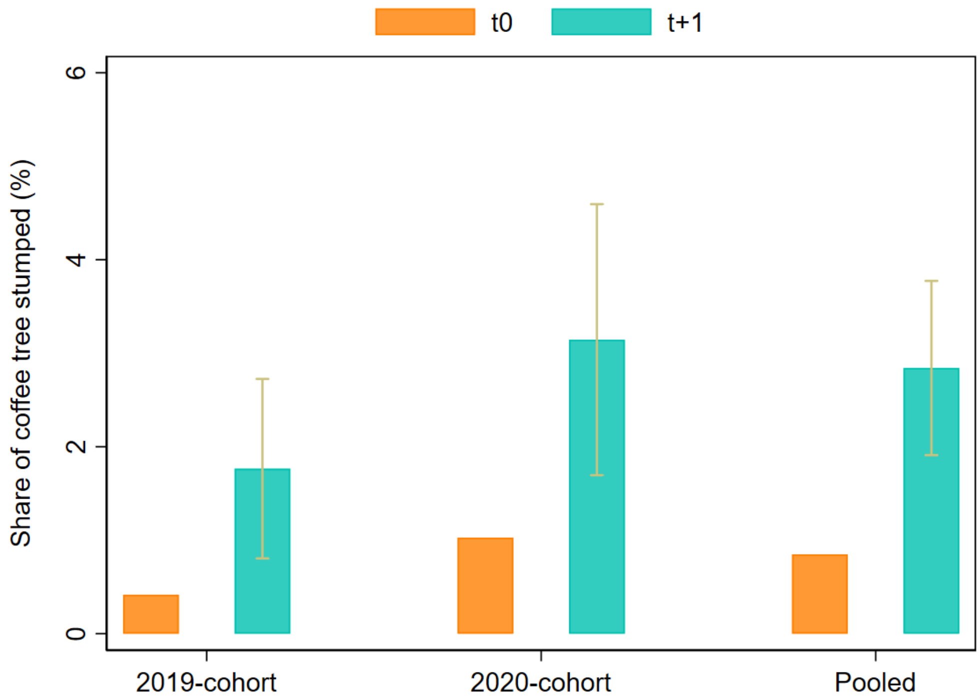
Figure 6. Estimates of treatment effects on number of stumped coffee trees, by cohort



Note: See Table A1 in the appendix for the detailed results. t+1=after the training (regression coefficients from the difference-in-difference estimation) and t0= before the training (outcome for training participants before the training). Capped bars are 95% confidence intervals.
Source: Authors' calculation based on 2019 and 2020 coffee agronomy baseline and follow-up survey data.

Similarly, training participants stumped a relatively large share of their coffee trees after the training—i.e., about 3 percentage points increase on share of stumped coffee trees after the training (Figure 7). Again, with only about 1 percent of the coffee trees stumped before the training (a very low base), the impact of the training on the share of stumped coffee trees represents a threefold increase after the training.

Figure 7. Estimates of treatment effects on share of stumped coffee trees, by cohort



Note: See Table A1 in the appendix for the detailed results. t+1=after the training (regression coefficients from the difference-in-difference estimation) and t0= before the training (outcome for training participants before the training). Capped bars are 95% confidence intervals.
Source: Authors' calculation based on 2019 and 2020 coffee agronomy baseline and follow-up survey data.

Overall, the relative increase on intensity of stumping is large, but very marginal in absolute terms. While the program recommended that farmers stump 20 percent of their older/unproductive trees, farmers who adopted the practice stumped a much smaller share. It could be the case that farmers want to learn about the yield gain of stumping through experimentation before scaling up to a larger share of coffee trees. The production loss could be also at play since stumping means that coffee trees become unproductive for 2 years. Accordingly, compensation of lost income may further increase farmers' willingness to stump more trees (e.g., a pilot Cash for Stumping (CFS) intervention show a promising result in the same study area).

