

The impact of coffee rehabilitation on the productivity and income of smallholder farmers in Ethiopia

Study design

Submitted to
HereWeGrow

Research Team¹

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1. Introduction

Background

Coffee remains Ethiopia's most important export crop and a primary source of livelihood for millions of smallholder farmers. While total coffee production and cultivation area have increased over the past decade, productivity remains low and shows a long-term declining trend. This is largely due to aging coffee trees and insufficient renovation and rejuvenation practices among smallholder farmers. According to recent World Bank (2021) estimates, 80 percent of Ethiopia's coffee trees require rejuvenation and renovation and are producing suboptimal yields. Limited knowledge of effective agronomic practices and poor access to inputs further compound the problem. This persistent low productivity directly threatens the livelihoods of millions of smallholder coffee farmers and others along the value chain. Indirectly, it also contributes to Ethiopia's chronic foreign exchange shortage, given coffee's role as a leading export commodity—ultimately putting the country's growth prospects at risk.

In response, development partners (e.g., TechnoServe and the Hans R. Neumann Foundation), in collaboration with the government, private sector, and philanthropic actors (e.g., HereWeGrow), have launched large-scale agronomy programs promoting regenerative practices to improve coffee yields. These programs encourage the adoption of proven techniques such as rejuvenation (stumping), renovation (replanting), plant nutrition and health, shade management, weeding, and erosion control—delivered through participatory, experiential learning approach. To date, they have reached hundreds of thousands of coffee-farming households across Ethiopia's major coffee-producing zones.

Evidence on adoption is promising. For instance, impact studies of TechnoServe's Coffee Farm College – conducted by IFPRI and Laterite in Sidama and Jimma – show improved farmer knowledge and adoption of key regenerative practices, especially rejuvenation. However, the impact of these programs on core outcomes such as yield and income has not yet been rigorously assessed. This is partly because it takes several years for stumped trees to return to full productivity.² Existing yield data come either from demonstration plots or from early-stage harvests – typically within two to three years of stumping – before trees have fully matured. The evidence on the dynamic effects of rejuvenation on yield levels over the years after stumping is also limited. Consequently, despite the significant investments in

² Existing studies on coffee yield have focused on understanding the effects of planting density (Nigussie et al. 2017), spacing (Kufa et al. 2001), intercropping (Mekonnen et al. 2020), shade (Bote and Struik 2011), weed management (Daba et al. 2023) on coffee production and productivity.

promoting rejuvenation and renovation, considerable uncertainty remains about its true impact on coffee yields.

Objective and research questions

The proposed study aims to rigorously assess the impact of coffee rehabilitation – specifically rejuvenation/stumping – on coffee yield and income, with the goal of informing future policy and investment decisions. While the primary focus is on rejuvenation, the study will also make an attempt to assess the yield performance of newly planted coffee trees (an alternative rehabilitation approach practiced by farmers to fully renovate their coffee farms), if they are present on the same plots visited for the rejuvenation analysis. Specifically, it will explore the following research questions, focusing on yield impacts and cost-effectiveness:

- **Yield impacts**

- Does rejuvenation (stumping) meaningfully increase coffee yield? [If data allow, how do yields of newly planted (renovated) trees compare to unstumped trees?]
- How do yield effects evolve over time?
- How do these effects vary by rehabilitation method (stumping vs. replanting) and production system (garden vs. semi-forest/forest)?³

- **Cost-effectiveness**

- What is the cost-effectiveness of stumping? [If data allows, how does the cost-effectiveness of replanting compare?]
- How many years does it take for farmers to break even on rejuvenation [and renovation] investments, accounting for the initial loss of income during the recovery/growing period?
- Is the yield gain from rejuvenation [and renovation] sufficient to improve farmers' income after accounting for implementation costs (e.g., labor, seedling, yield loss during the recovery/growing period)?
- What is the plot-level profitability of stumping [and replanting]?

In addition, the study will conduct a back-of-the-envelope analysis to estimate the potential implications of widespread adoption of rejuvenation [and renovation] practices on national coffee production and export earnings.