Robustness check

As indicated above, we further check the robustness of the estimates using a semiparametric difference-in-difference (SDID) estimator. One of the main assumptions in the simple difference-in-difference estimator is that, in the absence of the training, outcomes of interest followed the same trend in training participants and non-participants groups. This assumption may not be plausible if selection for treatment is associated with observable household and plot characteristics that affect the state of outcome variables. The SDID estimator addresses potential imbalance of these observable characteristics between the treated and comparison groups (Abadie, 2005)

The results from the SDID estimates show similar evidence that participation in the rejuvenation training led to a statistically significant increase in the adoption rate and intensity of stumping (Table 3). The magnitudes of impact are also comparable with the main results in Figures 5 - 7 (i.e., about threefold increase in adoption rates and intensity of stumping after the training intervention).

Table 3. Estimates of treatment effect on adoption and intensity of coffee stumping by cohort: semiparametric difference-in-differences (SDID)

	2019-cohort	2020-cohort	Pooled
Stumping uptake (yes=1)	0.20***	0.17***	0.18***
	(0 .03)	(0.03)	(0.02)
Number of coffee tree stumped	7.82***	5.87***	6.27***
	(1.68)	(1.35)	(1.01)
Share of coffee tree stumped (%)	1.88***	3.44***	2.82***
	(0.52)	(0.73)	(0.51)
Obs.	782	955	1737

Note: The estimates account for household, plot, and location characteristics. Household characteristics include age and gender of the head of the household, household size, household head education, household membership in cooperatives, livestock ownership, asset index (measured using principal component analysis). Plot characteristics include age of coffee tree, farm size, number of coffee trees, and number of coffee fields/plots. Location characteristics include distance to mill, distance to all weather road, distance to woreda capital, and distance to coffee fields/plots. *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculation based on 2019 and 2020 coffee agronomy baseline and follow-up survey data.

Results from our alternative identification strategy are provided in Table A4 and show similar effects. Accordingly, stumping adoption rate of 2019-cohort training participants at time t+1 is 15 percentage point higher than their 2020-cohort counterpart at time t0. Given that the stumping adoption rate of 2020-cohort training participants at t0 is 6 percent, the effect of the training on adoption of stumping for 2019-cohort represent a more than twofold increase. We also find comparable results on intensity of stumping as measured by the number of coffee trees stumped (Table A4).

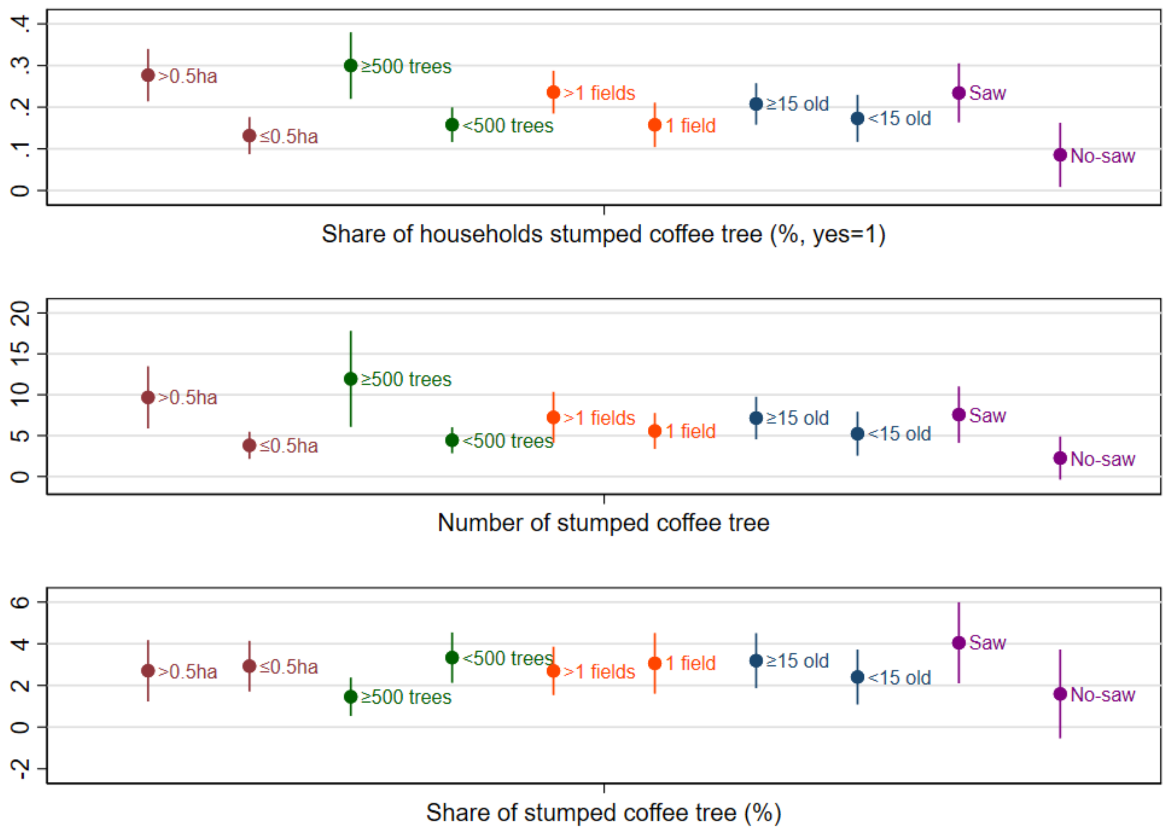
Impact heterogeneity

The impact of the training on adoption rate and intensity of stumping could vary by plot and household characteristics since adoption decisions can be affected by the condition of the coffee plot and/or households' ability to implement the practices. To explore this possibility, we conduct a sub-sample analysis for a selected number of plot and household level characteristics that could presumably affect adoption rate and intensity. These variables include number of coffee trees, number of coffee fields, age of coffee trees, and access to a stumping saw (Figure 8).

Overall, the results show a substantial impact heterogeneity across these plot- and household-level characteristics (see Table A6 in the appendix for detailed results including tests for equality of coefficients). For instance, the impact of training on adoption rate and intensity of stumping increases with the number of coffee trees. Training participants with 500 coffee trees or more, are twice more likely to adopt stumping ($p<0.001$). Similarly, training participants with 500 or more coffee trees stumped more than twice as many coffee trees than their counterpart ($p<0.014$). The share of stumped coffee trees is however higher for training participants with less than 500 coffee trees ($p<0.015$). The impact heterogeneity results by total farm size are comparable with that of number of coffee trees: training participants with >0.5ha of farmland are twice more likely to adopt stumping ($p<0.000$) and stumped more than twice as many coffee trees compared to training participants with ≤0.5ha of farmland ($p<0.005$).

A higher adoption rate by relatively large coffee farmers (as measured by farm size and number of coffee trees) is plausible since adoption entails some setup costs in terms of learning and implementation. Moreover, size of farm or number of coffee trees is a surrogate variable for a number of important factors that can potentially affect adoption such as access to information, capacity to bear risk, and access to complementary/necessary inputs.

Figure 8. Estimates of treatment effects heterogeneity (adoption and intensity), pooled sample



Note: *Note*: See Table A6 in the appendix for the detailed results. The subsample analysis is conducted by total farm size (maroon), number of coffee trees (dark green), number of coffee fields (orange red), age of coffee trees (navy), and access to stumping saw (purple). The circle dotes are regression coefficients from the difference-in-difference estimations and bars are 95% confidence intervals. The estimates account for household, plot, and location characteristics. The results on access to saw are based on the 2020-cohort sample only, since this variable were not part of the 2019-cohort survey.
Source: Authors' calculation based on 2019 and 2020 coffee agronomy baseline and follow-up survey data.

While similar patterns of impact heterogeneities are observed by number of coffee plots and age of coffee trees, the difference in magnitude is relatively modest and not statistically distinguishable from zero. On the other hand, the results show significant impact variations by sample households' access to a stumping saw. Training participants with access to a stumping saw are 15 percentage point more likely to adopt stumping than their counterpart ($p<0.004$). Likewise, Training participants with access to a stumping saw stumped an average 5 more coffee trees ($p<0.015$) and 2.5 percent more coffee trees ($p<0.090$) compared to training participants with no access to a stumping saw.