³ The comparison between stumping vs. replanting will be conducted if the data allow (i.e., if there are newly planted trees on the same plots visited for the rejuvenation analysis).

2. Methodology

Sampling approach

Study locations

The study will leverage earlier cohorts of farmers who were exposed to HereWeGrow-funded interventions promoting stumping in Ethiopia’s Sidama region and Jimma zone (see Table 1 for a full list of study cohorts, location, number of districts and sample size and stumping rates at endline). These sites span diverse coffee-growing areas with varying production systems, offering a strong basis for external validity and relevance to policymaking across Ethiopia’s coffee sector.

Table 1. Study sites

TNS/HWG cohorts	Location	Number of woredas	Sample size (endline)	Stumping rate (endline)
Cohort 2019	Sidama	2	893	28%
Cohort 2020	Sidama	3*	932	47%
Cohort 2022	Jimma	1	930	38%
Cohort 2023	Jimma	3	2160	NA

Note: *Excluding Dale woreda which was also part of the Sidama 2019 cohort. NA = Not Available (the endline for Cohort 2023 is planned in April-May 2026 and the sample size indicated in column 4 is from baseline). The study will also include other TechnoServe cohorts in Sidama and Jimma that are implemented with support from donors other than HereWeGrow.

The research team will revisit a subset of households within these cohorts, focusing on those that have stumped existing coffee trees. The primary objective of the planned yield surveys is to compare the productivity of stumped and unstumped trees. If feasible, newly planted trees will also be included in the sample.

Sampling strategy and statistical power

We propose a two-stage sampling strategy. First, we will identify households that have engaged in coffee rejuvenation activities within a specified time frame. These households will be identified through program records or alternatively through community informants. Second, from each household, we will sample a sufficient number of coffee trees from each relevant category (unstumped and stumped) on the same plot. As we discuss below, this within-plot design provides strong control over confounding plot-level characteristics.

To analyze the dynamic effects of stumping (i.e., to understand how yield effects change as a function of time since stumping occurred), we will stratify the sample by stumping year. In

each plot, we will include both stumped and unstumped trees, and we aim to obtain an equal number of plots with trees stumped in each calendar year from 2019 to 2023, five calendar years in total.

Our target is to achieve 80% power to detect these yield differences at the 5% significance level. Our planned sample involves 100 plots for each stumping year between 2019 and 2023. Each plot will contain both stumped and unstumped trees. From each plot, we will randomly select five stumped and five unstumped trees, yielding a total of 500 observations (trees) per group and 1,000 (trees) observations overall per stumping year⁴. Because the treatment comparison occurs within the same plot, the design allows for tight control of plot-level characteristics that might otherwise confound yield estimates.

Power calculations are based on prior yield data from a study by Laterite and IFPRI in Sidama (2019), in which farmers were asked to self-report the number of coffee trees and coffee production on their main coffee plot. From that data, we estimate an average yield among non-stumped trees of 1.08 kg/tree and a standard deviation (SD) of 0.88 kg/tree. In the absence of precise intra-class correlation coefficient (ICC) estimates, we use a conservative value of 0.3 for the ICC, reflecting a high level of correlation in tree-level yields within the same plot.

To account for intra-plot correlation in our power calculations, we inflate the standard deviation to 1.3 kg/tree based on the corresponding design effect.⁵ Using this adjusted value, we ran a two-sample power calculation with 500 observations per group (or trees per plot), a control mean of 1.08 kg/tree, adjusted SD = 1.3 kg/tree and 80% power at the 5% significance level.⁶ The analysis showed that the study is powered to detect a minimum yield difference of 0.23 kg/tree, which is one-fourth of the yield difference estimated in Laterite (2023). Given that the Laterite study estimated a substantially larger yield effect, our study is likely to be well-powered to detect yield impacts of practical and policy relevance within

⁴ The protocol for the selection of stumped and unstumped coffee trees will be described in the pre-analysis plan after close consultation with a coffee agronomist from EIAR and reviewing previous experiences (e.g., the yield pilot study by Laterite).