6. Conclusions

This study evaluates the short-term (immediate) impact of the Coffee Farm College's first rejuvenation training on adoption rate and intensity of stumping in Sidama zone, Ethiopia. The rejuvenation training aims at revitalizing low-yielding aged coffee trees, which is a main constraint in Ethiopia for coffee trees in attaining its full yield potential. This particular training mainly promotes stumping, a practice that entails properly cutting of old and unproductive coffee trees at its base for a complete renewal which will result in an increase in the quantity and quality of coffee harvests after a two-year period.

The unique feature of the Coffee Farm College agronomy program is that it is held in small groups at focal farmer (development) group level to facilitate and ensure active participation of smallholder coffee farmers. Moreover, training sessions are held at demonstration plot that are owned by a member of the focal farmer group to facilitate learning-by-doing and to serve as a demo plot where farmers can see first-hand the results of properly implemented best agronomic and farm management practices on the health of the coffee plants and its productivity.

Using detailed household and plot (field) level data collected before and after the first rejuvenation training and a difference-in-difference estimation approach, we find that participation in the rejuvenation training had a positive and statistically significant effect on both adoption rate and intensity of stumping. Specifically, we find that the training increased the adoption rate and intensity of stumping by 19 and 3 percentage points, respectively. Given the low adoption rates of stumping at baseline, these impacts represent close to a threefold increase in the rates and intensity of adoption after the training intervention.

The study also explores possible impact heterogeneity by key plot and household characteristics through sub-sample analysis and find that the magnitude of the training impact on adoption rate and intensity of stumping significantly increases with farm size, number of coffee trees, and access to a stumping saw. Overall, the results provide robust evidence that participation in the rejuvenation training has led to a significant increase in the adoption rate and intensity of stumping. This finding has important practical and policy implications given that most coffee trees in Ethiopia are reportedly old and rejuvenating ageing and unproductive coffee trees markedly improve the plant health and its productivity sustainably.

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Annex: Supplementary tables

Table A1. Estimates of treatment effects on adoption of stumping, by cohort

	Stumping adoption (yes=1)					
	2019-cohort		2020-cohort		Pooled	
Training participant (yes=1)	-0.013	-0.017	-0.005	-0.023	0.000	-0.020*
	(0.014)	(0.015)	(0.016)	(0.017)	(0.011)	(0.012)
Round (follow up=1)	-0.002	-0.002	0.019	0.019	0.007	0.007
	(0.011)	(0.011)	(0.018)	(0.018)	(0.010)	(0.010)
Training x round	0.206***	0.206***	0.180***	0.180***	0.194***	0.194***
	(0.029)	(0.029)	(0.027)	(0.027)	(0.019)	(0.019)
log(age of household head)		0.035		0.016		0.020
		(0.030)		(0.032)		(0.022)
Gender of head (female=1)		0.007		-0.027		-0.016
		(0.022)		(0.021)		(0.015)
log(household size)		-0.004		0.020		0.011
		(0.022)		(0.025)		(0.017)
Head attended elementary edu.		0.044**		0.021		0.026**
		(0.018)		(0.018)		(0.013)
Head attended secondary edu.		0.030		0.025		0.022
		(0.024)		(0.025)		(0.017)
Membership in coop (yes=1)		0.024		0.020		0.020*
		(0.015)		(0.019)		(0.012)
Livestock ownership (TLU)		0.005		-0.004		0.000
		(0.007)		(0.005)		(0.004)
Asset index (PCA)		-0.006		-0.009*		-0.009***
		(0.005)		(0.005)		(0.003)
log(farm size)		0.068*		0.106***		0.086***
		(0.041)		(0.036)		(0.027)
Number of coffee trees		-0.012		-0.004		-0.008
		(0.009)		(0.012)		(0.007)
log(number of coffee trees)		0.001		0.016**		0.010**
		(0.007)		(0.007)		(0.005)
log(age of trees in years)		0.002		0.012		0.011
		(0.012)		(0.010)		(0.008)
log(distance to coffee wet mill)		0.001		0.013		0.007
		(0.008)		(0.011)		(0.006)
log(distance to all weather road)		-0.002		-0.001		-0.003
		(0.009)		(0.009)		(0.006)
log(distance to woreda capital)		-0.014*		0.007		-0.006
		(0.008)		(0.012)		(0.007)
log(distance to coffee plots)		-0.010		0.007		-0.002
		(0.012)		(0.013)		(0.009)
Cohort (2020=1)						0.054***
						(0.013)
Constant	0.041***	-0.096	0.066***	-0.261**	0.051***	-0.196**
	(0.009)	(0.108)	(0.013)	(0.126)	(0.007)	(0.084)
Number of observations	1,554	1,554	1,910	1,910	3,464	3,464
R2	0.079	0.097	0.071	0.091	0.079	0.096
Adjusted R2	0.077	0.085	0.069	0.081	0.079	0.091

Note: *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculation based on 2019 and 2020 coffee agronomy baseline and follow-up survey data.

Table A2. Estimates of treatment effects on number of coffee trees stumped, by cohort

	Number of coffee trees stumped					
	2019-cohort		2020-cohort		Pooled	
Training participant (yes=1)	-0.738	-1.052	0.840	-0.271	0.341	-0.532
	(0.769)	(0.870)	(0.845)	(0.823)	(0.642)	(0.622)
Round (follow up=1)	-1.092*	-1.092*	-0.288	-0.288	-0.766*	-0.766*
	(0.652)	(0.655)	(0.586)	(0.588)	(0.454)	(0.455)
Training x round	7.292***	7.292***	5.613***	5.613***	6.347***	6.347***
	(1.527)	(1.535)	(1.212)	(1.217)	(0.965)	(0.968)
log(age of household head)		1.350		0.539		0.683
		(1.419)		(1.260)		(0.943)
Gender of head (female=1)		0.321		-0.241		-0.090
		(0.796)		(0.663)		(0.496)
log(household size)		-0.025		0.376		0.397
		(0.932)		(0.962)		(0.681)
Head attended elementary edu.		2.207***		0.526		1.042**
		(0.609)		(0.678)		(0.491)
Head attended secondary edu.		0.709		0.041		0.046
		(0.813)		(1.200)		(0.740)
Membership in coop (yes=1)		0.283		0.775		0.441
		(0.568)		(0.934)		(0.538)
Livestock ownership (TLU)		-0.174		0.052		-0.027
		(0.184)		(0.273)		(0.176)
Asset index (PCA)		0.156		-0.223		-0.111
		(0.205)		(0.172)		(0.135)
log(farm size)		1.263		4.499***		2.940***
		(1.318)		(1.617)		(1.061)
Number of coffee trees		-0.295		0.228		-0.044
		(0.541)		(0.453)		(0.342)
log(number of coffee trees)		0.637**		1.603***		1.197***
		(0.296)		(0.372)		(0.250)
log(age of trees in years)		0.812		0.704**		0.795***
		(0.542)		(0.317)		(0.278)
log(distance to coffee wet mill)		-0.256		0.139		0.028
		(0.361)		(0.432)		(0.277)
log(distance to all weather road)		0.430		0.070		0.192
		(0.385)		(0.488)		(0.329)
log(distance to woreda capital)		-0.061		0.661		0.153
		(0.298)		(0.466)		(0.247)
log(distance to coffee plots)		-0.893		0.405		-0.292
		(0.567)		(0.726)		(0.439)
Cohort (2020=1)						1.955***
						(0.594)
Constant	1.656***	-9.206*	1.536***	-16.788***	1.607***	-13.554***
	(0.584)	(5.477)	(0.509)	(4.993)	(0.403)	(3.826)
Number of observations	1,554	1,554	1,910	1,910	3,464	3,464
R2	0.032	0.051	0.033	0.068	0.035	0.058
Adjusted R2	0.031	0.039	0.031	0.059	0.034	0.052

Note: *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculation based on 2019 and 2020 coffee agronomy baseline and follow-up survey data.