⁵ The adjusted standard deviation accounts for the design effect using the formula: $DEFF = 1 + (m - 1) \times \rho$, where $m = 5$ is the number of stumped trees per plot and $\rho = 0.30$ is the estimated intra-class correlation coefficient (ICC). This yields $DEFF = 1 + 4 \times 0.3 = 2.2$. The adjusted standard deviation is then calculated as: $0.88 \times \sqrt{2.2} \approx 1.3$. This is likely an overestimate of the true residual variation in yield, since the analysis will include plot fixed effects, which absorb all time-invariant plot-level heterogeneity and substantially reduce the residual variance of the outcome.

⁶ The corresponding Stata command to estimate the minimum detectable effect size is *power twomeans 1.08, sd(1.3) n1(500) n2(500) power(0.8) alpha(0.05)*.

each stumping year, while also allowing for heterogeneity analyses if needed.⁷ Moreover, the power calculations are based on self-reported yield data, which likely has substantially higher variance than measured yields. With more precise tree-level measurements, the actual minimum detectable effect (MDE) could be meaningfully smaller than 0.23 kg per tree. This suggests that the study is likely to be well powered to detect even smaller yield impacts.

Table 2. Calendar year specific power calculations based on Sidama 2019 yield data⁸

Parameter	Value
Unit of analysis	Tree
Clustering level	Plot
Significance level	5%
Power	80%
Observations per plot	10 (5 stumped, 5 unstumped)
Number of plots	100
Total sample size	1,000 trees (500 per group)
Control group mean	1.08 kg/tree
Adjusted standard deviation *	1.30 kg/tree
Intra-class correlation (ICC)	0.3 (assumed)
Minimum detectable effect (MDE)	0.23 kg/tree

*Note: * The adjusted standard deviation incorporates the design effect to account for intra-plot correlation.*

Across the five planned stumping years (2019, 2020, 2021, 2022, 2023), the study will cover a total of 500 plots – each contributing 10 observations (5 stumped and 5 unstumped trees) – resulting in a combined sample of 5,000 trees (2,500 per zone).

Selection of study plots

Before the yield survey, we will conduct a listing exercise in the study areas to identify eligible coffee plots. The initial listing will be based on TechnoServe’s farmer rosters (if access is granted). As these rosters may include thousands of farmers per woreda, we will randomly

⁷ Potential dimensions for heterogeneity analyses include coffee production system (e.g., garden vs. semi-forest), area (Sidama versus Jimma), tree age at time of stumping, farmer characteristics (such as education or access to extension services).

⁸ Coffee yields are relatively low in Jimma, and we will be able to detect a much smaller effect than 0.23 kg/tree. For instance, based on JCP 2022 cohort baseline data we estimate an average yield among non-stumped trees of 0.45 kg/tree and a standard deviation (SD) of 0.44 kg/tree (0.65 kg/tree with adjustment for design effect). The power analysis following the same parameters (a conservative value of 0.3 for ICC and 80% power at the 5% significance level) showed that the study is powered to detect a minimum yield difference of 0.11 kg/tree in Jimma.

select a subset (e.g., 1,000 farmers per cohort) from those who stumped coffee trees for detailed listing.

The listing form will contain the following questions:

1. Region?
2. Zone?
3. Woreda?
4. Kebele?
5. Farmer's name?
6. Plot name?
7. Does the plot contain both stumped and unstumped trees (at least 10 in each category)?
8. If Q7=yes: in which year(s) was stumping done?
9. Were there any stumped trees that died on this plot? And how many?
10. Are there coffee trees planted since 2019 on the plot?
11. If Q9=yes: in which year(s) were the trees planted?

After compiling the listing data across all study sites, we will randomly select the plots to be included in the study so we will have 100 plots both with stumped and unstumped trees for each calendar year of stumping. To ensure geographic balance, we aim to stratify the sample so that each stumping year includes an equal number of plots from both Jimma and Sidama, provided that there are sufficient eligible plots in each area for each year. We will also draw replacement plots for each year to account for potential ineligibility or non-response during fieldwork.