Table A3. Estimates of treatment effects on share of coffee trees stumped, by cohort

	Share of coffee trees stumped (%)					
	2019-cohort		2020-cohort		Pooled	
Training participant (yes=1)	-0.125	-0.080	-0.115	0.097	0.063	-0.115
	(0.288)	(0.307)	(0.438)	(0.482)	(0.255)	(0.273)
Round (follow up=1)	-0.299	-0.299	0.038	0.038	-0.162	-0.162
	(0.183)	(0.184)	(0.476)	(0.478)	(0.222)	(0.222)
Training x round	1.765***	1.765***	3.145***	3.145***	2.842***	2.842***
	(0.487)	(0.490)	(0.736)	(0.739)	(0.474)	(0.476)
log(age of household head)		0.725		0.427		0.507
		(0.552)		(0.832)		(0.535)
Gender of head (female=1)		-0.052		0.930		0.533
		(0.296)		(0.966)		(0.585)
log(household size)		-0.345		0.275		0.071
		(0.333)		(0.639)		(0.376)
Head attended elementary edu.		0.869***		0.153		0.434
		(0.293)		(0.471)		(0.318)
Head attended secondary edu.		0.519*		0.635		0.505
		(0.293)		(0.631)		(0.373)
Membership in coop (yes=1)		0.181		0.700		0.392
		(0.189)		(0.556)		(0.280)
Livestock ownership (TLU)		-0.066		0.061		0.012
		(0.057)		(0.135)		(0.080)
Asset index (PCA)		0.003		-0.184		-0.103
		(0.044)		(0.122)		(0.063)
log(farm size)		0.023		2.658**		1.577**
		(0.422)		(1.149)		(0.674)
Number of coffee trees		-0.199**		-0.239		-0.175
		(0.100)		(0.256)		(0.135)
log(number of coffee trees)		-0.171*		-0.707***		-0.500***
		(0.103)		(0.208)		(0.136)
log(age of trees in years)		0.305*		0.343		0.346**
		(0.176)		(0.208)		(0.154)
log(distance to coffee wet mill)		-0.020		0.107		0.069
		(0.138)		(0.336)		(0.169)
log(distance to all weather road)		-0.037		-0.185		-0.101
		(0.109)		(0.256)		(0.149)
log(distance to woreda capital)		-0.107		0.210		-0.027
		(0.102)		(0.282)		(0.117)
log(distance to coffee plots)		-0.038		0.244		0.114
		(0.113)		(0.378)		(0.192)
Cohort (2020=1)						0.995***
						(0.250)
Constant	0.542***	-1.214	1.143***	-1.076	0.786***	-1.206
	(0.164)	(1.903)	(0.368)	(3.282)	(0.179)	(2.018)
Number of observations	1,554	1,554	1,910	1,910	3,464	3,464
R2	0.021	0.039	0.028	0.044	0.030	0.046
Adjusted R2	0.019	0.027	0.026	0.034	0.029	0.040

Note: *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculation based on 2019 and 2020 coffee agronomy baseline and follow-up survey data.

Table A4. Estimates of treatment effects on adoption and intensity of stumping, 2019 *training participants* at t+1 (after training) vs. 2020 cohort *training participants* at t0 (before training)

	Stumping adoption (yes=1)		Number of stumped coffee trees		Share of stumped coffee trees (%)	
Training participant (yes=1)	0.172***	0.152***	4.743***	3.445*	0.855*	0.609
	(0.029)	(0.033)	(1.458)	(1.827)	(0.466)	(0.570)
log(age of household head)		0.060		0.090		-0.274
		(0.047)		(2.336)		(0.960)
Gender of head (female=1)		-0.041		-1.640*		-0.978***
		(0.029)		(0.865)		(0.320)
log(household size)		-0.030		-0.842		-0.682
		(0.037)		(1.849)		(0.616)
Head attended elementary edu.		0.026		1.654		0.629
		(0.027)		(1.314)		(0.513)
Head attended secondary edu.		-0.012		-3.111*		-0.367
		(0.037)		(1.729)		(0.672)
Membership in coop (yes=1)		0.043		-0.075		0.662
		(0.028)		(1.568)		(0.667)
Livestock ownership (TLU)		0.002		-0.022		0.004
		(0.007)		(0.321)		(0.108)
Asset index (PCA)		-0.004		0.050		-0.032
		(0.008)		(0.365)		(0.126)
log(farm size)		0.120**		5.792***		1.620**
		(0.048)		(1.900)		(0.759)
Number of coffee trees		-0.006		0.781		-0.411
		(0.015)		(1.041)		(0.276)
log(number of coffee trees)		0.004		1.398**		-0.240
		(0.010)		(0.613)		(0.193)
log(age of trees in years)		0.002		0.615		0.213
		(0.016)		(0.680)		(0.216)
log(distance to coffee wet mill)		-0.009		-0.014		0.008
		(0.017)		(0.633)		(0.281)
log(distance to all weather road)		0.018		-0.075		-0.069
		(0.012)		(0.979)		(0.264)
log(distance to woreda capital)		-0.010		-0.291		-0.129
		(0.016)		(0.683)		(0.296)
log(distance to coffee plots)		-0.014		-0.569		0.135
		(0.018)		(1.463)		(0.313)
Constant	0.061***	-0.161	2.376***	-7.722	1.028***	3.875
	(0.010)	(0.181)	(0.675)	(8.774)	(0.238)	(3.765)
Number of observations	836	836	836	836	836	836
R2	0.062	0.092	0.015	0.052	0.004	0.021
Adjusted R2	0.061	0.073	0.014	0.032	0.003	0.001

Note: *** p<0.01, ** p<0.05, * p<0.1.
Source: Authors' calculation based on 2019 and 2020 coffee agronomy baseline and follow-up survey data.

Table A5. Estimates of treatment effects on adoption and intensity of stumping, pooled and full (unmatched) sample

	Stumping adoption (yes=1)		Number of stumped coffee trees		Share of stumped coffee trees (%)	
Training participant (yes=1)	0.000	-0.020*	0.351	-0.531	0.068	-0.114
	(0.011)	(0.012)	(0.639)	(0.621)	(0.254)	(0.273)
Round (follow up=1)	0.007	0.007	-0.759*	-0.761*	-0.161	-0.161
	(0.010)	(0.010)	(0.450)	(0.453)	(0.220)	(0.221)
Training x round	0.194***	0.194***	6.327***	6.343***	2.834***	2.841***
	(0.019)	(0.019)	(0.962)	(0.966)	(0.473)	(0.475)
log(age of household head)		0.020		0.704		0.489
		(0.022)		(0.939)		(0.533)
Gender of head (female=1)		-0.016		-0.048		0.498
		(0.015)		(0.488)		(0.575)
log(household size)		0.010		0.390		0.076
		(0.017)		(0.675)		(0.374)
Head attended elementary edu.		0.026**		1.034**		0.442
		(0.013)		(0.491)		(0.317)
Head attended secondary edu.		0.022		0.043		0.508
		(0.017)		(0.740)		(0.373)
Membership in coop (yes=1)		0.020*		0.437		0.394
		(0.012)		(0.536)		(0.280)
Livestock ownership (TLU)		0.000		-0.028		0.013
		(0.004)		(0.175)		(0.080)
Asset index (PCA)		-0.009***		-0.111		-0.103
		(0.003)		(0.135)		(0.063)
log(farm size)		0.086***		2.941***		1.576**
		(0.027)		(1.060)		(0.674)
Number of coffee trees		-0.008		-0.041		-0.178
		(0.007)		(0.341)		(0.135)
log(number of coffee trees)		0.010**		1.189***		-0.494***
		(0.005)		(0.249)		(0.134)
log(age of trees in years)		0.011		0.799***		0.343**
		(0.008)		(0.278)		(0.153)
log(distance to coffee wet mill)		0.007		0.035		0.063
		(0.006)		(0.276)		(0.168)
log(distance to all weather road)		-0.003		0.187		-0.098
		(0.006)		(0.329)		(0.148)
log(distance to woreda capital)		-0.006		0.151		-0.025
		(0.007)		(0.246)		(0.116)
log(distance to coffee plots)		-0.002		-0.296		0.116
		(0.009)		(0.438)		(0.192)
Cohort (2020=1)		0.054***		1.936***		1.010***
		(0.013)		(0.590)		(0.250)
Constant	0.051***	-0.196**	1.593***	-13.581***	0.779***	-1.184
	(0.007)	(0.084)	(0.400)	(3.824)	(0.177)	(2.016)
Number of observations	3,484	3,474	3,484	3,474	3,484	3,474
R2	0.079	0.097	0.035	0.058	0.030	0.046
Adjusted R2	0.079	0.092	0.034	0.052	0.029	0.040