Outcome measurement

Yield measurement

Accurately measuring the yield of coffee farms/trees is challenging due to several reasons. First, coffee farms/trees are typically harvested 4 – 6 times over the harvest season in 2–3 weeks interval depending on the local altitude and climate conditions that affect the pace of berry ripening. This is because fruits borne on a tree and even on a branch do not uniformly attain harvesting/ripening stage at the same time, and farmers normally harvest cherries individually at peak ripeness, when they turn bright red to maximize the quality of the coffee. Second, coffee farms/trees do not produce the same number of cherries every year due to biennial/alternative bearing, which is commonly observed in Arabica coffee. These two challenges entail that one has to measure coffee harvest multiple times in a season, but also

across production seasons to accurately measure yield levels.⁹ Third, not all coffee farmers precisely know the size of their coffee area and the number of coffee trees, a key variable to accurately estimate yield.

There are several methods for measuring coffee yields, each with its own strengths and limitations in terms of precision and costs. While the easiest and most cost-effective method is asking farmers to estimate yield (pre- or post-harvest), it is prone to recall bias unless it is aided with diaries or cards to record production every time a farmer harvest cherries. A full harvest yield measurement is the most precise, but it can be time consuming and expensive if it is done following the normal harvesting that involves harvesting cherries individually whenever it ripens. Even in the absence of resource constraints, conducting full harvest as the cherries ripen by enumerators can be challenging to organize. Alternatively, one can strip the berries when all the fruits turn to hard green and use a calibrated conversion factor to obtain the yield levels in red cherries or green beans. The full harvest method following stripping of hard green berries is relatively cost effective but may not be as precise as the full harvest of red cherries following the normal harvest calendar, given it does not consider the growth stage of berries (e.g., variability in the maturation process from green to red cherries). Another method is estimating yield based on fruit (berry) counting prior to ripening (hardening) or harvesting (ripening) stages and using a calibrated conversion factor to obtain yield levels in red cherries.

With support from HereWeGrow, we conducted a feasibility assessment of three coffee yield estimation approaches in the 2025 production season—evaluating each for feasibility, rigor, and practicality. The methods tested were: (a) harvesting, counting, and weighing coffee berries from selected sample trees; (b) estimating the number of berries per tree using paired fruit-bearing branches sampled from the upper, middle, and lower canopy layers; and (c) counting the total number of berries on sampled trees without harvesting. The assessment was carried out in two major coffee-producing regions of Ethiopia: Gera and Gumay districts in the Jimma Zone of the Oromia Region, and Dale and Aleta Chuko districts in the Sidama Region.

Findings from this rapid assessment indicate that full harvesting and counting produce the most reliable data but are labor-intensive and time-consuming. Branch sampling, by contrast, generates reasonably accurate estimates—particularly for stumped trees—while

⁹ Stumped trees cut in the same year may synchronize their biennial growth cycles, while unstumped trees of varying ages may be desynchronized. As a result, a single harvest can systematically over- or under-estimate yields for a given cohort, and cross-sectional data may have limitations in separating true growth dynamics from biennial cycle effects. This may influence interpretation of event-study coefficients, particularly for adjacent stumping years (e.g., 2019 vs. 2020).

requiring only a fraction of the time and labor. Full fruit counting without harvesting, although less labor-intensive than full harvest, tends to underestimate yields in older, unstumped trees with complex canopy structures. Considering feasibility, rigor, and practicality, we recommend implementing the full harvest counting method for the main yield study, as it provides a precise fruit count per tree and yields a more accurate production estimate without the sampling errors inherent in alternative approaches. To estimate harvestable yield, we will apply a calibrated conversion factor to translate green berry counts into red cherry weight.

Income measurement

To complement the yield data, we will estimate the financial returns to stumping by combining yield estimates with farmgate coffee prices. Revenue will be calculated as the product of estimated yield (in kilograms of red cherries) and the average local price received by farmers during the harvest season in their locality.

To estimate net income, we will subtract the associated costs of stumping and replanting, including:

- Labor costs (e.g., for stumping, weeding, and composting, etc.),
- Input costs (e.g., tools such as stumping saw, wheelbarrow, etc.),
- The opportunity cost of foregone production, particularly relevant for stumped trees that are out of production for one or more seasons.

Where possible, these costs will be estimated using a combination of farmer self-reports, local wage data, and market prices for inputs.

This will allow us to compute net income trajectories over time and conduct break-even analyses, identifying the number of years required for cumulative revenue gains to offset initial investment costs. We will also calculate cost-effectiveness metrics, such as the cost per additional kilogram of coffee produced or per additional birr of net income, to inform the economic viability of rejuvenation.

Estimation approach

The study will focus primarily on estimating the yield impact of rehabilitation through rejuvenation/stumping. The main comparison will be between stumped and unstumped trees within the same plot, allowing the analysis to control for time-invariant farmer, plot, and tree characteristics. If some plots also contain newly planted (renovated) trees, their yield will be recorded, and – where sample sizes permit – compared to the yields of unstumped trees as an additional analysis.

A simple comparison of yields between stumped or newly planted trees with unstumped trees across households is likely to produce biased estimates, as the decision to stump or replant may be correlated with both farmer characteristics (e.g., skills, motivation, access to labor) and plot characteristics (e.g., soil quality, elevation, shade) that also influence yields. To address these concerns, the study will compare yields within the same plot, using plot-level fixed effects to control for time-invariant farmer and plot attributes. This strategy helps isolate the impact of stumping or replanting from confounding household- or plot-level factors. The remaining source of potential bias stems from the non-random selection of coffee trees (within the same plot) to be stumped or uprooted.

We assume – subject to verification in the survey – that farmers tend to stump or uproot the least productive trees. If this holds, the yield impact estimates derived from within-plot comparisons will be conservative, representing a lower bound of the true effect of stumping or replanting. In other words, any observed yield gains are likely underestimated, since the counterfactual (unstumped trees) is composed of more productive trees to begin with. However, farmers may also select trees for stumping based on accessibility, location within the plot, or proximity to other stumped trees (to manage a section at a time). If stumping decisions correlate with favorable micro-conditions (e.g., more sun, better drainage), the bias could go in the opposite direction. We will explore these hypotheses by directly asking farmers why they chose particular trees for stumping in our survey.

To analyze the dynamic effects of stumping – that is, how yields change with the number of years since stumping – we will use an event-study framework. We will create categorical variables capturing the number of years since stumping and interact these with treatment indicators to trace yield trajectories over time. This approach follows standard event-study methods in policy evaluation and applied econometrics, where variation in treatment timing across units allows for estimation of dynamic effects relative to a baseline group (here: unstumped trees).

The event-study model takes the following form:

$$(1) \quad Yield_{ip} = \sum_{k=0}^K \beta_{1k} (Stumped_{ip} * YearsSinceStumping_{ip}^k) + X'_{ip} \delta + \gamma_p + \epsilon_{ip},$$

where:

$Yield_{ip}$ is the yield (e.g., kg/tree) of tree i on plot p .

$Stumped_{ip}$ is a binary indicator for whether the tree was stumped.

$Stumped_{ip} * YearsSinceStumping_{ip}^k$ is a set of interaction terms indicating whether a tree was stumped k years ago.

X_{ip} is a vector of tree-level characteristics that may influence yield outcomes. These may include the age of the tree, exposure to shade, number of suckers, stem diameter, tree height, and signs of disease or pest damage (e.g., coffee berry disease or leaf rust). Including these covariates helps improve precision and accounts for residual variation in yield that may not be captured by plot fixed effects alone.

γ_p represents plot fixed effects, controlling for time-invariant plot and farmer characteristics.

ϵ_{ip} is the error term.