Note: *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors' calculation based on 2019 and 2020 coffee agronomy baseline and follow-up survey data.

Table A6. Estimates of treatment effects heterogeneity on adoption and intensity of stumping, pooled sample

Sub-samples	Obs.	Share of household adopted stumping (%, yes=1)	Number of stumped coffee trees	Share of stumped coffee trees (%)
Total farm size				
>0.5ha	1424	0.277***	9.676***	2.704***
		(0.032)	(1.938)	(0.751)
≤0.5ha trees	2040	0.132***	3.807***	2.924***
		(0.023)	(0.849)	(0.620)
chi2(1)		*13.84*	*7.80*	*0.05*
Prob > chi2		*[0.000]*	*[0.005]*	*[0.819]*
Number of coffee trees				
≥500 trees	842	0.300***	11.938***	1.458***
		(0.041)	(2.990)	(0.469)
<500 trees	2622	0.158***	4.428***	3.333***
		(0.021)	(0.810)	(0.616)
chi2(1)		*9.79*	*6.02*	*5.95*
Prob > chi2		*[0.001]*	*[0.014]*	*[0.015]*
Number of coffee fields				
>1 coffee fields	1614	0.236***	7.229***	2.695***
		(0.026)	(1.586)	(0.592)
1 coffee field	1850	0.158***	5.570***	3.059***
		(0.027)	(1.122)	(0.745)
chi2(1)		*4.37*	*0.74*	*0.15*
Prob > chi2		*[0.036]*	*[0.390]*	*[0.699]*
Age of coffee trees				
≥15 years old	2080	0.208***	7.145***	3.188***
		(0.025)	(1.325)	(0.674)
<15 years old	1384	0.173***	5.231***	2.403***
		(0.029)	(1.372)	(0.672)
chi2(1)		*0.82*	*1.02*	*0.69*
Prob > chi2		*[0.365]*	*[0.312]*	*[0.406]*
Access to stumping saw				
Yes	1194	0.234***	7.564***	4.046***
		(0.036)	(1.756)	(0.990)
No	716	0.086**	2.247*	1.592
		(0.039)	(1.339)	(1.084)
chi2(1)		*7.98*	*5.92*	*2.86*
Prob > chi2		*[0.004]*	*[0.015]*	*[0.090]*

Note: The estimates account for household, plot, and location characteristics. Household characteristics include age and gender of the head of the household, household size, household head education, household membership in cooperatives, livestock ownership, asset index (measured using principal component analysis). Plot characteristics include age of coffee tree, farm size, number of coffee trees, and number of coffee fields/plots. Location characteristics include distance to mill, distance to all weather road, distance to woreda capital, and distance to coffee fields/plots. The results on access to saw are based on the 2020-cohort sample only, since this variable were not included in the 2019-cohort survey. *** p<0.01, ** p<0.05, * p<0.1.

Source: Authors' calculation based on 2019 and 2020 coffee agronomy baseline and follow-up survey data.

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