Unstumped, mature trees will serve as the reference group. The coefficients β_{1k} represent the yield difference between trees stumped k years ago and unstumped trees. Given the assumption that farmers stump the least productive trees, these coefficients are expected to provide lower-bound (conservative) estimates of the true yield effect of stumping.

Pooling the β -estimates, the results will be visualized in a graph, with the vertical axis representing average yield (kg/tree) and the horizontal axis indicating years since stumping. This event-study-style approach will provide a clear, comparative picture of how yields evolve over time under stumping, helping identify when productivity gains begin to materialize and how they evolve as time since stumping elapses.

The standard errors in all analyzes will be clustered at the plot level.

Cost-effectiveness

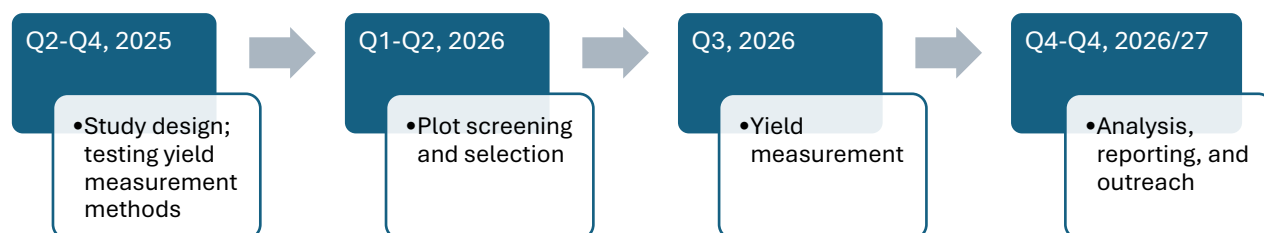
Time-varying yield estimates from the event-study analysis will be converted into monetary values using average farmgate coffee prices. Converting yield into coffee income measures is essential for conducting cost-effectiveness and break-even analyses. By combining estimated income gains over time with detailed cost data – including labor, input use (e.g., seedling), and the opportunity cost of foregone production – we will assess the net financial benefit of stumping.

We will conduct a break-even analysis to determine the year in which cumulative income gains offset the initial costs and temporary yield losses. This will indicate how long farmers must wait to recover their investment.

3. Timeline

As noted above, the study began with a feasibility assessment of candidate yield measurement methods during the 2025 meher harvest, which allowed us to test measurement protocols and refine data collection procedures. The main yield study will be based on data collected during the 2026 meher harvest, following the finalized protocols.¹⁰ Under this plan, the full study—from initial plot screening and selection, through data collection, analysis, and interpretation, to dissemination of results—is expected to take approximately 24 months. The chart below outlines the key activities and their tentative timeline, providing an overview of the study’s planned progression.

Figure 1. Tentative study timeline



4. Study partners

The study will involve researchers from the Ethiopian Institute of Agricultural Research (EIAR) as research collaborators. EIAR will be primarily responsible for developing the yield measurement protocol, training enumerators, and providing high-level supervision of the yield data collection process. The study team will also consult relevant stakeholders (e.g., TechnoServe, Laterite, and the World Resources Institute) on the study design, including the proposed yield measurement methodology. The Ministry of Agriculture and its affiliated agencies (i.e., the Ethiopian Coffee and Tea Authority and the Federal Cooperative Agency), as well as sector representatives (e.g., ECX), will be engaged as policy partners.

¹⁰ Conducting a repeated yield measurement on the same plots and sample of trees over multiple seasons would be preferable to account for potential seasonal variation (biennial bearing). However, multi-season yield measurement will have significant implication on the cost of the study. We assume that the effect of seasonal variation on the yield differential between the stumped/replanted and unstumped trees within the same plot will be minimal, given both types of trees are subjected to similar production environment.

5. Expected outcomes

The study will provide rigorous evidence on the yield (and income) impact of coffee rehabilitation and its implication on total coffee production and export. Such evidence will ultimately influence public policies on coffee rejuvenation and investment decisions by farmers, development partners, and private actors. The evidence will ensure the effective use of scarce resources that aim to improve the income and living standards of smallholder coffee farmers.

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